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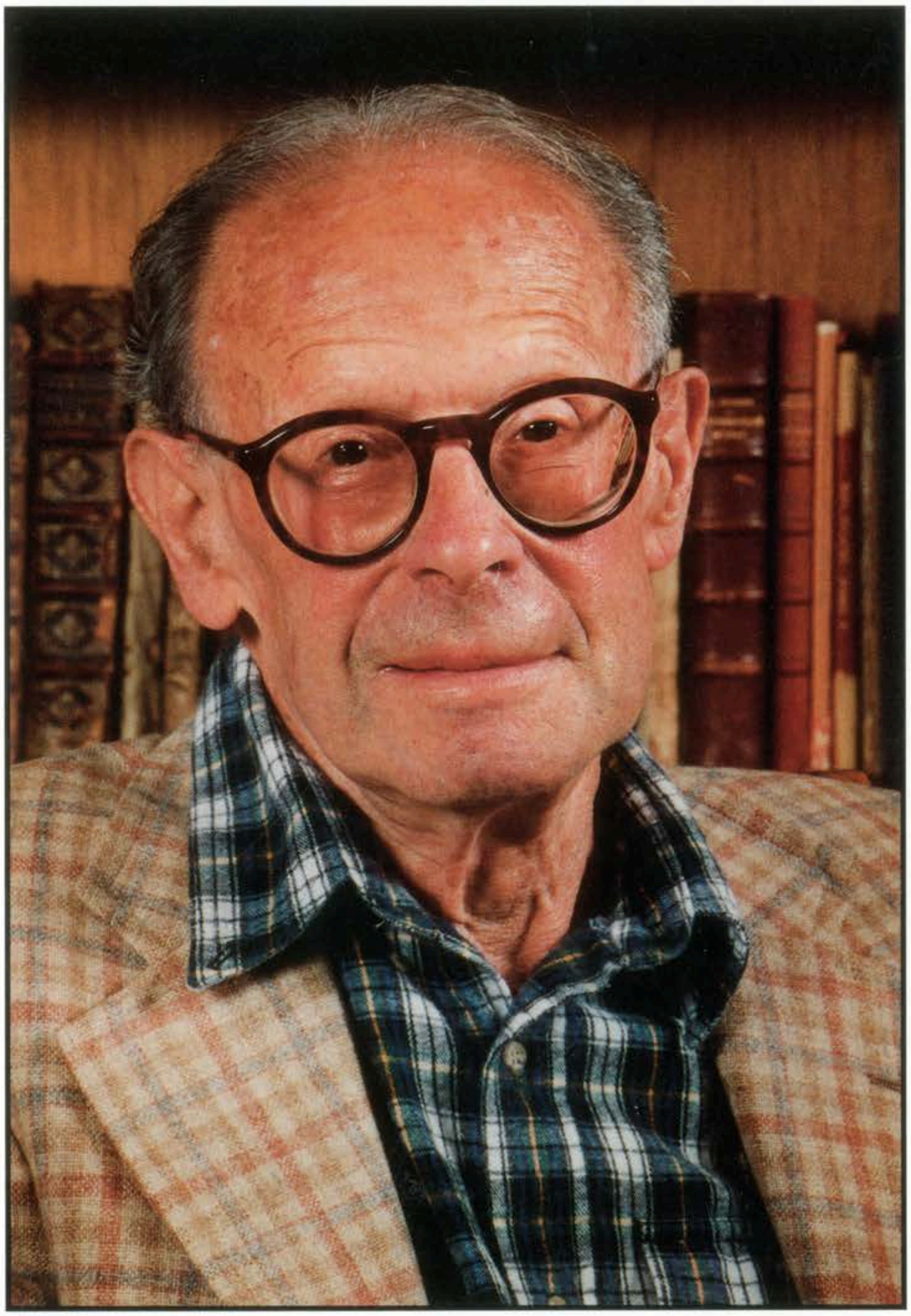

André Weil (See page 420)

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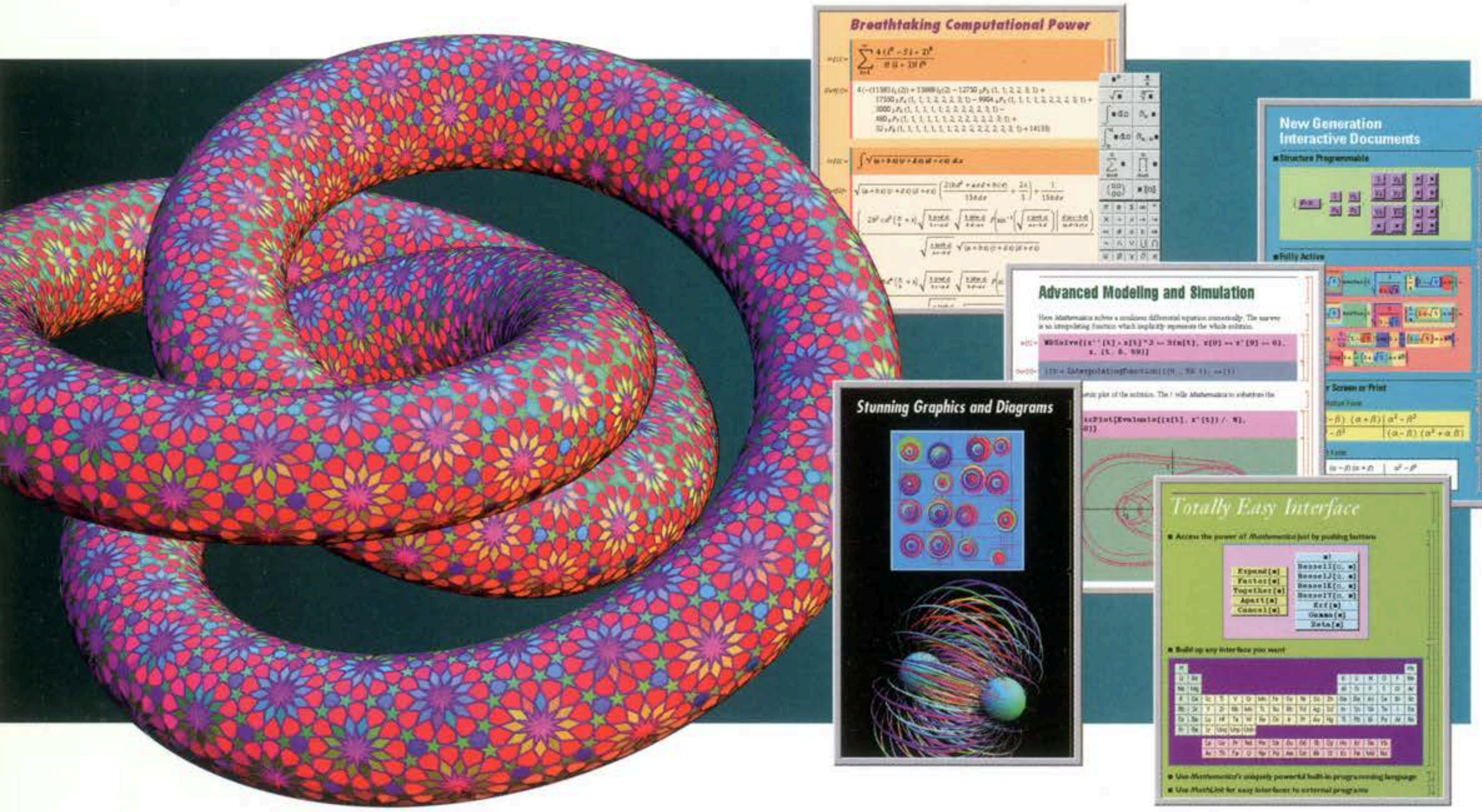

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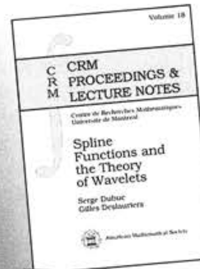
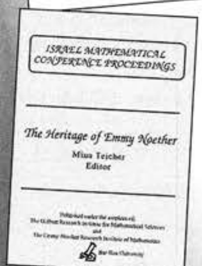
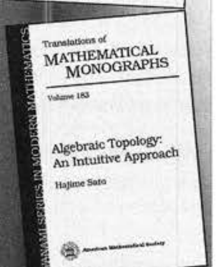
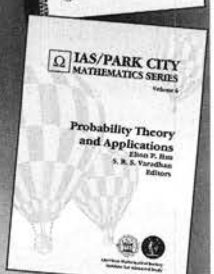
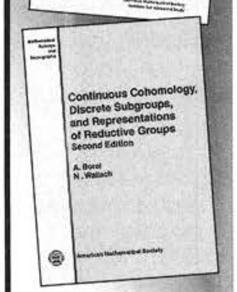
New Titles from the AMS











Spline Functions and the Theory of Wavelets

Serge Dubuc, *Université de Montréal, PQ, Canada*, and
Gilles Deslauriers, *Ecole Polytechnic de Montréal, PQ, Canada*, Editors

This work is based on a series of thematic workshops on the theory of wavelets and the theory of splines. Important applications are included. The volume is divided into four parts: Spline Functions, Theory of Wavelets, Wavelets in Physics, and Splines and Wavelets in Statistics.

Part one presents the broad spectrum of current research in the theory and applications of spline functions.

Part two considers two developments in subdivision schemes; one for uniform regularity and the other for irregular situations.

In part three, the multifractal formalism is extended to fractal functions involving oscillating singularities.

In part four, ways in which wavelets can be used to solve important function estimation problems in statistics are shown.

The volume features many applications and interesting new theoretical developments. Readers will find powerful methods for studying irregularities in mathematics, physics, and statistics.

CRM Proceedings & Lecture Notes, Volume 18; 1999; 397 pages; Softcover; ISBN 0-8218-0875-3; List $110; Individual member $66; Order code CRMP/18NT94

The Heritage of Emmy Noether

Mina Teicher, *Bar-Ilan University, Ramat-Gan, Israel*, Editor

A publication of Bar-Ilan University.

Named for the noted mathematician, the Emmy Noether Research Institute for Mathematics held a two-day conference dedicated to her heritage and her influence on mathematics and physics in the 20th and 21st centuries. This volume presents the proceedings of that conference. It includes a comprehensive description of her contributions to commutative and noncommutative algebra, algebraic geometry, topology, and physics given by world experts in these fields. Also included is a profile of her life. The volume is a comprehensive collection of Noether's valuable contributions to mathematics and physics.

Distributed worldwide by the AMS.

Israel Mathematical Conference Proceedings, Volume 12; 1999; 101 pages; Softcover; List $39; Individual member $23; Order code IMCP/12NT94

Recommended Text

Algebraic Topology: An Intuitive Approach

Hajime Sato, *Nagoya University, Japan*

The single most difficult thing one faces when one begins to learn a new branch of mathematics is to get a feel for the mathematical sense of the subject. The purpose of this book is to help the aspiring reader acquire this essential common sense about algebraic topology in a short period of time. To this end, Sato leads the reader through simple but meaningful examples in concrete terms. Moreover, results are not discussed in their greatest possible generality, but in terms of the simplest and most essential cases.

In response to suggestions from readers of the original edition of this book, Sato has added an appendix of useful definitions and results on sets, general topology, groups and such. He has also provided references.

Translations of Mathematical Monographs (*Iwanami Series in Modern Mathematics*), Volume 183; 1999; 122 pages; Softcover; ISBN 0-8218-1046-4; List $20; All AMS members $16; Order code MMONO/183NT94

Probability Theory and Applications

Elton P. Hsu, *Northwestern University, Evanston, IL*, and
S. R. S. Varadhan, *Courant Institute, New York University, NY*, Editors

This volume, with contributions by leading experts in the field, is a collection of lecture notes of the six minicourses given at the IAS/Park City Summer Mathematics Institute. It introduces advanced graduates and researchers in probability theory to several of the currently active research areas in the field. Each course is self-contained with references and contains basic materials and recent results. Topics include interacting particle systems, percolation theory, analysis on path and loop spaces, and mathematical finance.

Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price.

IAS/Park City Mathematics Series, Volume 6; 1999; 374 pages; Hardcover; ISBN 0-8218-0590-8; List $56; All AMS members $45; Order code PCMS/6NT94

Continuous Cohomology, Discrete Subgroups, and Representations of Reductive Groups

Second Edition

A. Borel, *Institute for Advanced Study, Princeton, NJ*, and
N. Wallach, *University of California, San Diego, La Jolla*

It has been nearly twenty years since the first edition of this work. In the intervening years, there has been immense progress in the use of homological algebra to construct admissible representations and in the study of arithmetic groups. This second edition is a corrected and expanded version of the original, which was an important catalyst in the expansion of the field. Besides the fundamental material on cohomology and discrete subgroups present in the first edition, this edition also contains expositions of some of the most important developments of the last two decades.

Mathematical Surveys and Monographs; 1999; approximately 265 pages; Hardcover; ISBN 0-8218-0851-6; List $59; All AMS members $47; Order code SURV-BORELNT94

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Table of Contents

April 1999

Feature Articles

Memorial Article

Communications

Departments

Notices

of the American Mathematical Society

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In This Issue

André Weil

Five articles in this issue are about André Weil and his mathematics. Weil, one of the leaders of twentieth-century mathematics, died in August 1998. The memorial article with "Prologue" in its title is a biographical essay about him, indicating where some of his mathematics fits into his personal and professional history. The other memorial article gives reminiscences by five people who knew him well; they write of their interactions with Weil over the years. A longer reminiscence by Goro Shimura appears as one of the two feature articles.

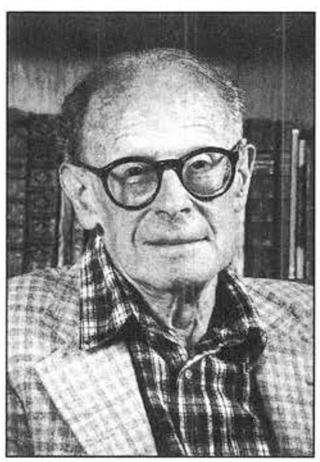
Weil's research profoundly influenced most areas of pure mathematics. In the other of the two feature articles, Armand Borel describes some of Weil's work in algebraic topology and the role it played. The plan is that articles in later issues will describe some of Weil's work in other areas.

In 1991 Weil published an autobiography in French of his life through 1947, the year he settled as a professor in the United States. This autobiography has been translated into English, German, Italian, and Japanese. V. S. Varadarajan reviews the 1992 English translation, *The Apprenticeship of a Mathematician*, in this issue.

For a 1968–69 guest lecture in topology, the audience was packed into the lecture room of Old Fine Hall in Princeton and included Weil and many other notables. At one point someone in the audience rose to object that the lecturer was not giving proper credit for a particular theorem. The questioner went on in impassioned tones for what seemed an eternity. Finally Weil rose, turned to the questioner, and said in a loud voice, "I am not interested in priorities!" The discussion was over, and the lecturer resumed without further interruption. This was the quintessential Weil. Mathematics to him was a collective enterprise.

—*Anthony W. Knapp*

About the Cover



Weil at the Time of Winning the Kyoto Prize

The cover is a photograph of André Weil from 1994, the year that he received the Kyoto Prize in Basic Sciences. Copyright 1994 by photographer Randall Hagadorn of Titusville, New Jersey, and reproduced in the *Notices* with the kind permission of the photographer.

Commentary

In My Opinion

The AMS Is Us

For many years—most of my career—the AMS struck me as an amorphous, ethereal organization, located somewhere along the East Coast, and run by unspecified influential, omniscient mathematicians. Perhaps the overlords lived in Washington, DC, and also directed the NSF; maybe the two organizations even met concurrently to set mathematical policy. While wrapped in the mystery of ignorance, the issues of geography, composition, and purpose seemed rather irrelevant to me. More consequential personally was the recurrent reality of the AMS meetings: sectional meetings, the annual January festival now called the Joint Mathematics Meetings, an occasional Summer Research Conference, and even one Summer Institute. They sustained and stimulated my research existence. In retrospect, publications probably should have carried more impact. Several volumes from the Colloquium Publications Series formed a small part of my personal library, supplemented sporadically by various conference proceedings. Except for the *Mathematical Reviews*, whose subordinate relationship to the AMS was unduly obscure, the Society's journals loomed larger than its books on my mental horizon, too easily taken for granted but nevertheless useful for the obvious reasons. Participation shaped the difference; the heart of the AMS *was* its meetings.

Vague mental impressions of the Society arranged themselves in sharper focus rather quickly in the 1990s, after the forging of a strong link due to my unexpected appointment as an associate secretary. Until 1999 the prominent connection has continued to be through meetings. The AMS associate secretaries—four in all, one for each of the geometrically unbalanced territories—pilot virtually all aspects of AMS meetings within their sections, and they rotate responsibility for shepherding and implementing scientific programs of national meetings and of the new phenomenon, joint international meetings. National meetings, which have endured through or despite a complexity elaborated in extensive scheduling agreements between the AMS and the MAA, represent an overdetermined system. Sectional meetings, which operate under fewer constraints, offer flexible formats and direct user input. An exemplary model for events sponsored by a member-driven society, they are easily assembled, readily transportable, cost effective, and valuable to the participants.

Ease of assembly, the crucial point here, stems from deploying the workload over a broad base. Briefly, here is how that is accomplished. The meeting becomes viable once a site is arranged, through happenstance or persuasion. Additional form emerges with the selection of Invited Speakers, usually four of them, by a small AMS program committee. Although those four have a pronounced effect, the character of the event depends most critically upon the collection of 8–15 Special Sessions. Together with people making local arrangements, the Special Sessions organizers, a significant cadre of whom ordinarily come from faculty at the host institution and from Invited Speakers or their designates, do the foundational spadework, basically by issuing invitations to speak in their sessions. With rare exceptions, travel funding is arranged by participants themselves from their own pockets or institutions. In spite of this financial handicap, organizers report a high invitational acceptance rate. Ultimately speakers provide abstracts, make their lodging arrangements, and deliver talks; organizers suggest a schedule; the AMS publishes a meeting program and abstracts booklet; and people get together and do mathematics. Repeatedly I have heard postmeeting testimony that individual workloads are unexpectedly light, small compared to the concerted effort required to put together, say, a non-AMS research meeting from scratch, in part since so many logistical details such as publicity, housing arrangements, and the program schedule are handled through the AMS.

What about Special Sessions organizers outside the special cadre? Either they are solicited or they volunteer. Volunteers, those who "lob proposals over the transom", are in short supply. One reason, I suspect, is a widespread, mistaken belief of its being too presumptous on the proposer's part, that the overlords would not approve. To the contrary, associate secretaries, the people closest to the events, welcome the lobs. And unless local constraints dictate otherwise, there is room for more spontaneous suggestions. I have solicited several Special Sessions for every Southeastern Sectional meeting occurring over the past six years. In itself that is no problem; the frequency and speed with which people allow a twisting of their arms makes me believe that large numbers appreciate, perhaps even anticipate, being asked. A more genuine problem, though, is the proportion of Special Sessions hatched by solicitation. Neither associate secretaries nor sectional program committees maintain extensive enough networks to effectively solicit proposals across the full spectrum of available topics. More lobs, please!

Members today almost certainly carry other misconceptions, like my own, about what the AMS does and how it functions beyond its endeavors concerning meetings. One misconception that should not be allowed to persist, however, is that we have a closed society dominated by a tight inner circle; it is not, does not strive to be, could not survive if it were. The process of shadowing Robert Fossum, my predecessor as secretary, throughout 1998, traveling to meetings of policy committees and wading through reports about far-reaching activities, made it clear that the number of members playing an active role in AMS governance is huge. And, finally, opportunity to expand these circles of involvement is available: the secretary's office would be pleased to receive suggestions (self-suggestions included) of people, new blood, to serve on the Society's 100+ committees.

—Robert J. Daverman
Associate Editor

André Weil and Algebraic Topology

Armand Borel

André Weil is associated more with number theory or algebraic geometry than with algebraic topology. But the latter was very much on his mind during a substantial part of his career. This led him first to contributions to algebraic topology proper, in a differential geometric setting, and then also to the use in abstract algebraic geometry and several complex variables of ideas borrowed from it.

According to [W3], I, p. 562, his first contacts with algebraic topology took place in Berlin, 1927, in long conversations with, and lectures from, Heinz Hopf. The first publication of H. Hopf on the Lefschetz fixed point formula appeared the following year, so it is rather likely that Weil heard about it at the time. At any rate, his first paper involving algebraic topology is indeed an application of that formula to the proof of a fundamental theorem on compact connected Lie groups (which Weil attributes to E. Cartan, but is in fact due to H. Weyl): Let G be a compact connected Lie group. Then the maximal tori (i.e. maximal connected abelian subgroups) of G are conjugate by inner automorphisms and contain all elements of G ([1935c] in [W3], I, 109–111).

The proof is a repeated application of the Lefschetz fixed point formula to translations by group elements on the homogeneous space G/T, where T is a maximal torus. Note that the isotropy groups on G/T are the conjugates of T, so that an element belongs to a conjugate of T if and only if it fixes some point in G/T. Weil first points out that T is of finite index in its normalizer $N(T)$. If $t \in T$ generates a dense subgroup of T, then its fixed points are the same as those of T, and a local computation shows their indexes to be simultaneously equal to 1 or to -1. The Lefschetz number of t is then $\neq 0$. But since t is connected to the identity, this number is equal to the Euler-Poincaré characteristic $\chi(G/T)$ of G/T, which is therefore $\neq 0$. As a consequence, any element $g \in G$ has a non-zero Lefschetz number, hence a fixed point, and belongs to a conjugate of T. If T' is another torus and t' generates a dense subgroup of T', then any torus containing t' will also contain T', whence the conjugacy statement.

This was the first new proof of that theorem, completely different from the original one, which relied on a study of singular elements (cf. H. Weyl, *Collected Papers II*, 629–633). It was rediscovered independently, about five years later, by H. Hopf and H. Samelson (*Comm. Math. Helv.* **13** (1940–41), 240–251).

For about ten years, from 1942 on, topology was present in several works of Weil, often pursued simultaneously, which I first list briefly:

a) In algebraic geometry: foundations, introduction of fibre bundles, formulation of the Weil conjectures.

b) New proof of the de Rham theorems. Together with Leray's work, this was the launching pad for H. Cartan's work in sheaf theory.

c) Characteristic classes for differentiable bundles: Allendoerfer-Weil generalization of the Gauss-Bonnet theorem, theory of connections, the Chern-Weil homomorphism, the Weil algebra.

d) Joint work with Cartan, Koszul, and Chevalley on cohomology of homogeneous spaces.

e) A letter to H. Cartan (August 1, 1950) on complex manifolds, advocating the use of analytic fibre bundles in the formulation of problems such as those of Cousin.

There is a last item I would like to add, dating from 1961–62:

f) Local rigidity of discrete cocompact subgroups of semisimple Lie groups.

On the face of it, it does not belong to algebraic topology, but can be fitted under my general title when stated as a theorem on group cohomology. This formulation was originally an afterthought, but turned out to be important to suggest further developments.

Algebraic Geometry

The algebraic geometry, as developed mainly by the Italian School, did not offer a secure framework for the proof of the Riemann hypothesis for curves and

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Armand Borel is professor emeritus of mathematics at the Institute for Advanced Study. His e-mail address is `borel@ias.edu`.

This article is based on a lecture at the Institute for Advanced Study on January 8, 1999, as part of a conference on the Work of André Weil and Its Influence, January 8-9, 1999.

The article is also appearing in the Gazette des Mathématiciens.

other researches of Weil in algebraic geometry. He had to develop new foundations, with as one of its main goals a theory of intersections of subvarieties. It had also to be over any field. This implied a massive recourse to algebra, but Weil still wanted to keep a geometric language and picture. Until then, only projective, affine, or quasi-projective varieties had been considered, i.e. subvarieties of some standard spaces. He wanted a notion of "abstract variety" which would be the analogue of a manifold (albeit with singularities). His first version [W1] is a bit awkward, as acknowledged in the foreword to the second edition, because no topology is introduced. From ([1949c], [W3], I, 411–413) on, however, he uses the language of the Zariski topology (introduced in 1944 by O. Zariski), and I shall do so right away. Fix a "universal field" K, i.e. an algebraically closed field of infinite transcendence degree over its prime field. Let V be an algebraic subset of K^n, i.e. an affine variety. In the Zariski topology, the closed subsets of V are the algebraic subsets. The open sets are, of course, their complements and are quite big. If V is irreducible, any two nonempty ones intersect in a dense open one, so that the topology is decidedly not Hausdorff (unless V is a point), which may explain some reluctance to use it initially. To define an (irreducible) abstract variety V, start from a finite collection $(V_i, f_{ji}), (i, j \in I)$, where V_i is an irreducible affine algebraic set, f_{ji} a birational correspondence from V_i to V_j satisfying certain conditions, so that, in particular: f_{ii} is the identity, $f_{ij} = f_{ji}^{-1}$, there exist open subsets $D_{ji} \subset V_i$ such that f_{ji} is a biregular mapping of D_{ji} onto D_{ij}, and $f_{ji} = f_{jk} \circ f_{ki}$. Two points $P_i \in D_{ji}$ and $P_j \in D_{ij}$ are equivalent if $f_{ji}(P_i) = P_j$. The "abstract variety" V is by definition the quotient of the disjoint union $\tilde{V}$ of the V_i by that equivalence relation.

Note that V is obtained by gluing together disjoint affine sets. For lack of suitable concepts, it was not possible to start from a topological space and require that it be endowed locally with a given structure, as is done for manifolds (as was done later by Serre using the notion of ringed space [S2]). As a result, the V_i and f_{ji} are part of the structure, which is rather unwieldy and requires a somewhat discouraging amount of algebra to be worked with. Nevertheless, Weil develops the theory of such varieties and of the intersection of cycles. For the latter, the analogy with the complex case and the intersection product in the homology of manifolds (on which he had lectured earlier at the Hadamard Seminar ([W3], I, 563)) is always present. In particular, a key property is the analogue of Hopf's inverse homomorphism (see [W1], Introduction, xi–xii). Weil also introduces an analogue of compact manifolds, the complete varieties, which include the projective ones. [W1] supplied the framework for a detailed proof of the Riemann hypothesis for curves and for further work on abelian varieties, and it supplied essentially the only framework for algebraic geometry over any field until Grothendieck's theory of schemes (from about 1960 on).

Weil (left) with Armand Borel in Chicago about 1955.

Photograph courtesy of Sylvie Weil.

Algebraic topology also underlies the formulation of the conjectures in ([1949b], cf. [W3], I, 399–410), soon to be called the Weil conjectures, which suggest looking for a cohomology theory for complete smooth varieties in which a Lefschetz fixed point formula would be valid. This vision, which turned out to be prophetic, was unique at the time.

In ([1949c], cf. [W3], I, 411–12), Weil introduces in algebraic geometry fibre bundles with an algebraic group, say G, as structural group. Given a variety B and a finite open cover $\{V_i\}(i \in I)$ of B, assume one is given regular maps $s_{ij} : V_i \cap V_j \to G$ $(i, j \in I; s_{ii}$ is the constant map to the identity), with the usual transitivity conditions. Let F be a variety on which G operates. Then a fibre bundle E on B, with typical fibre F, is obtained by gluing the products $V_i \times F$ by means of the s_{ij}, as usual. Weil also considers the case of principal bundles ($F = G$, acted upon itself by right translations). In particular, if $G = \mathbb{C}^*$ is the multiplicative group of nonzero complex numbers, the isomorphism classes of such bundles correspond to linear equivalence classes of divisors. It also allowed Weil to interpret in a more conceptual way earlier work on algebraic curves (see [W3], I, 531, 541, 570 for comments). A detailed exposition is given in [W2], where the classification of such bundles is studied in some simple cases.

In view of the big size of the neighborhoods on which such a bundle is trivial, it was not a priori clear this would lead to an interesting theory. That it did is one reason why Weil began to gain confidence in the Zariski topology. Of course, his definition of fibre bundle was greatly generalized later. Already in [1949c], Weil points out it would be desirable to have a notion broad enough so that B could be the set of prime spots of a number field. Later (Séminaire Chevalley 1958, I), J.-P. Serre introduced an important generalization of local triviality: a bundle is locally isotrivial if every point has an open neighborhood admitting an unramified covering on which the lifted bundle is trivial. This notion, which encompasses the fibration of an algebraic group by a closed subgroup, led A. Grothendieck to the definition of étale topology.

The de Rham Theorems

In January 1947 Weil wrote a letter to H. Cartan ([W3], II, 45–47) outlining a new proof of the de Rham theorems, published later in ([1952a], [W3], II, 17–43), the first one since de Rham's thesis. It is limited to compact manifolds, but this restriction is lifted, with very little complication, in the final version.

Given a smooth compact connected manifold M, Weil first shows the existence of a finite open cover $\{U_i\}_{i \in I}$ of M such that any nonempty intersection of some of the U_i's is contractible. Let N be the nerve of this cover, and, for each simplex $\sigma \in N$, let U_σ be the intersection of the U_i represented by the vertices of σ. Given $p, q \in \mathbb{N}$, let $A^{p,q}$ be the function assigning to each p-simplex σ of N the space of differential q-forms on U_σ. The direct sum A of $A^{p,q}$ is endowed with two differentials

$$(1) \quad d : A^{p,q} \to A^{p,q+1}, \qquad \delta : A^{p,q} \to A^{p+1,q},$$

where d stems from exterior differentiation and δ from the coboundary operator on N, followed by restriction of differential forms. Let $F^{p,q}$ (resp. $H^{p,q}$) be the subspace of $A^{p,q}$ of elements annihilated by $d\delta$ (resp. d or δ). Then Weil establishes the isomorphisms

$$(2) \quad F^{0,m}/H^{0,m} = H^m_{DR}(M), \qquad F^{m,0}/H^{m,0} = H^m(N).$$

$$(3) \quad F^{p,q}/H^{p,q} = F^{p+1,q-1}/H^{p+1,q-1} \qquad (0 \leq q \leq m),$$

where $H^m_{DR}(M)$ refers to real de Rham cohomology and $H^m(N)$ to the real cohomology of N. This proves, by induction, that $H^m_{DR}(M)$ is isomorphic to $H^m(N)$, hence to $H^m(M)$, since the U_σ are contractible. This last fact is taken for granted in the letter, but Weil also shows in [1952a] by similar arguments that $H^m(M)$ is equal to the m-th singular cohomology of M over the reals.

H. Cartan had studied the work of Leray in topology, in particular his wartime paper (*J. Math. Pure Appl.* **29** (1945), 95–248), and he noticed a similarity with Weil's proof. That was tremendously suggestive to him and quickly gave rise to a flurry of letters to Weil, in which Cartan initiated his theory of *faisceaux et carapaces* (sheaves and gratings), of which he gave later three versions (see [B] for references), first following Leray rather closely, arriving eventually at a much greater generality.

What Cartan had noticed is an analogy between the proofs of the isomorphisms in (3) and an argument which occurs repeatedly in Leray's paper, to which Leray himself traced later the origin of the spectral sequence (see [B]). However, Weil's argument was completely independent from it: As stated in a slightly later letter to Cartan, Weil did not know that paper and in fact suspected, on the strength of a report by S. Eilenberg in *Math. Reviews*, that it did not bring much new, if anything. On the other hand, it is quite plausible that the definition of the $A^{p,q}$ was in part inspired by a short conversation Weil had with Leray in summer 1945, in which the latter spoke of a cohomology "with variable coefficients". In fact, an analogue of A in the theory Leray was developing at the time would be a *couverture*, N, with coefficients in the differential graded sheaf associated to differential forms.

Characteristic Classes

In 1941–42 Weil was for some time at Haverford College, Pennsylvania, where he met C. Allendoerfer. This led to their joint work on the generalized Gauss-Bonnet theorem [AW]. Given a smooth compact oriented Riemannian manifold M of even dimension m, it expresses the Euler-Poincaré characteristic $\chi(M)$ of M as the integral over M of a differential m-form built from the components of the curvature tensor. Such a formula had already been proved by Allendoerfer and by Fenchel for submanifolds of euclidean space. At the time, the Allendoerfer-Weil theorem was in principle more general, since it was not known whether a Riemannian manifold was globally isometrically diffeomorphic to a submanifold of euclidean space, though it had been established locally. Because of that, the nature of their proof forced them to prove a more general statement, though I do not know whether the added generality has led to further applications.

Recall the Gauss-Bonnet formula in the most classical case: P is a relatively compact open subspace on a surface in $\mathbb{R}^3$, bounded by a simple closed curve, union of finitely many smooth arcs. Then the integral of the Gaussian curvature K on P, plus the sum of the integrals of the curvature on the boundary arcs and of the outside angles at the meeting points of those, is equal to 2π. The Allendoerfer-Weil formula gives a generalization of such a formula for a Riemannian polyhedron. It is proved first for polyhedra in euclidean space. The general case then follows by using a polyhedral subdivision, small enough so that its building blocks can be isometrically embedded in euclidean space, and by proving a suitable addition formula.

In 1944 S. S. Chern produced a proof of the Allendoerfer-Weil formula for closed manifolds (*Ann.*

Math. **45** (1944), 747–52) which was much simpler and a harbinger of further developments on characteristic classes. On M choose a vector field X with only one zero, of order $|\chi(M)|$ at some point x_0, which is always possible. Let E be the unit tangent bundle to M, $p : E \to M$ the canonical projection, and Ω the Gauss-Bonnet form. The key point is that $p^*\Omega = d\Pi$ is the exterior derivative of some explicitly given form Π, the restriction of which to a fibre F represents the fundamental class [F] of the fibre. The vector field X defines a submanifold V in E, a copy of $M - \{x_0\}$, with boundary the unit sphere $F_0 = p^{-1}(x_0)$, with multiplicity $|\chi(M)|$. The Gauss-Bonnet formula then follows from the Stokes theorem, applied to $V \cup F_0$.

The relationship between Ω, Π, and $[F_0]$ is a first example of a notion developed later under the name of *transgression* in a fibre bundle: a cohomology class β of a fibre F is transgressive if there is a cochain (in the cohomology theory used, here a differential form) on the total space E whose restriction to F is closed, represents β, and whose coboundary belongs to the image of a cohomology class η of the base B, under the map induced by the projection $p : E \to B$. The classes β and η will be said to be related by transgression. This notion, and the terminology, were introduced first by J.-L. Koszul in a Lie algebra cohomology setting in his thesis (*Bull. Soc. Math. France* **78** (1950), 65–127).

In *Ann. Math.* **47** (1946), 85–121, Chern gives several definitions of the characteristic classes $c^i(M) \in H^{2i}(M;\mathbb{C})$, since then called the Chern classes $(1 \le i \le m)$. In particular, if M is endowed with a hermitian metric, they can be expressed by closed differential forms which are locally defined in terms of the curvature tensor. Again, each one is related by transgression in a suitable bundle to the fundamental class of the fibre.

It is at this point that Weil comes in. He was familiar with the work of Chern, with the theory of fibre bundles, in particular with the classification theorem in terms of universal bundles, having written jointly with S. Eilenberg, with some help from N. Steenrod, a report on fibre bundles for Bourbaki (which, incidentally, provided much background material for the second Cartan seminar [C2]). He was also aware of Ehresmann's publications on fibre bundles and on the formulation of E. Cartan's theory of connections in that framework, as well as of Koszul's work towards his thesis quoted above. All this came together in a series of letters to Cartan, Chevalley, and Koszul, of which the first four were published (almost completely) for the first time thirty years later ([1949e], in [W3], I, 422–36). Some were shown around at the time, however. In particular, the first one is the basis of Chapter III in [C4], and this is how its contents became widely known.

Let G be a compact connected Lie group, ξ a principal G-bundle, E (resp. B) the total space (resp. base) of ξ. A connection on ξ is defined by means of a 1-form on E with values in the Lie algebra $\mathfrak{g}$ of G, satisfying certain conditions. Let I_G be the algebra of polynomials on $\mathfrak{g}$ invariant under the adjoint representation and $P \in I_G$ a homogeneous element of degree q. Replacing the variables in P by the components of the curvature tensor of the connection, Weil associates to P a differential $2q$-form on M, which is proved to be closed, hence to define an element $c_P \in H^{2q}(M;\mathbb{R})$. A fundamental theorem asserts that c_P is independent of the connection. The proof is short but stunning. In the fall of 1949, in Paris, I read this letter and said once to Cartan that this proof seemed to come out of the blue and I could not trace it back to anything. "That's genius. You don't explain genius," was his answer. The image of I_G under this homomorphism, which became known as the Chern-Weil homomorphism, is then the characteristic algebra of ξ.


Photograph courtesy of Armand Borel.

Weil at the Tata Institute of Fundamental Research in Bombay, January 1967.

At the end of the first letter, Weil states a conjecture relating the primitive generators of $H^*(G;\mathbb{R})$ (recall that it is an exterior algebra with a distinguished set of generators, called primitive) to the characteristic algebra by transgression, soon proved by Chevalley. This already provided a generalization of Chern's treatment of characteristic classes of hermitian bundles, modulo some normalization and plausible identifications. In the third letter, which, like the fourth, was addressed to Koszul, Weil makes the analogy closer. Recall that in the classical case the characteristic classes are the images of cohomology classes of a classifying space (a complex Grassmannian for hermitian bundles), under the homomorphism induced by a classifying map (see [C4], for example). Weil proposes an algebraic analogue of that situation. He introduces an algebra which, following Cartan [C3], I shall denote $W(\mathfrak{g})$ and call the Weil algebra of $\mathfrak{g}$. By definition, $W(\mathfrak{g}) = S(\mathfrak{g}^*) \otimes \wedge\mathfrak{g}^*$ is the tensor product of the symmetric algebra $S(\mathfrak{g}^*)$ by the exterior algebra $\wedge\mathfrak{g}^*$ of the dual $\mathfrak{g}^*$ of $\mathfrak{g}$. It is graded, anticommutative, an element $x \in \mathfrak{g}^*$ being given the degree 1 (resp. 2) if it is viewed as belonging to $\wedge\mathfrak{g}^*$ (resp. $S(\mathfrak{g}^*)$). The Weil algebra is further endowed with a specific differential. The latter leaves $S(\mathfrak{g}^*) \otimes \mathbb{R}$ stable, the cohomology of which is isomorphic to I_G. The algebra $\wedge \mathfrak{g}^*$, endowed with the Lie algebra cohomology differential, is a quotient of $W(\mathfrak{g})$. The transgression in $W(\mathfrak{g})$ provides a bijection of the space of primitive generators of $H^*(\mathfrak{g})$ (which is isomorphic to $H^*(G;\mathbb{R})$) onto a space spanned by independent homogeneous generators of I_G (the latter is, by a theorem of Chevalley, a polynomial algebra). A connection on ξ provides a homomorphism of $W(\mathfrak{g})$ onto a subalgebra of differential forms on E which, after having passed to cohomology, yields the Chern-Weil homomorphism. Thus $W(\mathfrak{g})$ plays the role of an algebra of differential forms on a universal G-bundle, an analogy reinforced by the fact, proved by Cartan [C3], that $W(\mathfrak{g})$ is acyclic.

So far, I have focused on characteristic classes. But these letters, combined with Koszul's thesis, led to further correspondence on the cohomology of homogeneous spaces and to more results announced by H. Cartan (*Colloque de Topologie*, C.B.R.M., Bruxelles, 1950, 57–71) and J.-L. Koszul (ibid., 73–81). A full exposition is given in [GHV].

Complex Manifolds and Holomorphic Fibre Bundles

On August 1, 1950, Weil wrote to H. Cartan a letter about global analysis in several complex variables (unpublished). He first claims that it is high time to stop viewing the object of these investigations as a sort of "domain" spread over n-space or complex projective space. One should look at complex manifolds, noting, of course, that not much can be proved without further assumptions such as compact, Kähler, global existence of holomorphic functions with nonzero Jacobians, etc. Then he points out that analytic fibre bundles underlie some classical problems. For instance, the Cousin data for the multiplicative Cousin problem (find a function with a given divisor of zeros and poles) lead to a principal $\mathbb{C}^*$-bundle. For a solution to exist, the bundle should first be topologically trivial. This condition is not always sufficient, but it is on a domain of holomorphy. Pursuing that idea, he conjectures that a complex vector bundle on a polycylinder with structural group a complex Lie group which is topologically trivial should be analytically trivial.

Unfortunately, I could only find the first page of this letter in Weil's papers; the original seems to be lost, or at any rate could not be located. The beginning of the last sentence: *"Once one has taken the habit to look for fibre bundles in these questions, one soon sees them everywhere (or 'almost everywhere') and there is an enormous gain..."*, makes one strongly wish to see the rest.

These remarks were taken into account by H. Cartan (*Proceeding I.C.M.*, Vol. 1, 1950, 152–164), who also pointed out that the first Cousin problem (find a meromorphic function with given polar parts) leads to a principal complex bundle too, but with fibre the additive group of $\mathbb{C}$.

Local Rigidity

It is well known that compact Riemann surfaces of higher genus have moduli (noncompact ones too, but I confine myself to the compact case). Such a surface is a quotient $\Gamma\backslash X$ of the upper half-plane $X = \mathbf{SL}_2(\mathbb{R})/\mathbf{SO}(2)$ by a discrete cocompact subgroup Γ of $\mathbf{SL}_2(\mathbb{R})$. Equivalently, this means that there are small deformations of Γ in $\mathbf{SL}_2(\mathbb{R})$ which are not conjugate to Γ. In the 1950s it began to be suspected that these phenomena were pretty much unique to that case among compact locally symmetric spaces $\Gamma\backslash X$, where $X = G/K$ is the quotient of a noncompact semisimple Lie group with finite center by a maximal compact subgroup K. The question is then to show that the locally symmetric space structure on $\Gamma\backslash X$ is locally rigid (no small deformation which is not an isomorphism) or, equivalently, that Γ is locally rigid (any local deformation of Γ in G is a conjugate of Γ). The first results along those lines were obtained by E. Calabi [C1]; E. Calabi-E. Vesentini [CV], from the geometric point of view; and A. Selberg [S1], for $G = \mathbf{SL}_n(\mathbb{R})$, from the group theoretical point of view.

The paper [S1] and an unpublished sequel to [C1] were the starting point for the three papers of Weil on that topic ([1960c], [1962b], [1964a] in [W3], II, 449–464, 486–510, 517–525). In the first one, Weil proves, for any connected Lie group, a conjecture of Selberg in [S1], to the effect that if Γ is discrete cocompact, any small deformation of Γ is discrete, cocompact, isomorphic to Γ. To formulate the problem, he introduces the variety $R(\Gamma, G)$ of homomorphisms of Γ into G. The group Γ is finitely presented (as fundamental group of the compact smooth manifold G/Γ). Let $(g_1, \dots, g_N)$ be a generating subset. Then $R(\Gamma, G)$ may be viewed as the real analytic subvariety of the product $G^{(N)}$ of N copies of G defined by the relations between these generators. Let $x_o = (g_1, \dots, g_N)$. The theorem is then that x_o has a neighborhood in $R(\Gamma, G)$, all elements of which represent discrete, cocompact subgroups of G isomorphic to Γ.

Assume now that G is semisimple, with finite center (an assumption which is implicit in [1962b], but could be lifted) with no factor which is compact or three dimensional. Then it is shown in [1962b] that Γ is locally rigid, as conjectured in [S1] too, by proving that the orbit

$$G.x_o = \{g.g_1.g^{-1}, \dots, g.g_N.g^{-1}, \ (g \in G)\}$$

contains a neighborhood of x_o in $R(\Gamma, G)$. The theorem is further extended to the case where G has some factors locally isomorphic to $\mathbf{SL}_2(\mathbb{R})$, provided that the projection of Γ on any such factor is not discrete. At the time, it was rumored (and in fact stated in [S1]) that Calabi had proved local rigidity when X is the hyperbolic n-space ($n \geqq 3$), but this was not contained in his only publication on that matter [C1], and Weil kept telling me that an essential idea was still missing. But he found it in notes by Kodaira of some 1958–59 seminar lectures by Calabi, and then proved the above results within a few days.

The paper [CV] considers first of all the case where X is an irreducible bounded symmetric domain and shows that its complex structure is locally rigid, provided X is not isomorphic to the unit ball in $\mathbb{C}^n$ ($n \geq 2$). Both [C1] and [CV] follow the model of the Kodaira-Spencer theory of deformations of complex structures. Local rigidity follows then from the vanishing of a first cohomology group, with coefficients in germs of Killing vector fields in [C1], of holomorphic tangent vector fields in [CV]. In [1964a] Weil provides similarly a cohomological translation of [1962b] by showing that the proof there implies the vanishing of the first group cohomology space $H^1(\Gamma; \mathfrak{g})$ of Γ with coefficients in the Lie algebra $\mathfrak{g}$ of G, acted upon by the adjoint representation.

The proof in [1962b] was already cohomological in spririt and is described so by Weil in his comments. It is first reduced to the case of a one-parameter group of deformations, defined by a vector field ξ. Without changing its class modulo inner automorphisms, he replaces ξ by a "harmonic" one, i.e. by the minimum of a suitable variation problem. It is then shown to be G-invariant and a direct Lie algebra computation shows that it is zero if G has no factor which is either compact or locally isomorphic to $\mathbf{SL}_2(\mathbb{R})$.

Weil was in fact not a newcomer to group cohomology. In 1951, he had asked a student, Arnold Shapiro, to prove a certain lemma on the cohomology of finite groups. The latter complied and the lemma came up later in countless variations, all known as "Shapiro's lemma".

Weil never came back to these questions, but several further developments originated in these papers. If instead of $\mathfrak{g}$ we take $\mathbb{C}$ acted upon trivially, then $H^1(\Gamma; \mathbb{C})$ is trivial if and only if the commutator subgroup of Γ is of finite index in Γ. The vanishing of $H^1(\Gamma; \mathbb{C})$ was proved in many cases, using an approach similar to Weil's, by Matsushima, who extended it further to determine some higher cohomology groups (*Osaka J. Math.* **14** (1962), 1–20). Later I generalized Matsushima's theorem to noncocompact arithmetic groups, which yielded the determination of the rational K-groups of rings of algebraic integers (*Ann. Sci. École Norm. Sup. Paris* (4) **7** (1974), 235–272) and led to the study of higher regulators in algebraic K-theory (*Ann. Sci. École Norm. Sup. Pisa* (4) **4** (1977), 613–656). In another direction, N. Mok, Y.-T. Siu, and S.-K. Yeung used a nonlinear version of Matsushima's approach to establish archimedean superrigidity of cocompact discrete subgroups (*Invent. Math.* **113** (1993), 57–83).

This concludes my survey of algebraic topology in the work of A. Weil. Viewed as part of his overall output, it is quantitatively minor. Still, it reaches out to an impressive amount of mathematics, has been very influential, and testifies to the breadth of his outlook, as well as to his concentration on essential questions.

Photo by C. J. Mozzochi, provided couretsy of Armand Borel, with permission of the photographer.

Weil 1987.

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André Weil As I Knew Him

Goro Shimura

Bathed in the sunlight of late summer, I was walking a quiet street of Takanawa, a relatively fashionable district in southern Tokyo, toward the Prince Hotel Annex, where André Weil was staying. It was the afternoon on a warm day of early September in 1955. He was among the eight foreign participants of the International Symposium on Algebraic Number Theory, to be held in Tokyo and Nikko that month. The Korean War had ended two years earlier, and in the United States Eisenhower's first term had begun in the same year. Five years later, in 1960, his planned visit to Japan would be hindered by the almost riotous demonstrations of labor unions and students in the city, but nobody foresaw it in the peaceful atmosphere of the mid 1950s. While walking, I had a mildly uplifted feeling of expectation and curiosity about what would happen, the first of those I would experience many times later whenever I was going to see Weil.

My acquaintance with him began in 1953, when I sent my manuscript on "Reduction of algebraic varieties with respect to a discrete valuation of the basic field" to him in Chicago, asking his opinion. I told him my intention of applying the theory eventually to complex multiplication of abelian varieties. In his answer, dated December 23, 1953, he was quite favorable to the work and encouraged me to proceed in that direction; he also advised me to send the paper to the *American Journal of Mathematics*, which I did. By that time I had read his trilogy *Foundations*, *Courbes Algébriques*, and *Variétés Abéliennes*, as well as his 1950 Congress lecture [50b] 1) and a few more papers of his. I was also aware of the existence of many of his other papers or had some vague ideas about them, [28], [35b] 2), [49b], [51a], for example. But I don't think I had read all those before 1955. The article "L'avenir des mathématiques" [47a] and his review [51c] of Chevalley's book on algebraic functions were topics of conversation among young mathematicians in Tokyo. Later, while in Japan, when he was asked to offer his opinion on various things, he jokingly complained that he was being treated like a prophet, not a professor. But to some extent that was so even before his arrival.

In any case, when he accepted the invitation to the Tokyo-Nikko conference, we young mathematicians in Japan expected him with a sense of keen anticipation. I shook hands with him for the first time on August 18, in a room in the Mathematics Department, University of Tokyo. He looked gentler than the photo I had seen somewhere. He was forty-nine at that time. Our meeting was short, and there was not much mathematical discussion, nor did he make any strong impression on me that day. He was given, perhaps a few days later, a set of mimeographed preliminary drafts of papers of most Japanese participants, including my 49-page manuscript titled "On complex multiplications", which was never published in its original form. 3)

About two weeks later a message was forwarded to me: Professor Weil wishes to see me at his hotel. So I brought myself there at the appointed time. He appeared in the lobby wearing beige trousers with no jacket or tie. He had read my manuscipt

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by then, and, sitting on a patio chair in a small courtyard of the hotel, he asked many questions and made some comments. Then he started to talk about his ideas on polarization of an abelian variety and a Kummer variety. He scribbled various formulas on some hotel stationery, which I still keep in my possession. At some point he left his chair; pacing the courtyard from one end to the other, he impatiently tried to pour his ideas into my head. He treated me as if I was an expert who knew everything. I knew of course what a divisor meant and even the notion of linear and algebraic equivalence, as I had read his 1954 *Annalen* paper on that topic, but I lacked the true feeling of the matter, not to speak of the historical perspective. Therefore, though I tried hard to follow him, it is fair to say that I understood little of what he said. At the end we had tea, and he ate a rather large piece of cake, but I declined his offer of the same, perhaps because his grilling lessened my appetite.

During the conference and his stay in Tokyo afterward, I saw him many times. On each occasion he behaved very naturally, if in a stimulating way. It was as if that hotel encounter had the effect of immunization for me, and possibly for him too. I remember that I asked him about the nature of the periods of a differential form of the first kind on an abelian variety with complex multiplication. He said, "They are highly transcendental," which was not a satisfactory answer, but as good as anything under the circumstances. At least, and at long last, I found someone to whom I could ask such a question. Those several weeks were truly a memorable and exciting period. To make it more exciting, one of my colleagues would make a telephone call to the other, imitating Weil's voice and accent: "Hello, this is Weil. I didn't understand what you said the other day, so I'd like to discuss with you ..." Sometimes the prank worked. A few days before his leaving Tokyo for Chicago, I, together with three such naughty boys, visited him in another hotel in the same area. Taniyama promised to come, but didn't; apparently he overslept as usual. During our conversation, Weil advised us not to stick to a wrong idea too long: "At some point you must be able to tell whether your idea is right or wrong; then you must have the guts to throw away your wrong idea."

As he said in his *Collected Papers*, his stay in Japan was one of his most enjoyable and gratifying periods. He found an audience of young people who were not afraid of him and who were sophisticated enough to understand, or at least willing enough to try to understand, his mathematics; he certainly had an audience in the United States then, but apparently of a different kind.

More than two years passed before I saw him again, which was in Paris in November 1957. Henri Cartan, accepting his suggestion, had secured a position of chargé de recherches at CNRS for me. Weil was on leave from Chicago for one year and sharing an office with Roger Godement at the Institute Henri Poincaré, but he occupied it alone for most of the time. In that period he was working on various problems on algebraic groups, the topics which can be seen from [57c], [58d], and [60b], for example. He was giving lectures on one such subject at the École Normale and regularly attended the Cartan seminar. He lived in an apartment at the southeast corner of the Luxembourg garden, with a fantastic view of Sacré Coeur to the far north and the Eiffel Tower to the west. One of his favorite restaurants was Au Vieux Paris, in the back of the Panthéon. A few days after my arrival, he invited me to have lunch there. I remember that he had *radis au beurre* (radish with butter) and *lapin* (rabbit) *sauté*, a fairly common affair in those days, but perhaps somewhat old-fashioned nowadays. I don't remember his choice of wine, but most likely a full-sized glass of red wine for each of us. To tell the truth, it was not rare to find him snoozing during the seminar. From his apartment, the Institut and the Panthéon could be reached in less than ten minutes on foot. Paris in the 1950s retained its legendary charm of an old city which had not changed much—he once told me—since the days of his childhood. It is sad to note that the city went through an inevitable and drastic transformation in the 1970s.

Though I was working on a topic different from his, he was earnestly interested in my progress, and so I would drop into his office whenever I had something to talk about. For instance, one day I showed him some of my latest results for which I employed Poincaré's theorem on the number of common zeros of theta functions. He smiled and said, "Oh, you use it, but it is not a rigorously proved theorem." Then he advised me to take a different route or to find a better proof; later he told me a recently proved result concerning divisors on an abelian variety, by which I was able to save my result, as well as Poincaré's theorem.

On another occasion, I heard some shouting in his office. As I had only a brief message for him, I knocked on the door. He opened it and introduced me to Friederich Mautner[4)], professor at Johns Hopkins, who was his shouting partner. After a minute or so I left. As soon as I closed the door, they started their shouting again. When I was walking through the corridor after spending half an hour in the library, the shouting match was still going on; I never knew when and how it began and ended, nor who won.

From time to time he fetched me for a walk in the city. The topics of our conversation during those walks were varied; he would suggest to me, for example, that I go to churches to listen to religious music; he said it was necessary for me only to stand up and sit down when others did. When asked about his faith, he said, "Pas du tout" ("Not at all"). According to him, one of the best ways to learn French or any foreign language was to see the same movie in that language again and again, staying in the same seat in the same movie theatre, a piece of advice I followed perhaps too faithfully. It was the time when Brigitte Bardot and Zizi Jeanmaire were at their zenith. Another method he suggested was to read newspapers, but I was not so diligent in this task. Perhaps as he became impatient with my slow progress in French, he asked me whether I was doing my homework in that respect. I dodged the issue by mentioning an old Oriental saying: "He who runs after two rabbits will catch neither." Maybe I subconsciously remembered the rabbit for his meal. "What's your rabbit? Hecke operators?" he asked. Then we discussed the possible method or philosophy of how a Frobenius of a reduced variety can be lifted. A few days later he caught me in the library and asked again, "What about your rabbit?" He was an extremely sharp man, and clearly he sensed that I was up to something, which was true. In this article, however, I should leave the rabbit at large, merely mentioning that he would later say, "How is your rabbitry doing?"

Starting in the fall of 1958, he was at the Institute for Advanced Study permanently, and I was a member there for that academic year. So I practically followed him, and I had the same daily routine with him for another several months. Looking back on those days, I am filled with a sense of deep gratitude to him for paying such unusual and personal attention to me; also, I must note to my regret that, unaware of the real meaning of my situation at that time, I did not take full advantage of my fortunate privilege of being constantly with such an extraordinary man in his prime.

In the spring of 1961 he spent a few months in Japan with his wife, Eveline. Though they undoubtedly enjoyed their stay and I was happy to have a person at hand who really understood me—perhaps the only one at that time—I may be excused for saying that overall his presence was less than a pale revival of his former visit.[5] As for myself, after spending three years in Japan, I came back to Princeton in September 1962, when I began a new and long chapter of my relationship with him. To continue my narrative, I will now present some interesting aspects of his words and deeds in this period, irrespective of the chronological order of the events.

As already mentioned, he liked to walk, partly for the purpose of physical exercise. In Princeton every Sunday he would walk one and a half miles from his home to buy the Sunday *New York Times*, and so, according to his daughters, his church denomination was pedestrian. At the Institute he would occasionally pick a walking partner among the members. He was not a good walker, however. Though he was physically fit and walked briskly, he often fell on his face by tripping on something on the ground. That happened when I was with him in the Institute wood, but I pretended to have seen nothing, as he hated being helped on such an occasion. Though he was not injured then, he was not so lucky other times. During such a walk, he would answer my questions or would tell his stories. Here are some samples:

When he was twelve or thirteen,[6] there was a magazine for elementary mathematics asking the reader to send in solutions to the problems; then they would print the best solutions. He contributed many, as he found great pleasure in seeing his name in the magazine, but he graduated from that level after about two years. Then he said, "Maybe I should have included some of the solutions in my oeuvres, he! he! he!"

Around the time when he was at Haverford, he asked Hermann Weyl to lend him some money. "How much?" asked Weyl. "Well, four or five hundred dollars." Then Weyl brought out his checkbook, and, after thinking awhile, he signed a check for four hundred and fifty dollars.

When he was teaching at Lehigh, a student asked him for help in calculus. After they spent a lot of time struggling to find out what his problem was, the student finally said, "I don't seem to understand this symbol x."[7]

A French gentleman's ideal is to have three concurrent loves: the first one, whom he cares about at present; the second, a potential one, whom he has his eye on with the hope that she will eventually be his principal love; the third, the past one, with whom he hasn't completely cut off his relations. Then he observed: "It's a good idea for a mathematician to have three mathematical loves in the same sense."

He would talk about Baudelaire, Proust, and Gide, their homosexuality in particular; Paul Claudel's treatment of his sister Camille; and also about the letter exchange between Paul Claudel and Madeleine Gide. He amused himself by twisting each story in his own fashion to make it funny, often with a piquant effect.

I asked, for what reason I don't remember, whether he read detective stories. "Yes, but only when I have a cold," he said, and added, "You know, when you have a cold, there is nothing else to do but read detective stories." He was rather apologetic, and so I asked, "How often do you catch cold?" "Very often" was his answer.

As to Fields medals, he said: "It's a kind of lottery. There are so many eligible candidates, and the whole selection process is a matter of chance. Therefore, the prize could be given to *any of them*, as in a lottery."[8]

He used to say that a good mathematician must have two good ideas. "It is possible for someone to have a really good idea, but it may be just a fluke. Once the person has a second good idea, then there is a good chance for him to develop into a better mathematician." He mentioned a well-known American as a prolific mathematician with a single idea. He also noted Mordell as a counterexample to his principle.

He could say something even harsher, but that was rare. In the summer of 1970, after the Nice Congress, I was talking with him somewhere in the Institute about French mathematicians. He observed that there were three young mathematicians in Paris who started brilliantly, and so there were high expectations for them. He mentioned three well-known names and said, "What happened to them? They utterly failed to produce anything great." That was more than a quarter century ago, but I cannot tell whether or not he changed his opinion, as we never talked on that matter again. Around 1975 he expressed, more than once, his pessimistic view that French mathematics had been declining for some time. Therefore, we should perhaps take his criticism in that context.

He held Riemann and Poincaré in high esteem, which was more than natural; Hecke was also a favorite. He rarely talked about Hilbert in our conversation. He didn't think much of Klein, which is not surprising. Picard was depicted by him as formal and stiff. Among his contemporaries, he thought highly of Siegel and spoke of Chevalley in amicable terms, but not so with Weyl, about whom he seemed to have a kind of ambivalence. He recognized the unusual talent of Eichler.[9)] Hadamard was his teacher, and their relationship is well documented in his autobiography. He paid due respect to Hasse, though he remembered the fact that Hasse wore a Nazi uniform at some point.[10)] He told me several anecdotes about Hardy, but he presented each story in a sarcastic tone. "Hardy's opinion that mathematics is a young man's game is nonsense," he said.

It may be too optimistic a view to say that most people mellow with advancing age. At least many do, and there are those who don't. It is told, for example, that Saint Saëns achieved an ever-increasing reputation as a man of bad temper through his long life of eighty-six years. Weil did mellow, but even after the age of seventy he was capable, if rarely, of being childishly irritable, as can be seen from the following episode. But first let me note: Around 1976 or 1977 he declared, "I am no longer a mathematician; I am a mathematical historian." Apparently he realized that there were no more subjects he could handle better than the younger generation. Coming to my story: In my teens I somehow got hold of a copy of a pirate edition, which was being called the Shanghai edition, of *Eindeutige Analytische Funktionen* by Rolf Nevanlinna. I enjoyed reading the first one-third of the book, but gave up on the rest. Still, my reading of the book remains as one of my fond memories. When I recognized Nevanlinna in a lecture hall at the 1978 Helsinki Congress, I introduced myself and shook hands with him, an incident which in my youth I never imagined would happen. He was eighty-three then. Weil gave a lecture titled "History of Mathematics: Why and How" there.

After the Congress I spent a week in Paris, and one day I was sipping coffee with Weil in a café near his apartment. I told him about that happy experience of mine at Helsinki. But he was much displeased with my story. He said with a grimace that Nevanlinna was not such a good mathematician worthy of my esteem, and so on. I was dumbfounded; I never idolized Nevanlinna, whose name I knew before acquainting myself with any of Weil's works, simply because the book was accidentally available. That must have been clear to him. After all, it was none other than Nevanlinna who saved him from being executed by the Finnish police, a fact he told me some years earlier and narrated in his autobiography, which also includes a passage on the Weil couple's happy stay in Nevanlinna's villa in 1939.

I should add, however, that he could be found on the other side of the world. When there was a discussion of a new appointment at the Institute, Morton White, professor of the school of history, was fiercely against the proposition, and at the faculty meeting he expressed his opinion in a heated fashion. Then Weil, sitting next to him, said, "Calm down, please, calm down." White later told me that he thought the scene rather funny in view of the normal temperament of Weil.

After Eveline's passing away in May 1986 at the age of seventy-five, his daughter Nicolette bought a microwave oven for him. However, saying that he didn't like to "push the button," he never touched it, and so the oven was returned to the dealer. The Weils had been our regular dinner guests, but since then, naturally he alone was with us, which happened not infrequently. It was sometime in December 1986. Weil, Hervé Jacquet, Karl Rubin, Alice Silverberg, my wife Chikako, and I had dinner at a Chinese restaurant and were having dessert at our place. When I prodded the guests to tell their ambitions in their next lives, Jacquet said he would like to be an opera singer, and that was not a joke for him. In fact, opera singing was his first love, mathematics being merely the second. Next, "I want to be a Chinese scholar studying Chinese poems," said Weil. After visiting China twice, he had been reading English translations of Chinese standard literature like *The Dream of the Red Chamber*. "That may be a rather dull life, and I don't think a person like you can stand it," said I. "All right then, I will be a house cat. The life of a house cat is very comfortable." Pointing to our neighbor's female white cat, who was also a guest, he said, "Maybe she will be my mother." Then Rubin said, "Perhaps a Chinese cat is a good solution." With laughter, everybody accepted it. That was about a week or two before Christmas, and so after a few days Chikako brought him a stuffed cat as a Christmas present, which pleased him greatly. In fact, the Weil family used to have a cat, and once he defended himself for having a Christmas tree in his house by saying that they had it because their cat loved it.

He was conscious of his old age, particularly after he became a widower. According to what he said, Eveline was afraid of becoming senile. But she was not at all senile when she died. A famous French mathematician who lived beyond eighty was senile in his last two years, but he knew it himself. So when he had visitors, he held a newspaper to show that he was at least able to read, but the paper was often upside down. Another, who lived longer, was not like that; even so, when Weil visited him, he brought out and showed him, one after another, the diploma of each of the many honorary degrees he had received.

As for Weil himself, he showed no such sign, as far as I remember. I talked with him sometime in November 1995 for half an hour or so in his office. He was alert and able to make a reasonable judgment on the matter for which I went to see him. There was a lunch party for his ninetieth birthday in May 1996 at a restaurant in Princeton; though he didn't talk much, he was in a good mood. Before and after that, Chikako had lunch at the Institute cafeteria several times; she would find him eating mostly alone, sometimes with his daughters. She would say hello to him, to which he would reply, "Is Goro here?" So she was relieved to find that he at least remembered her as someone related to me.

I saw him for the last time on December 19, 1996. For some reason he phoned me the day before. Since he had hearing difficulties, he finally suggested that I see him at the Institute. I proposed some date, but he said,"No, why don't you come tomorrow; otherwise I won't remember." So I had lunch with him there that day. From the previous night it had been drizzling endlessly. When I met him in the common room of Fuld Hall, he didn't have his hearing aid, and he asked me to drive him home to get it. After getting it, we went into the dining hall. He used to eat well, and almost twice as much as I. Around 1980 André, Eveline, Chikako, and I had lunch together at a restaurant in New Hope, Pennsylvania. That was a buffet style affair, and he was in high spirits. I remember that his appetite impressed the remaining three. Incidentally, he was not fussy about wine. Not that he didn't care, but it is my impression that Eveline cared more.

I was curious how he would eat this time. Not surprisingly, compared with what he ate sixteen years ago, the quantity he took was modest, less than half of the previous meal. Since he had hearing problems, it was difficult to conduct our conversation smoothly, and I often had to write words and sentences on a piece of paper. Unlike the occasion forty-one years ago, this time it was I who was writing. I was working on the Siegel mass formula [11)] with a new idea at that time, and that was one of his favorite topics. So I asked him about the history of that subject. For example, I asked him whether or how he studied the works of Eisenstein, Minkowski, and Hardy. He said he didn't remember about Eisenstein, [12)] but he had studied a little, but not much, of Minkowski's work; he never studied Hardy. He kept saying that it was a long time ago, and so he didn't remember, which must be true, and so we should not accept what he said at face value. In fact, to check that point, I asked him whether Minkowski was reliable. He said, "I think so." At that point I realized that his recollection was faulty, since Minkowski gave an incorrect formula, as Siegel pointed out, and that was known to most experts. If I was asking questions on what he did in his twenties or thirties, he might have remembered things better, but at that time I didn't take into account the fact that he worked on the Siegel formula in his fifties.

I asked him whether he was writing something on a historical topic. He said, "I cannot write anymore." To cheer him up, I then said, "That's why I told you long ago to get a computer." He also said he was half blind. Toward the end of the meal he said, "I'd like to see the Riemann hypothesis settled before I die, but that is unlikely."

That reminded me of a party at Borel's place in the 1970s. Wei-Liang Chow was the guest of honor. I was talking with Chow and Borel about a passage in Charlie Chaplin's autobiography. In it Chaplin in his twenties met a fortuneteller in San Francisco who told him that he would make a tremendous fortune, would be married so many times with so many children, and would die of bronchial pneumonia at the age of eighty-two. Hearing this story, Weil said, "Well, in my autobiography I might write that in my youth I was told by a fortuneteller that I would never be able to solve the Riemann hypothesis."

When we left the dining hall and were walking to the parking lot, he said, "You are certainly disappointed, but I am disappointed too," and added, after a few seconds, "with myself." He knew that I was expecting him to say something about Siegel's work. He again said, "I cannot write anymore." I drove him home and left. He was able to walk slowly, but I couldn't say he was in good shape; still, he was not in terrible shape, and so I had a sense of relief. While driving home alone under still drizzling rain, I could not help but recall our hotel encounter in 1955 and the lunch in 1957, though I did not think much about the possibility that I would never see him again.

André Weil as a mathematician will of course be remembered by his colossal accomplishments, witnessed by the three volumes of his *Collected Papers* and several books, the trilogy mentioned at the beginning in particular. In my mind, however, he will remain chiefly as the figure with two mutually related characteristics: First, he was flexible and receptive to new ideas of others and new directions, quite unlike many of the younger people these days who can work only within a well-established framework. Second, more importantly and in a similar vein, he had a deep and penetrating understanding of mathematics, or, rather, he strived tirelessly to understand the real meaning of every basic mathematical phenomenon and to present it in a clearer form and in a better perspective. He did so by endowing each subject with new concepts and setting up new frameworks, always in a fresh and fundamental way. In other words, he was not a mere problem solver. Clearly, his death marked the end of an era and at the same time left a large vacuum which will not easily be filled for a long time to come.

Endnotes

1) Each number in brackets refers to the article designated by that number in his *Collected Papers,* with "19" omitted.

2) It seems that [35b] is the first paper which mentions the fact that the coordinate ring of a variety is integral over a subring obtained by considering suitable hyperplanes (see *Collected Papers*, vol. I, p. 89). Zariski attributed it to E. Noether. It is my impression that she considered generic hyperplane sections, but not the fact of elements being integral. Weil agreed with me on this and said, "Perhaps Zariski didn't like to refer to the work of a younger colleague, a common psychological phenomenon." On the other hand, though he must have had his own citation policy, frankly I had difficulty in accepting it occasionally. See 9) below.

3) As to my paper on "Reduction of algebraic varieties, etc." he said, "Il (Shimura) me dit, il eût plutôt eu en vue d'autres applications" (*Collected Papers*, vol. II, p. 542). This is not correct. Probably he misunderstood me when I told him that I was interested in Brauer's modular representations at one time. Brauer was also a participant of the conference.

4) Mautner was responsible for introducing Weil to Tamagawa's idea; see Weil's comments on [59a].

5) In his *Collected Papers* he says practically nothing about his second visit, though he mentions it; see vol. II, p. 551.

6) This is what he told me. In his autobiography, however, the story is assigned to an earlier period, which may be true.

7) This is also what he told me. A somewhat different version is given in his autobiography. He referred to his Lehigh days as his period of "overemployment".

8) There is a big difference. In order to win a lottery, we have to buy a ticket, but by doing so we put our trust in the fairness of the system.

9) Whenever he spoke of strong approximation in algebraic groups, he always referred to Kneser's theorem. That is so in [65], for example, which is understandable. But that was always so, even in his lectures in the 1960s, though in [62b] Eichler is mentioned in connection with the fact that the spinor genus of an indefinite quadratic form consists of a single class. However strange it may sound, it is possible, and even likely, that he was unable to recognize Eichler's fundamental idea and decisive result on strong approximation for simple algebras and orthogonal groups, and he knew only its consequence about the spinor genus. In his *Collected Papers* he candidly admits his ignorance in his youth. Though he had wide knowledge, his ignorance of certain well-known facts, even in his later years, surprised me occasionally. He knew Hecke's papers to the extent he quoted them in his own papers. It would be wrong, however, to assume that he was familiar with most of Hecke's papers. Besides, his comments in his *Collected Papers* include many insignificant references. For these reasons, the reader of those comments may be warned of their incompleteness and partiality.

10) According to Weil, Hasse, in such a uniform, once visited Julia, who became anxious about the possibility that he would be viewed as a collaborator.

11) In [65] he says, "On a ainsi retrouvé, quelque peu généralisées, tous les résultats démontrés par Siegel au cours de ses travaux sur les formes quadratiques, ainsi que ceux énoncés à la fin de [12] (Siegel's *Annalen* paper in 1952) à l'exception des suivants. Tout d'abord, ..." (*Collected Papers*, vol. III, p. 154). I think this is misleading, since the list of exceptions does not include the case of inhomogeneous forms, which Siegel investigated. It is true that Siegel's product formula for an inhomogeneous form in general can be obtained from the "formule de Siegel" (in Weil's generalized form, combined with some nontrivial calculations of the Fourier coefficients of Eisenstein series), and one might say that that is not so important. Still, it should be mentioned at least that the inhomogeneous case is not just the matter of the Tamagawa number and that nobody has ever made such explicit calculations in general, even in the orthogonal case. In the mid 1980s I asked Weil about this point, but he just said, "I don't remember."

12) In [76c] he reviews the complete works of Eisenstein; also the title of [76a] is *Elliptic Functions according to Eisenstein and Kronecker.* It is believable, however, that he didn't study Eisenstein's papers on quadratic forms in detail, though he must have been aware of them.

André Weil: A Prologue

Anthony W. Knapp

André Weil, one of the truly great mathematicians of the twentieth century, died in Princeton on August 6, 1998. Weil succeeded in being a universal pure mathematician, making notable advances in at least eight of the nineteen areas of pure and applied mathematics recognized by the International Mathematical Union: algebra, number theory and arithmetic algebraic geometry, algebraic geometry, differential geometry and global analysis, topology, Lie groups and Lie algebras, analysis, and history of mathematics. He is known also as cofounder, with Henri Cartan and others, of the Bourbaki group, whose books put a large portion of basic modern mathematics on a sound footing and helped revitalize French mathematics in the wake of two world wars.

Photograph courtesy of Sylvie Weil.

André Weil in Princeton working with his cat Catsou, November 1960.

The breadth of Weil's mathematics is extraordinary. Here are just a few high points: the fundamental Mordell-Weil Theorem for elliptic curves, the construction of the Bohr compactification in the theory of almost periodic functions, the development of harmonic analysis on locally compact abelian groups, a proof of the Riemann hypothesis for curves over finite fields, the introduction of fiber bundles in algebraic geometry, the formulation of the Weil conjectures for the number of points on a nonsingular projective variety, the derivation of a high-dimensional Gauss-Bonnet formula jointly with Allendoerfer, the introduction of the Weil group in class field theory as a tool more useful than the Galois group, a Cauchy integral formula in several complex variables that anticipates the Silov boundary, and the number theory of algebraic groups. In addition, he did foundational work on uniform spaces, characteristic classes, modular forms, Kähler geometry, the use of holomorphic fiber bundles in several complex variables, and the geometric theory of theta functions. Weil's own commentary on his papers may be found in his *Collected Papers.*[1]

A substantial portion of Weil's research was motivated by an effort to prove the Riemann hypothesis concerning the zeroes of the Riemann zeta function. He was continually looking for new ideas from other fields that he could bring to bear on a proof. He commented on this matter in a 1979 interview:[2] Asked what theorem he most wished he had proved, he responded, "In the past it sometimes occurred to me that if I could prove the Riemann hypothesis, which was formulated in 1859, I would keep it secret in order to be able to reveal it only on the occasion of its centenary in 1959. Since 1959, I have felt that I am quite far from it; I have gradually given up, not without regret."[3] An example of his bringing ideas from other fields to bear on a proof is his fascination with the Lefschetz fixed-point formula. In a 1935 paper he used this formula to give new proofs of some structure-theoretic theorems about compact con-

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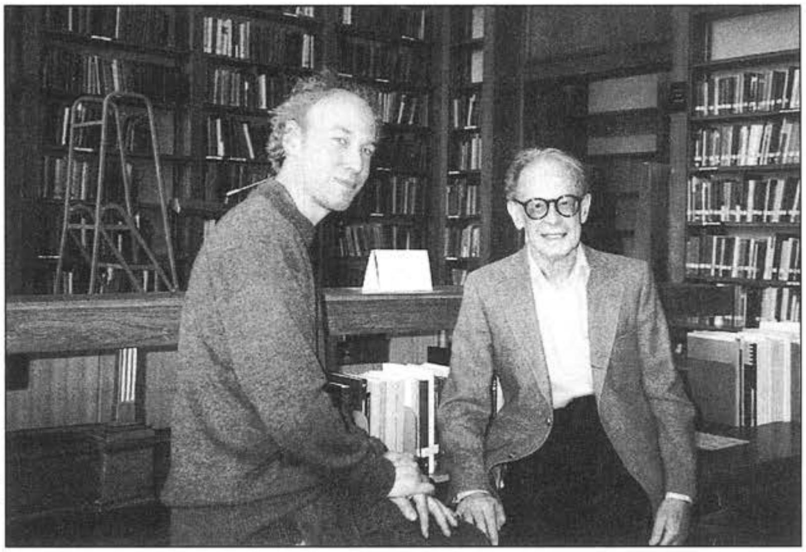
[1] Œuvres Scientifiques, Collected Papers, *vol. I–III, Springer-Verlag, New York, 1979.*

[2] Pour la Science, *November 1979.*

[3] *"Autrefois, il m'est quelquefois venu à l'esprit que, si je pouvais démontrer l'hypothèse de Riemann, laquelle avait été formulée en 1859, je la garderais secrète pour ne la révéler qu'à l'occasion de son centenaire en 1959. Comme en 1959, je m'en sentais encore bien loin, j'y ai peu à peu renoncé, non sans regret."*



Photograph courtesy of Sylvie Weil.

Weil with Pierre Deligne in the library at the Institute for Advanced Study, about 1990.

nected Lie groups. Later, in 1949, he evidently had in mind a conjectural analog of the Lefschetz formula, valid over finite fields, when he stated the Weil conjectures,[4] having established them earlier in the one-dimensional case. The last of these conjectures is known as the "Riemann hypothesis over finite fields", and thus he had indeed found a connection between the Lefschetz formula and the Riemann hypothesis.

Weil had high standards, even for prizes. Early in his career he participated in a revolt against the introduction of some medals in France to recognize particular academic accomplishments. He felt that this kind of prize did more harm than good. But he seemed not to be averse to recognition of lifetime achievement. On his own vita at the Institute for Advanced Study, he listed just one prize he had received, the Kyoto Prize of 1994, which is the grandest of all the lifetime-achievement awards. He accepted also, but did not list, the Wolf Prize in Mathematics for 1979, received jointly with Jean Leray, and the AMS Steele Prize of 1980 for lifetime achievement. The citation for the Steele Prize aptly summarized his career to that point: "To André Weil for the total effect of his work on the general course of twentieth century mathematics, especially in the many areas in which he has made fundamental contributions."

The early part of his life, until 1947, is the subject of his autobiography, *The Apprenticeship of a Mathematician.*[5] André Weil was born on May 6, 1906, in Paris. He was a child prodigy, read widely, and became consummately cultured by his late teens. By 1921 he knew Greek, Latin, some German and English, and a little Sanskrit; he would learn more languages later. He was introduced to Jacques Hadamard in 1921, and Hadamard gave him occasional advice from then on. He finished high school and entered the École Normale Supérieure in 1922, attending the Hadamard Seminar from the start. He decided that it was important to read the masters and began to do so in mathematics and all the other subjects that interested him. He began to read Riemann in 1922. In 1925 he passed the Agrégation examination and thereby finished at the École Normale Supérieure.

It was during his period at the École Normale that he was introduced to the *Bhagavad Gita*, the core of an Indian epic poem. This was to become the foundation of his own personal philosophy, and in turn this philosophy was to be a decisive factor in what happened to him in World War II.

The circumstances of World War I affected Weil's way of learning mathematics and later played a role in establishing the goals of Bourbaki. This matter is discussed at length in *The Apprenticeship* and in articles by A. Borel[6] and J. Dieudonné[7] about Bourbaki. Briefly, the problem was that France, unlike Germany, wanted everyone of suitable age, mathematicians included, to go to the front lines in World War I. The result was that after the war there were few mathematicians living in France who were born between 1880 and 1900. Some old masters were still alive, but they could not be said to be fully aware of new developments in mathematics internationally. In addition, their interests, except in the case of Élie Cartan (who was little understood), were rather confined, basically developing the lines of study begun a century

Photograph courtesy of Sylvie Weil.

André Weil, Paris, 1907, age one.

[4]*These are now theorems, due to B. Dwork, A. Grothendieck, M. Artin, and P. Deligne.*

[5]*Birkhäuser, Basel, 1992, translated from the French original (*Souvenirs d'Apprentissage, *Birkhäuser, Basel, 1991) by Jennifer Gage, reviewed elsewhere in this issue of the* Notices.

[6]Notices, *March 1998, 373–380.*

[7]Amer. Math. Monthly *77 (1970), 134–145.*

earlier by Fourier and Cauchy. The only serious window to international mathematics was Hadamard's Seminar, and it was insufficient.

Thus it was that Weil began traveling extensively. During the year 1925–26, he spent six months in Rome, with Vito Volterra as an informal advisor, and he learned algebraic geometry. The most significant event of the year for him mathematically was that he learned of L. J. Mordell's 1922 paper in which it was proved that the abelian group of $\mathbb{Q}$ rational points on an elliptic curve defined over the rationals $\mathbb{Q}$ is finitely generated, and he saw that it was related to some thoughts that he had had a year earlier. In more detail, if $y^2 = x^3 + qx + p$ has rational coefficients and distinct complex roots, Poincaré (1901) had shown that the operation of combining two rational solutions by connecting them with a straight line, finding the third intersection of the line and the curve, and then reflecting that point about the x axis is an abelian group operation, the 0 element being the point at infinity. Poincaré had asked whether this abelian group is finitely generated, and Mordell's theorem answers this question affirmatively.

The next year he spent partly in Germany on a fellowship, with Courant as advisor but learning from E. Noether, M. Dehn, C. L. Siegel, H. Hopf, A. Ostrowski, and O. Toeplitz, among others. He spent one month with G. Mittag-Leffler in Sweden, in theory doing some writing for Mittag-Leffler. Mittag-Leffler, who was the founding editor of *Acta Mathematica*, promised Weil that his thesis could be published in that journal. In the summer of 1927 Weil returned to Paris and the Hadamard Seminar to continue work in earnest on his thesis (thèse d'état) on Diophantine equations. At age twenty-one he was done with the mathematics and the writing in short order. He received his D.Sc. degree in 1928.

In order to describe the result, it is necessary to provide some further background about the work of Poincaré and Mordell. The terminology of the time was a little careless by modern standards about singularities. But modulo that detail, it had already been realized that birational transformations between curves over $\mathbb{Q}$ preserve $\mathbb{Q}$ rational points and therefore two birationally equivalent curves have the same rationality properties. As a consequence, the degree of the curve should not be regarded as an invariant; the fundamental invariant is the genus of the compact Riemann surface obtained by considering all complex solutions in projective space. Elliptic curves are nonsingular of genus 1, thus yield Riemann surfaces that are tori. Both Poincaré and Mordell used parametrizations of an elliptic curve by means of the associated Weierstrass $\wp$ function. Under this parametrization the abelian group operation is simply addition on the torus, with the point at infinity on the curve corresponding to the element 0 on the torus. Mordell found that the operation of division of the parameters by 2, in the special cases of the genus 1 projective curves $u^3 + v^3 = w^3$ and $u^4 + v^4 = w^2$, corresponded to Fermat's method of infinite descent for proving Fermat's Last Theorem for degrees 3 and 4. Mordell was then able to adapt the method of descent to elliptic curves, and a consequence was his theorem that the group is finitely generated.

Poincaré knew for curves of genus g that the appropriate thing to consider is not points on the curve but unordered sets of g points on the curve, repetitions allowed. The main theorem of Weil's thesis is a theorem of "finite generation" in this setting, with the additional generality that $\mathbb{Q}$ may be replaced by any number field (finite extension of $\mathbb{Q}$). More specifically, a curve C of genus g, being a compact Riemann surface, maps into its "Jacobian variety" $J(C)$, which is a certain torus of complex dimension g, and the map is canonical up to a translation. Fixing base points, we can then map unordered sets of g points on C to the sum of the images in $J(C)$. The Jacobi Inversion Theorem says that this map is onto, and it is one-one for the most part. Weil sets up and proves a version of the infinite descent argument used by Mordell for genus 1.

Finding a committee to approve the thesis was not so easy, since there were essentially no number theorists in France, but he succeeded anyway. Mittag-Leffler had died meanwhile, but his successor at the *Acta*, N. Nörlund, honored Mittag-Leffler's promise and published a paper about the thesis in 1928. When the results in the *Acta* are specialized to genus 1, what is obtained is an extension of Mordell's theorem from elliptic curves over the rationals to elliptic curves over number fields. For this corollary, known as the Mordell-Weil theorem, Weil published a simpler proof in *Bulletin des Sciences Mathématiques* in 1930.[8] Weil made clear in this paper that the argument can be framed in terms of the geometric definition of addition and does not require the use of the Weierstrass $\wp$ function.

Weil spent the year 1928–29 doing his compulsory military service, ending up as a lieutenant in the reserves. He jumped at the chance to have a job in India and took a post as the professor in mathematics at Aligarh Muslim University in northern India starting in early 1930 and lasting until early 1932. In his research he tried his hand at other fields. He combined the idea of ergodicity with von Neumann's work on unitary operators on Hilbert spaces and came up with the ergodic theorem in the L^2 sense. He tried to generalize Poincaré's theorem on the rotation number to a class of differential equations, but did not make much

[8]*Listed as 1929 in* Collected Works.

progress. He worked in several complex variables and extended the Cauchy integral to certain pseudoconvex domains; according to *The Apprenticeship*, this work, published in 1935, led to solving a problem posed by Bergmann and played an indispensable role in later research by Oka.

Weil spent an uneventful 1932–33 in a teaching position at the Université de Marseille and then obtained an appointment at the Université de Strasbourg, where he remained until 1939, rising to the rank of professor. In Strasbourg he was with his longtime friend Henri Cartan and was finally back in a mathematical atmosphere. Weil and some of his friends scattered throughout France started a seminar in Paris in 1933–34. G. Julia lent his name to the enterprise so that a room could be found, and the seminar became the "Séminaire Julia". It concentrated on a different theme each year. After World War II it was reborn as the Séminaire Bourbaki.

Weil describes the birth of the Bourbaki group as follows: He and Henri Cartan were teaching "differential and integral calculus" in late 1934 from the standard book by Goursat. Cartan was forever asking Weil for the best way to treat a given section of the curriculum, and Weil had his own questions for Cartan. Weil proposed that the two of them should get together with their friends who were teaching the same thing at other universities and decide these matters together. Out of this proposal came regular meetings in Paris of Cartan and Weil with Delsarte, Chevalley, Dieudonné, and "a few others", and the group soon called itself Bourbaki. As described in the articles by Dieudonné and Borel, their goal was to organize basic mathematics for a France otherwise cut off from many international developments in mathematics by the circumstances of World War I that were mentioned above. At first these mathematicians were making organizational decisions, and then they viewed themselves as writing textbooks. Weil acknowledges that later they had to be writing at a more advanced level, and perhaps it would be appropriate to say that they were working on something more like an encyclopedia than a series of texts.[9] Success was not immediate. Indeed, finished books did not appear in profusion for a number of years. But mathematics in France was indeed reestablished by soon after World War II, and in that sense a principal goal of Bourbaki had been realized. One cannot pretend that the Bourbaki volumes were the only factors in the reestablishing of mathematics in France, but to the extent that leading mathematicians in France and elsewhere educated soon after World War II learned from the Bourbaki writings, the project has to be reckoned a success.

Photograph by C. J. Mozzochi, provided courtesy of Armand Borel, with permission of the photographer.

Weil talking with Goro Shimura (left) in Princeton, October 22, 1987. Also in picture: Chikako Shimura (back to camera) and Vyjayanthi Chari (half hidden).

The first draft of each Bourbaki volume was always written by an expert. Dieudonné qualified as an expert on integration and produced a first draft of a volume on integration about 1937; this developed measures and then integrals in the same kind of progression that P. Halmos later used in his own book on measure theory. Weil too was an expert on this subject. Already in 1934 Weil had begun work on his celebrated advanced book on integration on groups; that book was sent to a publisher in 1937 but did not appear until 1940. An account in Weil's *Collected Papers*, vol. I, pp. 547–549, explains why he took it upon himself to write his own draft for Bourbaki, basing measure theory on locally compact spaces. The account in *The Apprenticeship* shows that he put considerable effort into this Bourbaki volume.[10] Bourbaki volumes contained sections of "Historical Notes", and it is known that Weil played an important role in the writing of these.

While at Strasbourg, Weil had two advanced students, Élisabeth Lutz and Jacques Feldbau, who worked on lower-level French theses for the "diplôme d'études supérieures".[11] Jacques Feldbau was interested in topology, obtained a problem through Weil from Ehresmann, published one paper under his own name and another under the pseudonym Jacques Laboureur, and subsequently died in a concentration camp. Élisabeth Lutz counts herself as a student of Weil from 1934 to 1938. In 1935 she began working on aspects of elliptic

[9] *Indeed, one of the principles of the Bourbaki was always to go from the general to the particular. This principle, reasonable in an encyclopedia, is exactly the opposite of one of the generally accepted principles for teaching in the U.S. from the 1950s onward.*

[10] *The published version of this volume contained an acknowledged mistake that needed to be addressed later: namely, it dealt with integration in such a way that integration could not be usefully applied in probability theory. This matter is addressed in the commentary in* Collected Papers, *vol. I, pp. 547–549, and in Borel's article on the Bourbaki, p. 376.*

[11] *This kind of thesis became a "thèse de troisième cycle" after World War II.*

André and Eveline Weil at the ICM at Harvard, 1950.

curves over p-adic fields. An elliptic curve over $\mathbb{Q}$ can be put in the form $y^2 = x^3 - Ax - B$ with A and B integers; recall that the abelian group of rational points is finitely generated. In her published paper on the subject,[12] Lutz makes two observations as a consequence of her analysis: first, that any $\mathbb{Q}$ rational point (x, y) of finite order on such a curve has integer coordinates and, second, that either y equals 0 or y^2 divides $4A^3 - 27B^2$. This result is now called the Nagell-Lutz Theorem. It implies that the torsion subgroup of $\mathbb{Q}$ rational points is effectively computable. It remains unknown, and it was a source of concern to Weil, whether the whole group of $\mathbb{Q}$ rational points is effectively computable. Weil describes Lutz's work, and its relationship to his own research, in his *Collected Papers*, vol. I, pp. 534–535. Perhaps as a testament to Weil's standards, Lutz's work was sufficient only for the lower-level French thesis. Lutz wrote a doctoral thesis (thèse d'état) after World War II on a different p-adic topic with a different advisor.

During this period Weil's mathematics flourished. He spent the year 1936–37 in the U.S. at the Institute for Advanced Study, returning thereafter to France. He married Eveline in late 1937. By the spring of 1939 he had decided that he would leave France. As a reserve lieutenant, he would have to serve if there were hostilities. Perhaps the effect of World War I on French mathematics would be repeated if there were another war. In *The Apprenticeship* he tells how his Indian philosophy played a role in his decision. It was not just his right to disobey unjust laws, but his duty. He and Eveline accepted an invitation from Lars Ahlfors to visit the Ahlfors family in Finland. A little later he was jailed in Finland as a spy, was spared execution[13] because of efforts by Nevanlinna, and was deported to Sweden. He spent time in jails successively in Sweden, England, and finally France, ending up in Rouen in February 1940. The time in jail in Rouen was a particularly productive one for him mathematically; it was when he proved the Riemann hypothesis for curves over finite fields, edited the proof sheets for his integration book, and made progress on his draft of a Bourbaki volume on integration. He realized the need to have solid foundations for algebraic geometry over any field, and filling this need was ultimately to result in his book *Foundations of Algebraic Geometry*. Charges were finally brought against him (he was accused of failure to report for duty), and a formal kind of trial was conducted on May 3, 1940. Instead of spending five years in jail, he asked to rejoin the army and permission was granted. After several moves in France and England, he finally arrived in Marseille. From there he went through the difficult task of reuniting with his wife and was told he had a job in the U.S. Following a circuitous route, he sailed in January 1941 and eventually succeeded in getting to New York City with Eveline.

His list of publications hardly reflects the turmoil in his life at this time. There was in fact no job in the U.S., but he did have some support from the Rockefeller Foundation. He spent part of 1941 in Princeton and was at Haverford College for 1941–42, with most of his support from the Rockefeller Foundation. It was there that he did his joint work with Allendoerfer on generalizing the Gauss-Bonnet formula. For 1942–43 he was an assistant professor at Lehigh University, with most of his salary again paid by the Rockefeller Foundation. He described his role as "to serve up predigested formulae from stupid textbooks and to keep the cogs of this diploma factory turning smoothly." He was able to continue work on his book *Foundations*, albeit more slowly; this was also the year in which he interacted with S. S. Chern. The year 1943–44 was the low point. The Rockefeller Foundation money had run out, and Weil's job at Lehigh was to teach "the elements of algebra and analytic geometry" for fourteen hours a week to army recruits who were being kept busy before being shipped elsewhere. Afterward he and Eveline vowed never to mention the name "Lehigh" again.

In January 1944, exasperated, Weil prepared to quit his job, regardless of the consequences. He wrote to Hermann Weyl, asking for help, and Weyl arranged for Weil to be awarded a Guggenheim Fellowship even though the deadline for applications had passed. He took a position as professor at the Universidade de São Paulo in Brazil, a center for algebraic geometry, in January 1945 and remained there until 1947. He was able to visit Paris in 1945.

Weil was appointed professor at the University of Chicago in 1947 and kept that position until 1958. He was on leave in Paris for 1957–58 and then became a professor at the Institute for Advanced Study starting in 1958. He remained at the Institute until his retirement in 1976. He traveled once more to India in 1967, and he made at least three trips to Japan—one in 1955 for an international

[12] *Sur l'équation $y^2 = x^3 - Ax - B$ dans les corps $\mathfrak{p}$-adiques*, J. Reine Angew. Math. ***177** (1937), 238–247.*

[13] *This is Weil's version. An article by O. Pekonen (L'affaire Weil à Helsinki en 1939,* Gaz. Math., *No. 52 (1992), 13–20) gives further historical background but disputes that Weil was about to be executed. In a postscript at the end of the Pekonen article, Weil points out that Pekonen provides no facts that contradict Weil's version.*

Between lectures September 8, 1955, at International Symposium on Algebraic Number Theory in Tokyo. Left to right: Teiji Takagi, Richard Brauer (back to camera), Shokichi Iyanaga, André Weil, and Emil Artin.

Photograph by Asako Hatori, provided courtesy of Shokichi Iyanaga, with permission of the photographer.

conference on algebraic number theory, another in 1961 for a second conference, and the last in 1994 to receive the Kyoto Prize.

His book *Foundations* was published in 1946, and the frequency of his papers increased. In 1949 alone he published his paper on the Weil Conjectures, as well as articles on fiber spaces in algebraic geometry, on theta functions, and on differential geometry. He was a speaker at the International Congress of Mathematicians (ICM) in Cambridge, MA, in 1950 and again in Amsterdam in 1954, and he was an hour speaker at the ICM in Helsinki in 1978. He was a member of the Académie des Sciences (Paris), a foreign member of the Royal Society (London), and a foreign member of the National Academy of Sciences of the U.S.A.

A list of the courses he taught at Chicago and the Institute appears in Volume I of his *Collected Works.* He had four successful Ph.D. students while at the University of Chicago: Arnold S. Shapiro (1950), Frank D. Quigley (1953), Norman T. Hamilton (1955), and David Hertzig (1957). For Weil's 1959–60 course on adeles and algebraic groups, Michel Demazure and Takashi Ono served as notetakers and converted the notes into a form that eventually became a book. Ono says of this experience that although he had already obtained his Ph.D. in Japan, "I always think of him as my real advisor and am proud of being his nonofficial student all my life."

Books by André Weil

- *Arithmétique et Géométrie sur les Variétés Algébriques*, Hermann, Paris, 1935.
- *Sur les Espaces à Structure Uniforme et sur la Topologie Générale*, Hermann, Paris, 1937.
- *L'intégration dans les Groupes Topologiques et Ses Applications*, Hermann, Paris, 1940; second edition, 1953.
- *Foundations of Algebraic Geometry*, Colloquium Publications, vol. 29, Amer. Math. Soc., New York City, 1946; second edition, Providence, RI, 1962.
- *Sur les Courbes Algébriques et les Variétés Qui s'en Déduisent*, Hermann, Paris, 1948.
- *Variétés Abéliennes et Courbes Algébriques*, Hermann, Paris, 1948; second edition of this and *Sur les Courbes Algébriques et les Variétés Qui s'en Déduisent* published together under the collective title *Courbes Algébriques et Variétés Abéliennes*, 1971.
- *Introduction à l'Étude des Variétés Kählériennes*, Hermann, Paris, 1958.
- *Basic Number Theory*, Springer-Verlag, New York, 1967; second edition, 1974; third edition, 1995.
- *Dirichlet Series and Automorphic Forms*, Lecture Notes in Mathematics, vol. 189, Springer-Verlag, New York, 1971.
- *Elliptic Functions according to Eisenstein and Kronecker*, Springer-Verlag, Berlin, 1976.
- *Œuvres Scientifiques, Collected Works*, vols. I–III, Springer-Verlag, New York, 1979.
- *Number Theory for Beginners*, with the collaboration of Maxwell Rosenlicht, Springer-Verlag, New York, 1979.
- *Adeles and Algebraic Groups*, Birkhäuser, Boston, 1982; based on notes by M. Demazure and T. Ono in 1959–60.
- *Number Theory: An Approach through History from Hammurapi to Legendre*, Birkhäuser, 1984.
- *Souvenirs d'Apprentissage*, Birkhäuser, Basel, 1991; English translation by Jennifer Gage, *The Apprenticeship of a Mathematician*, Birkhäuser, Basel, 1992; translated also into German, Italian, and Japanese.

In addition, there were several sets of unpublished lecture notes. The full list of Weil's publications through 1978 appears in his *Collected Works.*

André Weil (1906–1998)

Armand Borel, Pierre Cartier, Komaravolu Chandrasekharan, Shiing-Shen Chern, and Shokichi Iyanaga

Shiing-Shen Chern

I believe Weil and I first met in Paris in the fall of 1936 at the Julia seminar "Sur les travaux scientifiques de M. Élie Cartan". He soon went to Princeton, and I must have left no impression on him.

Our first scientific encounter came when he wrote in the newly started *Mathematical Reviews* a lengthy review of a short article of mine on integral geometry. Although he was somewhat critical, he generally liked my paper.

We first really met in the fall of 1943 when I came to the Institute for Advanced Study and he was teaching at Lehigh University and we became good friends. At that time he had just published his proof of the high-dimensional Gauss-Bonnet formula. But our common mathematical interest goes over the whole of mathematics, and I was always impressed by his vast knowledge and judgment.

We soon became colleagues at the University of Chicago in 1949–59 during the Stone period. Under Stone's leadership Chicago became an active mathematical center with excellent students. We had constant contact and took long walks along the south coast of Lake Michigan when it was still safe.

Weil was known as a leader of the Bourbaki group. This started when a group of young French mathematicians planned to introduce modern mathematics to France. It was an extremely talented group. Among their plans was the compilation of a book where all the theorems had complete and rigorous proofs. It is difficult to make success of such a plan if it is to include all mathematics. For instance, there is no generally agreeable Stokes theorem in differential geometry. But in any case, the Bourbaki volumes contain a large collection of rigorously proven fundamental mathematical theorems. It is a great asset in mathematical literature.

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Komaravolu Chandrasekharan

André Weil's passing brings back to memory Samuel Johnson's remark on the death of a close friend: "Howmuchsoever I valued him, I now wish I had valued him more." Weil was the first to introduce me (1947) to Georges de Rham's work on differential forms and multiple integrals and to the work of Laurent Schwartz on distributions. He personally introduced me to the glories of Greek sculpture at the Louvre in Paris on my first visit there (May 1949). After his lecture at the Amsterdam Congress (ICM 1954), to which he was fetched by Kloosterman direct from the airport, we spent the afternoon among the treasures of the Rijksmuseum. He was supportive in concrete ways at the turning points of my career, when I moved to Bombay (1949), and when I moved out of there (1965)—always kindly, hospitable, and encouraging. Unforgettable are the days we spent together at Pontresina, in the high Swiss Alps (1967), admiring the snow-clad peaks as well as Hecke's mathematical achievements.

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He left what he wanted his fellow human beings to know about him in his corpus of published work. All his work, however, was governed and unified by his remarkable personality. His French was pellucid. He was endowed with poetic sensibility and metaphysical insight. His creative élan and intellectual power will long be missed. He had that kind of charisma which demanded respect through admiration. When someone characterized him as cantankerous, someone else rejoined that his long and happy marriage showed that he could not be all that cantankerous. Eveline and he were as close as candlewick to candle flame. The distinctive hard shell of his personality was established at an astonishingly early age; he was confident, articulate, and independent. He had a tireless curiosity about the world, which was "so various, so beautiful, so new," in Matthew Arnold's words, and he had the capacity to assimilate ideas, attitudes, and qualities, combined with the sharply defined sense of his own wants. Mathematics and poetry (Greek and Sanskrit) afforded him a way into the sublime; travel lent enchantment to the enterprise.

He was a radical in the true sense who always tried to get to the root of things, though there were strains of traditionalism in him. This was so whether he was considering departmental budgets or diophantine equations, functional analysis on groups or zeta-functions, abelian varieties or the theory of correspondences on an algebraic curve. It has been said that the only success which is man's to command is to bring to his work a mighty heart. This he certainly did with his *Foundations of Algebraic Geometry* (1946), with "the precision of its language and the completeness of its proofs" in Harish-Chandra's words. His famous theorem (1940, 1948) on the Riemann hypothesis for curves over finite fields was built on those foundations and will remain a standing witness to his triumph as a mathematician, a triumph which stemmed from uncompromising self-reliance. "He lighted himself up with the fuel of himself." His radicalist approach to questions of administration did not always endear him to the authorities, some of whom resented his success and found his chirpy personality and dry humour not exactly ingratiating. He never courted popularity but was grateful when it came, as it did with the publication of his book on topological groups, with its dedication to Élie Cartan written in the confines of prison, or his last one on the years of his apprenticeship. He carried an air of quiet satisfaction whenever his audience in a lecture overflowed the auditorium, as it did at the Helsinki Congress (ICM 1978).

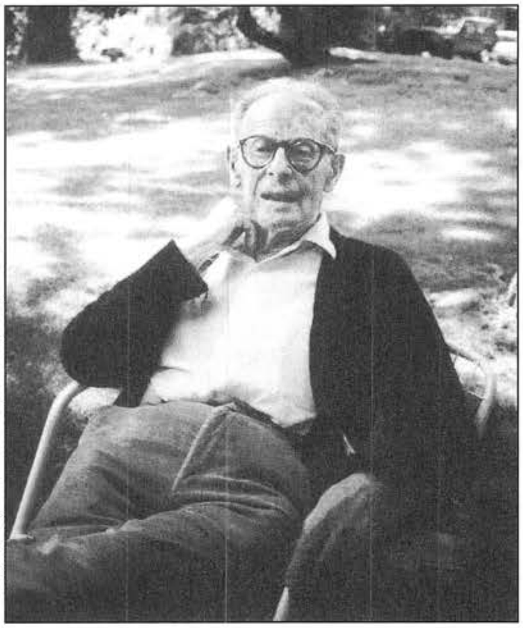
His precocious fascination for epic poetry began with Homer's *Iliad*, in Greek, which in turn quickened his interest in Sanskrit, and led inevitably to the great epic *Mahābhārata*. Its core, the *Bhagavad-Gīta* (the Song of God) stirred his blood as nothing else did either before or since. He acquired sufficient Sanskrit to be able to read the *Gīta* in the original with the help of a Sanskrit-French dictionary and an English translation. He was taken in as much by the beauty of the poem as by the thought that inspired it. The *Gīta* is perhaps the most systematic spiritual statement of the "perennial philosophy", embodying those universal truths to which no one people or age can make exclusive claim. Eminent Indologists like A. K. Coomaraswamy have expressed the opinion that it is "probably the most important single work produced in India." The *Gīta* remained Weil's close companion all his life, through thick and thin, as it did with Gandhi.

André Weil in the family apartment in Paris, 1952.

Photograph by Lucien Gillet, provided courtesy of Sylvie Weil.

Kālidāsa's lyric poem *Meghadūta* (the Cloud-messenger) enraptured him—as it has at least fifty generations of Indians—with its delicacy and grace, its mellifluous diction, its lyrical concision, and its suggestive power. Kālidāsa's deceptively simple Sanskrit is the despair of translators. Weil was struck by Kālidāsa's mastery of the Sanskrit language, of its grammar and rhetoric and dramatic theory, "subjects which Hindu savants have treated with great, if sometimes hair-splitting, ingenuity," in the words of Arthur Ryder (Berkeley, 1912). He came upon the fact that in India, Pāṇini's invention of grammar (ca. fourth century B.C.) had preceded that of the decimal notation and negative numbers. Pāṇini's *Aṣṭādhyāyi* (eight chapters) consists of nearly four thousand aphorisms, the *sūtras*, enumerating the technical terms used in grammar and the rules for their interpretation and application. The Sanskrit term for grammar is *Vyākaraṇa*, which literally means "undoing", implying linguistic analysis. Weil could very well say that "nothing he later came across in the writings of Chomsky and his disciples seemed unfamiliar to him."

Having delved that deep into Sanskrit studies, he was ready to jump at any offer of a chair in India, which eventually turned out to be mathematics (1930–32). It was in Helsinki on the opening day of the Congress (ICM 1978), as we emerged from a reception given by our Finnish hosts, and the evening was spread against the sky, that he suddenly asked me to recite the first line of the first stanza of *Meghadūta*, which he so dearly loved. I had not then known, as I did later, the intensity of the impact of India on his personality. Joseph Brodsky has said: "A



Photograph by Eric Weitzner, courtesy of Sylvie Weil.

Weil at home in Princeton, 1994.

man is what he loves. That is why he loves it; because he is a part of it." His colleagues at Princeton, Gödel and Oppenheimer, were ardent admirers of the *Gīta.* Oppenheimer's citation of lines (often misquoted) from the *Gīta* (Ch. XI, verse 32) as he witnessed the first nuclear explosion has entered the history of American science. Neither of them, however, could visit India as they had wished—the one for health reasons, and the other for political.

It is typical of him and his ways that some of Weil's most serious statements were made in short sentences in the most casual way in private conversation. When he came to see me in Zürich in 1970, he started a conversation by saying, "By the way, you know that I do not accept honorary doctorates." One recalls Marianne Moore's lines: "The deepest feeling always shows itself in silence; not in silence, but restraint." He was known for his short temper and for his sudden, provocative interventions, which sometimes resulted in abrasive confrontations. That was the less enduring side of his personality. It is in his writings that his personality really shows through—as a master of style, with deep reserves of reading, reflection, and self-scrutiny, with a hotline to the creative imagination.

Where he was, there was French culture. But one lapse of judgment on his part, at the outbreak of the war (1939–45), cost him no end of trouble in his mother country. America found him a position worthy of his talents, first in Chicago and then in Princeton, where he made his home. It is Auden, whom he knew, who said that home was a sort of honour, not a building site. Tagore, whom he met in India, used to say: "Blessed be he whose fame does not outreach the truth." Weil was blessed in that sense. I see his spirit floating serene over the rough reaches of time.

Armand Borel

André Weil had a strong sense of humor and a sharp wit. Whenever he perceived a comic aspect in some situation or statement or he strongly disagreed with someone's opinion, this would usually translate into an oral or written comment which could be biting, sometimes even hurting, or simply amusing, with little or no venom. I would like to describe two examples in the latter vein, pertaining to incidents which occurred while he was on the faculty at the Institute for Advanced Study.

The presence of Weil here of course enlivened considerably our faculty debates and meetings, maybe too much sometimes. Once, when we were considering projects for a new library, an extremely acrimonious discussion developed about the future location of the mathematics library. We have had in the course of the years our share of heated debates on various questions, but that one was really about a minor point, absurdly out of proportion with the tone of the discussion. The following day, I told Weil it had reminded me of *Le Lutrin.* The latter is a classic of seventeenth-century French literature, written by N. Boileau, which describes a battle between two factions of monks in a monastery about the location of a lectern (lutrin). It is a poem, written in the style of great epics like the *Iliad*, narrating how those monks heroically fight by hurling big dusty old books at one another. This comparison amused him. As far as I was concerned, that was the end of it, but not for him, because two or three days later our director, R. Oppenheimer, received a letter in seventeenth-century French (see sidebar), signed "Boileau", or, rather more ceremoniously, "of your Magnificence, the very humble and very obedient servant, Nicholas Boileau-Despreaux," addressed to Monsieur Robert Oppenheimer in his School (Eschole) of Princeton in the New Jersey at the Indians of America, saying in part: "In the kingdom of shadows, there is much talk about the debates, so glorious for you, in which you were pitted against some people who wanted to quickly dispatch here the rest of humanity. It is also said that you know modern and ancient languages, including that of the brahmins, so I shall express myself in French, my mother tongue, rather than in yours, which I understand well, but use only with some difficulty.

"You surely know that, once per century, our ruler Pluto grants us a leave during which we are allowed to reincarnate ourselves on the earth...Our queen Proserpina has informed me of the great war which is developing in your Eschole. It is even said that cannons have already thundered."

Boileau adds that as he wishes to come back as a historian, this would be a most appropriate topic of investigation for him, and so he applies for membership with stipend, because once on the earth he will have the same needs as ordinary mortals. He also gives as credentials *Le Lutrin* and his former official title of historian of the King.

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A version of this segment in French is appearing in the Gazette des Mathématiciens.

For the enjoyment of readers familiar with French, here is the original.

A MONSIEUR Monsieur Robert Oppenheimer En son Eschole de Princeton dans le Nouveau Jersey ches les Indiens d'Amérique

Je ne sçais, MONSIEUR, si ce peu de réputation que j'eus de mon vivant sera parvenu jusqu'à vous. Mais je puis bien vous dire qu'ici, au royaume des ombres, il n'est bruit que de vous et des débats, si glorieux pour vous, où vous fustes opposé à quelques savantastres dont le charitable dessein était d'expédier promptement chez nous tout ce qui reste d'hommes sur la terre. On dit aussi que vous sçavez parfaitement les langues tant anciennes que modernes, et mesme celle des brachmanes. C'est ce qui fait que pour vous escrire je m'exprime en françois, ma langue maternelle, plutost qu'en la vostre que j'entends fort bien, depuis que Messieurs Pope et Addison m'en communiquèrent l'usage, mais dont je ne me sers qu'avec un peu de peine.

Vous n'ignorez pas, MONSIEUR, qu'une fois par siècle notre auguste souverain Pluton nous accorde un congé durant lequel nous avons permission de nous réincarner sur terre. J'ay dès longtemps songé à consacrer à Calliope mon prochain séjour parmi les vivans, car j'eus autre fois pour l'histoire un goust fort prononcé. Mesme j'eus l'honneur d'estre historiographe du roy. J'advoue que je n'ay rien laissé qui m'acquitast envers la postérité de ce qu'elle eust eu droit d'attendre de moi à ce titre. Du moins osay-je me flatter que mon poème du LUTRIN aura asseuré à mon nom quelque durable renommée parmi les sçavans férus d'histoire ecclésiastique, et que votre docte confrère, M. le Conseiller Aulique Cantorovitche, si versé en celle-ci, ne manquera pas d'en témoigner.

Or notre auguste souveraine Proserpine, constamment informée par les voies les plus sûres de ce qui se passe au monde des vivans, a daigné me faire avertir de la grande guerre qui pointe en votre Eschole, sur le sujet de votre librairie ou bibliothèque. Mesme on dit que le canon aurait desjà tonné en vos murs, et que vos mathématiciens s'apprestent à la deffense. Je ne sçaurois certes trouver plus digne sujet pour ma Muse.

Mais, lorsque nous autres morts rendons visite aux vivans, nous devenons sujets, tout comme vous, à de fascheuses nécessités, c'est de manger et de boire. Des gens dignes de foi m'ont asseuré qu'il est en votre pouvoir, après avoir pris avis de vos conseillers ordinaires, d'accorder des pensions ou stipendia à ceux que vous en jugez dignes. Aussi osay-je m'adresser à vous, avec l'asseurance que ma requeste, dont l'effet sera d'immortaliser votre Eschole, ne peut manquer d'estre receue de vous avec faveur. C'est dans cette persuasion, MONSIEUR, que j'ay l'honneur de me dire ici

—De votre Magnificence
Le très-humble et très-obéissant serviteur
Nicholas BOILEAU-DESPREAUX"

Shortly after, Weil sent a short note to E. Kantorowicz, the executive officer of the School of Historical Studies:

> I hear that Dr. Oppenheimer has received an application for a stipend from my famous countryman, Monsieur N. Boileau. Obviously this concerns your school. May I nevertheless, without impropriety, put in a word of recommendation? His project seems most promising. It is true that he has been dead for a great many years. But surely, in the eyes of historians and scholars, this should be counted as a feather in his cap.

(A faint allusion to the fact that the average age of visitors in historical studies was much higher than in mathematics, an impression which Weil made more precise during his first year here, 1958–59, by drawing a graph of the age distribution of temporary members in the various schools. For mathematics it started at 21, had a high peak at 30–34, then decreased to at most one between 45–49 and 60–64. In historical studies it began at 27–29 with one member, had two peaks at 50–54 and 65–69, and showed still one member in the range 80–84.)

Some days later, Oppenheimer offered a 25-year fellowship to Boileau. Needless to say, the library discussions were hardly the same later on.

In July 1969, D. Montgomery felt unusually hot in his office at one end of the ground floor of Fuld Hall. Of course, there is nothing unusual about hot and humid weather in Princeton at that time of the year, but that was really out of the ordinary, so much so that Deane went down to the basement to see whether he could find a cause for it. To his great astonishment, he saw that a room was being permanently heated, serving as a breeding farm for pheasants and other high-class fowl. He wrote a short note to the general manager, asking that this be removed, which was done, but not before the news had spread all over. Deane, who was at the time executive officer of the School of Mathematics, soon received the following letter from Weil:

> It is my understanding that Fuld Hall is being converted into a Pheasant Breeding Farm, and that, for what must appear to everyone as narrowly selfish motives, you have raised objections against this excellent plan.
>
> Had you canvassed your colleagues first (as was your obvious duty), you would have discovered that there is widespread and enthusiastic agreement in favor of the aforesaid project—it being understood, of course, that a bonus of

Photograph courtesy of Sylvie Weil.

André and Eveline Weil in Princeton, about 1985.

> a brace or two of those valuable birds would be distributed at Christmas, Thanksgiving and other suitable occasions, to all members of our Faculty...I should be obliged if you would formally communicate these views of mine to all those who are in any way concerned with or interested in the Pheasant Project (first and foremost, of course, our Director).

Weil's irony was sometimes a way to let off steam in tense situations. Weil was indeed temperamental, could not stand cant or humbug, and was extremely serious, even intense, about matters of interest to him, which he pursued thoroughly. As anyone can gather from his autobiography *The Apprenticeship of a Mathematician* (Birkhäuser, 1992), his cultural and linguistic interests were broad and deep. Besides being fluent in several modern languages, he enjoyed reading in the original Latin (his daughter Sylvie told me once that, while preparing for the French "Baccalauréat", she would sometimes ask him for words encountered in Latin texts but not included in her dictionary, presumably on grounds of decency) or Greek or the *Bhagavad Gīta* in Sanskrit. Still, however substantial those were, mathematics had by far top priority. Obviously, he viewed it as his main mission to contribute to its progress, and his life was organized to a large extent with that goal in mind. As he told me once, thinking of his other interests, this indeed entailed shutting quite a number of doors. In personal mathematical contacts, he was a driving force, always ready or eager to discuss, explore, push further, inform, and be informed. In 1955 I was in Chicago, living with my wife and our first daughter in the same house as the Weils. Early one morning I had a mathematical idea which, though very simple, was so crucial for my work that I could not wait to check with him whether it was sound. I called, explaining why I wanted to see him. His wife, Eveline, who had answered, told me he was preparing to leave for a short trip out of town. So I said, slightly disappointed, I shall wait until he comes back. "Oh no," she replied after having talked with him, "for André, mathematics always comes first; he will find time to see you before leaving." The Weil family was living in an apartment on the ground floor. The room he had chosen for his office was sticking out, with windows all around, and he could be seen working there seemingly constantly, mostly typing, as if glued to his typewriter. Once the janitor told him, "You are working so hard. If you go on like that, you will become very famous." As Mark Twain has pointed out, it is always hazardous to predict, especially the future. Here she was in fact predicting the past as well as the future, so she was on safe grounds.

Pierre Cartier

In 1957 the University of Chicago accorded a sabbatical leave to André Weil, who spent it in Paris. In fall 1958 Weil was named a permanent professor at the Institute for Advanced Study (IAS).

He adapted immediately the Séminaire Hadamard of his youth into a "Joint Institute-University Seminar on Current Literature", which lasted from 1958 to 1962. Nearly every year he gave a course at the IAS. There were successively three great areas of interest, all linked to number theory:

a) adeles and algebraic groups; application to discrete subgroups of Lie groups;

b) automorphic functions and Dirichlet series;

c) history of number theory.

Weil was not what one would call a great speaker; I speak from experience, having taken at Princeton his courses in spring 1959, fall 1965 and 1969, and winter 1973–74. His written mathematical style was often heavy, not approaching the sarcastic elegance of his *Souvenirs*.[1] One learned much in taking his courses, but it was necessary to be intrepid, and this always limited the number of his students. He developed at length interminable calculations and took a cunning pleasure

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This segment is an authorized translation of an extract of the author's article "Andre Weil (1906–1998: Adieu à un ami" planned for a Web page at http://www.ihes.fr/.

A longer extract of this article is appearing in French in the Gazette des Mathématiciens.

[1]Souvenirs d'Apprentissage, *Birkhäuser, Basel, 1991; English translation by Jennifer Gage,* The Apprenticeship of a Mathematician, *Birkhäuser, Basel, 1992.*

in giving the point only at the very end. I remember in particular the last class in fall 1965, two days before Christmas. The audience was essentially European; each of us was carrying an airline ticket for the flight home, and we had left our luggage in the entry. He waited until the final minutes to formulate what would become the Taniyama-Shimura-Weil conjecture.

During all this period he had even fewer students formally than in Strasbourg or Chicago—only perhaps Demazure and Ono in 1960. Nevertheless, many of us would scrutinize each of his articles to find help or inspiration; number theory owes him an enormous debt, to the point of putting in place an important part of the strategy that was going to allow Wiles to solve the Fermat conjecture in 1994.

Viewed from the outside, his life in Princeton hardly differed from that of distant gods like Gödel or Einstein. He led a comfortable but austere life, modeled on that of the English colleges. After long sessions of work in his office in the basement of his house, surrounded by his wonderful library, came a ritual visit to the Institute a little before lunch. I had the immense good luck to share long walks with him in the Institute woods, or sometimes along the frozen Lake Carnegie in winter; we discussed his published articles or ones in progress, or we discussed the plans for Bourbaki. He had rather little social life, aside from concerts on the campus or in town and some parties at colleagues' homes. Few of us entered his house, in Princeton or in Paris, and caught sight of the retreat where he did his thinking.

André Weil never had the reputation of being an easy personality; his mockeries were formidable and fearsome. I remember several stories at the time of his settling in Princeton in 1958. Leray spent the fall at the IAS, and I listened to his course on the theory of residues for functions of several complex variables; as usual, this course was profound and obscure. Weil arrived some weeks late, and my wife and I had already firmly established a friendship with Leray, who was alone and happy to find a welcome. One day when all three of us were together, Weil found himself face to face with Leray, neither giving way. I knew that there were old feelings of hostility between Leray and Weil, and I tried to save the situation in comic fashion by introducing one to the other. I received several hours later two confessions in nearly identical terms: "...si vous le connaissiez depuis aussi longtemps que moi, vous comprendriez que son venin est désormais plus sucré... ."[2]

Some weeks later, Grothendieck spent several days in Princeton. Borel organized in his office an unpublicized seminar that lasted one Saturday from nine in the morning to six in the evening, with a short break for lunch. Grothendieck lectured on the same subject as Leray, with more generality, but, in contrast with the analyst Leray, he adopted a resolutely algebraic point of view. At the end of this long session, Weil commented in a loud voice, "We ought to ask our colleagues in physics to invent a principle of anti-interference, which would have light burst forth from two darknesses (Leray and Grothendieck)."

Weil retired in 1976. He remained in Princeton, since his family had settled in the northeastern part of the United States. It was his custom right up until his death to spend spring in Paris and summer in the Mayenne. He still wrote some articles, mainly about the history of mathematics, but his main achievement is composed of two books: the first[3] is a rereading of Eisenstein, which opened up new directions in algebraic number theory. The second[4] sprang from his last courses, in which he had had the ambition of going from Fermat to the present time. He explained there all he learned by reading Fermat and Euler. For him the history of mathematics signified above all rereading the classics for inspiration. At the same time, he edited his *Œuvres Scientifiques* in three volumes and added to each volume an extremely rich "commentary", which is in fact an intellectual autobiography.

Photograph courtesy of Sylvie Weil.

Weil and his daughters, Sylvie (left) and Nicolette, in Princeton, January 1966.

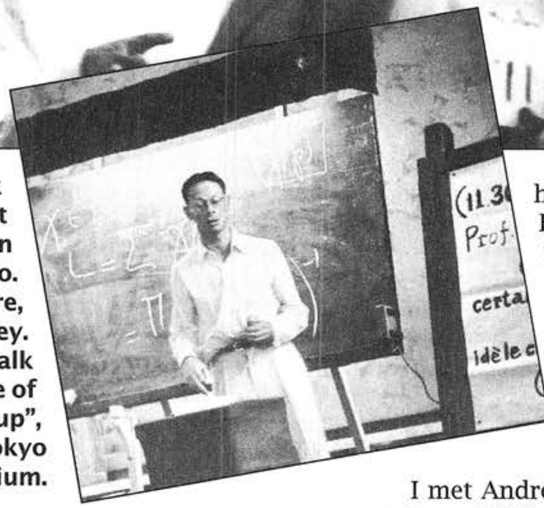
His wife, Eveline, died in 1986, a few days after André's eightieth birthday, definitely breaking his momentum. With his remaining strength he wrote his *Souvenirs*, as a last tribute to his wife and his sister. He kept to his old habits, but his lack of domestic sense and his poor eyesight left him a prisoner of various domestic helpers in Princeton and in Paris. Each time that I saw him in Paris, he was a bit lost in the large apartment of his parents, from where one dominated the Jardin du Luxemburg and from where one could view Paris as far as the Sacré Coeur. This apartment became his after the death of his mother, with whom he had protracted fights. It was also a Paris home for his older daughter, Sylvie, who has successfully combined the cultures of New York and Paris—Woody Allen and Sartre. After Eveline's death we customarily took

[2] *"If you had known him as long as I have, you would understand that his venom has become sweeter."*

[3] Elliptic Functions according to Eisenstein and Kronecker, *Springer-Verlag, Berlin, 1976.*

[4] Number Theory: An Approach through History from Hammurapi to Legendre, *Birkhäuser, 1984.*

Photographs by Asako Hatori, provided courtesy of Shokichi Iyanaga with permission of photographer.



Top: Group chatting after talk September 8, 1955, by Emil Artin at International Symposium on Algebraic Number Theory in Tokyo. Left to right: Artin, Jean-Pierre Serre, Weil, Claude Chevalley. Photo at right: Weil giving the talk entitled "On a certain type of characters of the idèle class group", also September 8, 1955, at the Tokyo symposium.

some meals each year in some restaurant in the Latin Quarter. I also sometimes took him for a day's visit to my home, in the woodlands of the Beauce, near enough to Chartres for a detour to visit there on the way. He was happy to be able to take a long walk in the beautiful woods and princely parks of my little region.

I remember clearly three of his later visits to Paris. First, there was the summer when unfortunately he broke his leg on one of those anti-car barriers that the Paris administration has put on many sidewalks (he was always nearsighted and paid the price for his myopia); Cartan, his elder by two years but still quite lively, had to struggle to get him to the hospital.

Next, after the publication of his *Souvenirs* he spent a long evening with me near Odéon, defending his story of his imprisonment in Helsinki in fall 1939, which was refuted by the Finnish police archives exhumed by a young colleague in Helsinki.

Finally, in 1994 he had just learned he would receive the grand Kyoto Prize for his work. He cared to go in person to the ceremony; Sylvie, like a modern Antigone, dressed completely in black, kept him company in Paris and agreed to share the long trip from Paris to Kyoto via Princeton with him. She was fearful of that journey, and rightly so. It was at this point that I perceived how much he had suffered from being exiled from Paris, even in the gold cage that is Princeton; the fact that his three grandchildren spoke little French and were unaware of all our culture and that his younger daughter had become so American weighed on him a great deal.

During his last two years he sensed himself weak and isolated. The ordeal of the end was relatively light for him; he died suddenly. He had no hope for eternal life, but took comfort that his work would survive him. While founding Bourbaki to promote the unity of mathematics, he believed that it would become the Euclid of the twentieth century; it is not very reassuring that Bourbaki was almost dead before the end of the century. As Valéry prophesied: "We others, civilizations, know that we are mortal."

Shokichi Iyanaga

I met André Weil for the first time in Paris in autumn 1932, soon after his return from India. I came there from Hamburg, where I had stayed for two semesters. After having studied in Tokyo with Takagi, I left Japan in 1931 to study further in Europe, first in Hamburg with Artin, where I was very fortunate to make the acquaintance of Claude Chevalley, who happened to be there just for the same period. At that time only a few French mathematicians were concerned with arithmetic; there were practically none, I believe, apart from Weil, Herbrand, and Chevalley, among whom Herbrand suffered a tragic death in an accident in the Alps in summer 1931, after which Weil and Chevalley were, so to speak, the only French arithmeticians. Weil had published his famous thesis on the arithmetic on algebraic curves in 1928, and I had heard much of him from Chevalley. Thus I had a respect for his work. I did not think that Weil had heard anything of me before our encounter, but he had perhaps some friendly feeling for me, as I was introduced to him by Chevalley. Once we sat side by side at a session of Hadamard's Seminar in the Collège de France. He handed me a little piece of paper with the words: "Écrivez en japonais 'A bas l'armée!'" (Write in Japanese "Down with the army!"). I knew that he was versed in many foreign

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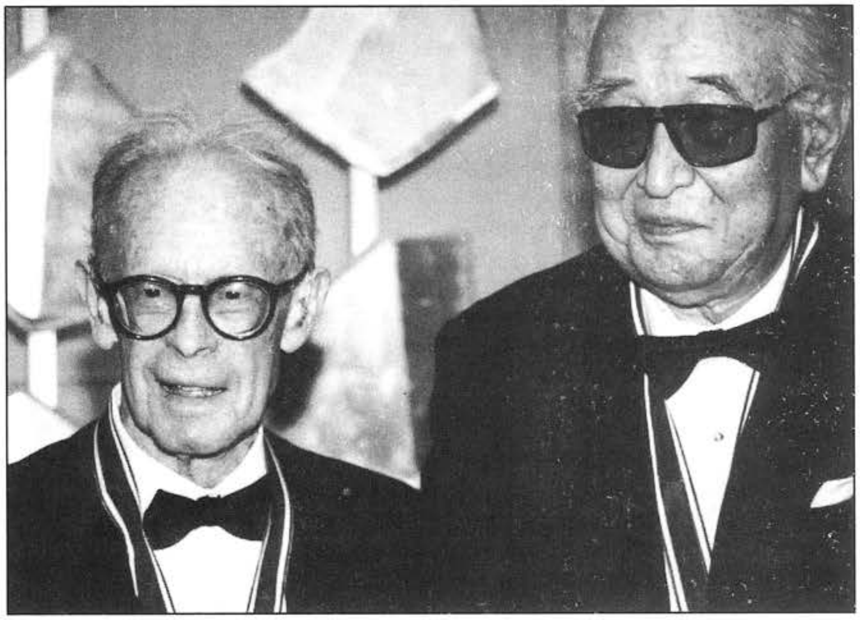
This segment is also appearing in the Gazette des Mathématiciens *and in the* Bulletin de la Société Franco-Japonaise des Sciences Pures et Appliquées.

languages, including Sanskrit, but I did not believe that he knew Japanese. I thought, however, that he wanted to see how I wrote these words as a citizen of the country whose army was making insidious maneuvers in China. Thus I wrote with a smile three Chinese characters meaning "Down with the army!" on the same piece of paper and returned it to Weil, which he received with a smile. I returned to Japan in 1934 and was nominated to a post on the teaching staff at the Tokyo University in 1935, but the general tendency of my country (and also of the whole world) went toward the war, to my great disappointment. It was only in 1950, five years after the end of the war, at the ICM in the U.S., that I could see again the mathematicians with whom I had enjoyed friendship in Europe before the war, and five more years later, in 1955, that we could organize the first international symposium on algebraic number theory in Japan, to which we could invite Artin, Chevalley, and Weil, among others.



Weil with film director Akira Kurosawa on the occasion of the ceremony for the awarding of Kyoto Prizes to each of them, Kyoto, 1994.

Weil came then to Japan from the U.S. by a Japanese ship, some weeks before the symposium. I went to meet him at Yokohama Port one afternoon and invited him to dinner in my family's home that evening. During our conversation, he was anxious to know about what we had been preparing for the symposium. I told him in particular of the works of Taniyama and Shimura on the theory of complex multiplication. He wanted to see them as soon as possible. Therefore I asked them by phone if they could come to my office at the Tokyo University the next afternoon to meet Weil, and I felt how surprised and delighted they were. The following day, Weil was apparently impressed at hearing their talk, but at the same time he found out their weak points; in particular, Taniyama had used van der Waerden's theory of moduli, which had to be corrected in introducing the concept of polarized varieties, as Weil had just intended to speak at the symposium. Arrangements were made among them during the following days about the plans of their talks at the symposium. Weil had already made personal acquaintance with a number of Japanese mathematicians like Nakayama, Kodaira, Iwasawa, and Igusa in the U.S., but it was in this way that his deep influence began to penetrate into the younger generation of Japanese mathematicians. In his comments on his papers contributed to our symposium (in Vol. 2 of his *Collected Papers*) he describes how he enjoyed this symposium. As is well known, Shimura was invited to Princeton, where he still continues his activities up to this day. Taniyama was also invited to Princeton, but very unfortunately he committed suicide before accepting this invitation. We find Weil's very friendly letter to commemorate Taniyama reproduced in Vol. 2 of his *Collected Papers*. (It is also well known that from their conversation during Weil's stay in Japan on this occasion there originated a conjecture on modular elliptic curves which played an important role in the genesis of the proof of Fermat's last theorem by Andrew Wiles.)

I shall now conclude this article by recounting our last encounter in 1994. He came to Japan with his daughter Sylvie in autumn that year to receive a Kyoto Prize. (He was eighty-eight years of age, just like me.) He spent the last several days in Tokyo before leaving for New York. For the last evening, he invited me, together with Mr. and Mrs. Satake, who took care of hotel arrangements, etc., for them in Tokyo, to dinner at his hotel. After dinner we accompanied him to the door of his room. We wished him a good trip to his home and expressed our hope of having another occasion to invite him to Japan. Weil thanked us for all that we had done and said, "the next time perhaps in another world ...", to which we could not find any appropriate words to respond. I parted from the Satakes at the door of the hotel and was left alone. Sitting in a subway train on my way home, I was suddenly taken by an overwhelming sorrow.

Book Review

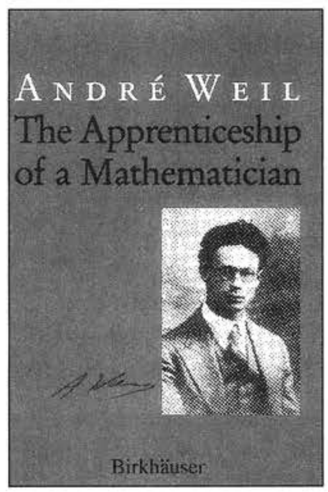
The Apprenticeship of a Mathematician—Autobiography of André Weil

Reviewed by V. S. Varadarajan

The Apprenticeship of a Mathematician—Autobiography of André Weil
Translation of Souvenirs d'apprentissage
Translated by Jennifer Gage
Birkhaüser
ISBN 3-7643-2650-6
ISBN 0-8176-2650-6
197 pages

My life, or at least what deserves this name—a singularly happy life, its diverse vicissitudes withal—is bounded by my birth on May 6, 1906, and the death on May 24, 1986, of my wife and companion, Eveline.... It is with these moving words that André Weil, one of the greatest mathematicians and mathematical personalities of this century, begins this extraordinary autobiographical account of his life from his childhood days until the fall of 1947, when he accepted a professorship in the department of mathematics of the University of Chicago offered by his friend Marshall Stone. In beautiful prose that at times becomes poetry and goes straight to the heart, Weil not only describes his life and its many ups and downs but also allows many deep glimpses into his heart and mind as he takes the reader along with him on his journey.

Weil describes his book as "an attempt to retrace the intellectual itinerary of a mathematician," and he has succeeded to a remarkable extent. It is as if he has detached himself mentally from his life and reviews it, giving the reader a faithful (but inevitably selective) recollection of what he saw and experienced, annotated with a commentary that is at various times trenchant, ironic, critical, moving, and yet ultimately very sincere and true to his own self. Some of the remarks he makes must be familiar to the readers of his "Commentaire" in his *Collected Papers*, and so this book is an attempt to reach a wider audience as well as to go beyond the strictly mathematical aspects of his intellectual and emotional development.



Early Days and the École Normale

André Weil's grandfather was Abraham Weill, a respected member of the Jewish community in Alsace. His father was Bernard Weil, who was a physician in Paris. His mother's family came from Russia. André was born in 1906, and his early days, spent in the company of tutors (he was clearly a precocious child) and his younger sister, Simone, were, by his own account, very happy ones but very different from the lives of most other children because of the emphasis on intellectual activities. He was fortunate to come into contact with exceptional teachers whose influence stayed with him throughout his life. His education was a comprehensive one, encompassing the sciences, languages, and hu-

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manities. His interest in and exceptional ability with languages were visible quite early, while his taste and passion for mathematics started from the time he was eight years old. When his mother expressed her fears to one of his early teachers that he may not be sufficiently well grounded in "arithmetic", the teacher replied, "No matter what I tell him on that subject, he seems to know it already."

The First World War touched the lives of the Weil family deeply, because his father was drafted into the medical corps of the army. The stupidity of the politicians and the generals and the relatively poor state of medical science contributed to huge casualties among the enlisted men, and Bernard Weil himself fell ill due to exhaustion and depression and was sent back from the front for rest and recuperation. There is a charming anecdote of how André and Simone planned to surprise their father with a birthday present, which was to be a reading of the newspaper for him by Simone, and how André was the fierce taskmaster during the secret preparations, making sure his sister pronounced all the subtle words in the correct way.

From the age of nine Weil started contributing to one of the journals which published mainly problems—essentially examination problems at the secondary school level—and the best solutions as well as the names of the successful solvers. Soon he found he could do some of these problems, and the day came when his solution was printed as the best. The years preceding his entry into the École Normale were spent in the Lycée Saint-Louis, which was acclaimed to be the best scientific *lycée* in France, although the humanities were by no means neglected. About a year before he left the Lycée Saint-Louis, when he was fourteen, he met Hadamard. Let me tell in Weil's own words his assessment of Hadamard at that time: "...The warmth with which he received me eliminated all distance between us. He seemed to me like a peer, infinitely more knowledgeable, but hardly any older; he needed no effort to make himself accessible to me...." When Weil received an endowment prize which allowed him to choose some books as a reward, Hadamard helped him make his choices. It was thus that he became acquainted with Jordan's *Cours d'Analyse* and Thompson and Tait's *Treatise of Natural Philosophy*.

While he was preparing to enter the École Normale, Weil met another person whose influence was decisive in his intellectual growth. This was Sylvain Lévi, leading scholar in the field of Indian studies in France at that time. Already, in his very early teens, Weil had formed a vague resolution to learn Sanskrit so as to be able to read Indian epic poetry, and the acquaintance with Lévi sparked this latent wish and started him on a path that would prove fateful in its implications later on. It would create an intense desire to go to India, and when the opportunity came later, he would grasp it. But more about this later.

He entered the École in 1922, when he was sixteen years old. He joined the famous Hadamard Seminar, where the participants would report on topics of current interest in mathematics. In its reach and diversity the Hadamard Seminar was almost universal and reflected the universality of Hadamard's mind. It is quite probable that it was this seminar, at least intellectually if not personally, that served as the model for Weil's own famous current literature seminar, which he conducted jointly with Princeton University for many years while at the Institute for Advanced Study. He attended Lebesgue's lectures. He also started two things which would be of tremendous importance for him later. He had already become convinced by his reading of the Greek poets that the only way to deeper knowledge was through the study of the works of the truly great minds. So he began to study Riemann, often seeking help from Felix Klein's mimeographed lecture notes on Riemann's work, which were available at the École library. In addition, he went to Sylvain Lévi to seek advice for some vacation reading (!) in Sanskrit. Lévi gave him a copy of the *Bhagavad Gita*[1] with the comment: "Read this. First of all, you cannot understand anything about India if you haven't read it," and here Lévi's face lit up, and he added, "and besides, it is beautiful." Weil read the *Gita* from cover to cover and was affected by its beauty immediately. The thought behind it impressed him profoundly and was, in his own words, the only form of religious thought that could satisfy his mind. As we shall see later in greater detail, the *Gita* is not a dry system of philosophy, but a prescription for action for a man confronted by conflicting choices. Weil's love and knowledge of the *Gita* was at the heart of many of the decisions and actions that would be critical later in his life: his decision to go to India

[1] *The* Bhagavad Gita, *or* Gita *for brevity, which literally means "The Song of the Lord", is a long poem imbedded in the Indian epic* Mahabharata. *It consists of the instruction and advice given by Krishna, an incarnation of the god Vishnu, to Arjuna, the great warrior king, on the eve of the battle of Kurukshetra, a central episode in the* Mahabharata. *The* Mahabharata *is an extraordinary but long and complex epic. It has become a part of the cultural heritage not only of India but of many of the countries of South and Southeast Asia. There is a very good translation by J. A. B. van Buitenen, published by the University of Chicago Press. It is, however, incomplete and in particular does not include the* Gita, *although van Buitenen has a very nice description of the* Gita *in the* Encyclopedia Brittannica, *15th edition, Macropedia, 8:937. Peter Brooks's nine-hour dramatization of the* Mahabharata *is a wonderful evocation in television of this great epic suitable for Western audiences. The influence of the* Bhagavad Gita *has been profound, and it has shaped the lives of many famous Indians, including Mahatma Gandhi.*

Courtesy of Sylvie Weil and reprinted from the work *Apprenticeship of a Mathematician* with permission from Birkahüser.

André Weil and his sister Simone vacationing in Knokke le Zoute, Belgium, summer 1922.

and immerse himself in Indian life and culture for a couple of years, his decision to refrain from joining the army when the Second World War broke out, and the fortitude with which he endured the traumatic consequences that flowed out of this decision. He felt that it was his understanding of the ideas in the *Gita* that made him comprehend his sister's way of thinking, which would often appear mystical in her later years.

He attended Jules Bloch's course on the *Veda*, Meillet's lectures on Indo-European linguistics, and Sylvain Lévi's course on *Meghaduta*, a beautiful poetic fantasy by one of ancient India's greatest poets, Kalidasa. He lovingly recalls the gentle voice of Lévi intoning Kalidasa's beautiful cadences. These years at the École, when his mind was at its most eager and receptive, were the seeds from which his life grew to its fullest stature in later years. In some sense everything that he did or that happened to him, either in mathematics or in his personal life, could be traced to these years of gestation at the École.

Travels and Thesis

In 1925, with the years at the École behind him, Weil started to travel. Normally he would have had to do military service for a year, but in his case, because he was very young, this was postponed, which gave him an opportunity to travel. He went to Italy, Germany, Scandinavia, and England, enriching his life not only by meeting the major mathematicians in these places but by immersing himself in the rich cultural ambiance that these countries provided. But before he started these travels, he had some time on his hands, and he slowly started making his future plans in mathematics. It was during this time that he began thinking about diophantine geometry, combining the ideas of Riemann with those of Fermat, and began his lifelong love affair (to borrow the felicitous phrase by which he himself described Emil Artin's work[2]) with the arithmetic of algebraic varieties.

In Rome he met Vito Volterra and became a close friend of Volterra's son, Edoardo. He met Severi and attended his lectures on algebraic surfaces. He also came to know of Mordell's famous 1922 paper on rational points on elliptic curves over the field of rational numbers. He then went to Frankfurt and met a remarkable and tightly knit group of mathematicians: Dehn, Hellinger, Epstein, Szász, and Siegel. Their knowledge, their attitude toward the philosophy of mathematics, and their insistence on seeing mathematics as a whole and not as a splintered collection of subdisciplines made a profound impression on him. Weil mentions a seminar session devoted to Cavalieri where Dehn showed how one should read Cavalieri's text, taking into account what was known at that time and contrasting this knowledge with the new ideas that Cavalieri was trying to introduce. He met Erhard Schmidt and, in Stockholm, Mittag-Leffler. Mittag-Leffler promised Weil that the *Acta Mathematica* would publish Weil's thesis, which was as yet unwritten. He then returned to Göttingen, where it suddenly occurred to him that his ideas on diophantine geometry would allow him to prove a far-reaching extension of Mordell's theorem. Although it would take him a year to turn this sudden insight into a rigorous proof, there is not much doubt that it was during this visit to Göttingen that the "phase transition" took place in his understanding of the arithmetic of algebraic varieties.

Upon his return to Paris, his immediate task was to write up his thesis and get it accepted. He had refined his ideas on diophantine equations and succeeded in proving the finite generation of the rational points of the Jacobian of a curve of arbitrary genus defined over a number field. He approached Hadamard and asked his advice about submitting his thesis, adding that he thought he might also be able to prove the Mordell conjecture. Hadamard advised him to wait till he settled the Mordell conjecture also (!) with the words : "Weil, several of us think highly of you; you owe it to yourself, when presenting your thesis, not to stop halfway through. What you say shows that your work is not yet mature." But Weil decided to present his thesis as it was, a decision that was wise, because the Mordell conjecture would not be settled for another fifty years and then only after the birth of a new vision of algebraic geometry due to Grothendieck.

Writing up the thesis, which he did in the summer of 1927 and the year following, was one thing, but getting it accepted was another entirely different proposition because of the bureaucratic requirements of the French university system. He

[2] *In his review of Artin's* Collected Papers *he says: "Perhaps the best part of (Artin's) career may be described as a love affair with the zeta function."*

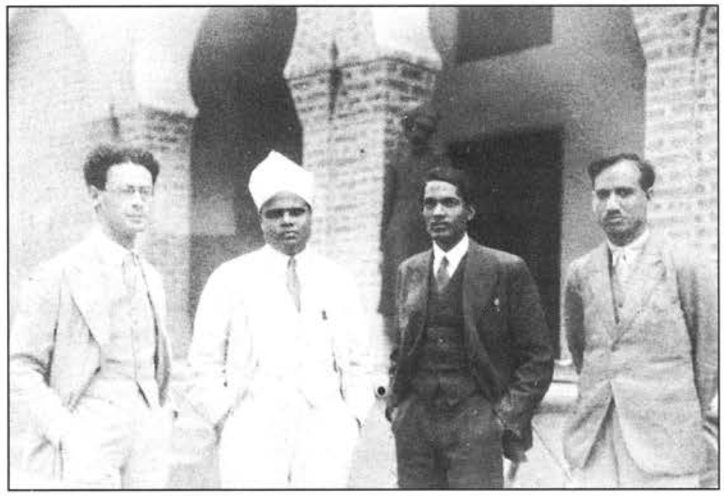
managed to persuade Picard to chair his thesis committee, but Picard did not want to write the report. Weil had already discussed his results with Siegel and knew that Siegel thought highly of his work. So all he had to do was to find another person to be a member of the committee and write a favorable report. Weil's account of how he succeeded in getting this done is both hilarious and charming. As mentioned already, the thesis would appear in the *Acta Mathematica*.

Once the question of the thesis was disposed of, Weil could turn to other matters. First of all there was the question of military service, which should have been done when he left the École and which was postponed because he was too young at that time. He joined the 31st Infantry regiment and endured battalion life for a year, which he succeeded in cutting short by a couple of months by some ingenious maneuvering and excuses. It was then time to see about getting a job. A position was about to open up in Strasbourg, but that was to go to his friend Henri Cartan. Slowly the idea that he should go to India began to take shape in Weil's mind. He mentioned this to Sylvain Lévi, obviously hoping that Lévi's contacts might lead to something in that direction.

In 1929 exactly what he was hoping for happened. Sylvain Lévi phoned him one day and asked him if he was prepared to go to India to teach French civilization in an Indian university. Weil told Lévi that he would do anything to go to India. Then Lévi asked him to take a taxi and come at once to his home. There Weil met Syed Ross Masood, vice chancellor of the Muslim University of Aligarh (a small town near Delhi). It was Masood's idea that French culture should find a place alongside English culture in Indian universities, and with the (unlimited) power given him, he was taking some of the first steps towards realizing that goal. Weil was very impressed with Masood, whom he describes as "a tall man who filled the room with his broad frame, stentorian voice and ringing laughter," with a "presence that makes itself felt anywhere." Nothing happened for a while after this meeting. But one day Weil received a cable from India: "Impossible create chair French civilization. Mathematics chair open. Cable reply." The answer was obvious.

India

He was in India for more than two years, from the beginning of 1930 to the early months of 1932, after which he returned to Paris. This was a stay whose memories and effects stayed with him forever afterwards. He went everywhere, met everyone who was anyone, dipped deeply into Indian culture and books with the help of his newly acquired Indian friends. His account of his travels and experiences in India communicate wonderfully his thrill and excitement of coming into deep contact



Courtesy of Sylvie Weil and reprinted from the work *Apprenticeship of a Mathematician* with permission from Birkhäuser.

Weil (left) in Aligarh, India, with Vijayaraghavan (second from left) and two students, 1931.

with a culture that was totally different from anything he had ever experienced. It is a tribute to his genius and the strength of his character that he absorbed most of the good elements of this ancient civilization and incorporated them into his personality at a deep level. Mathematically it was here that he had the ideas on functions of several complex variables that led him to a generalization of Cauchy's formulae in the higher-dimensional case and to results on representing a holomorphic function as a polynomial series on pseudoconvex domains.

His immediate task, however, as required by the University, was to assess the quality of the mathematics faculty there and report on it to the authorities. He had a virtual carte blanche in framing his report. This report would then serve as the basis for actions of dismissals and hirings that the University administration would undertake. One should imagine the circumstances: he, a young man only twenty-three years old, abruptly dropped into a world he knew only from books, dealing with a culture that had existed for several thousand years, and given unlimited power over the professional careers of the members of the faculty around him. The faculty was small and consisted of people who had no idea of what mathematics really was, the library was very inadequate, and there were no traditions to speak of. No wonder Weil blundered many times, especially in decisions involving human beings.

However, Weil was very lucky in one thing. He was able to get appointed to the faculty a young man, Vijayaraghavan, who was a pupil of Hardy's. Vijayaraghavan had written several papers, but unfortunately did not have a degree and so was overlooked by the administration. But Weil, not trusting the administrators (a trait that he would never lose throughout his life), insisted on looking at the qualifications of all the applicants before any selection was made. It was thus that he came across Vijayaraghavan's name and succeeded in getting him selected. Weil took an immediate liking to Vij (as he was called), and they became very close friends. Weil says that in the time they were both together in Aligarh, he almost never left Vijayaraghavan's side. He became virtually a member of Vij's family and even ate in their house often, although Vij's mother perhaps had reservations about feeding a foreigner who was outside the brahmin caste. It was Vijayaraghavan who helped Weil to go deeper into the Indian classics like the *Mahabharata* and the *Chandogya Upanishad*.[3] From Weil's description of his friendship with Vijayaraghavan it is clear that there was a true harmony between the two. Weil's account of Vijayaraghavan's death, learned from his son, is brief but poignant.

Weil's attempts to carry out his commission went awry because he simply did not understand the human issues involved. Intrigues began to develop, and after he came back from a vacation he learnt that Vijayaraghavan had been eased out and had gone to take up a position at Dacca University. Weil himself was then fired on trumped-up charges of travelling without permission, although this was not to be attributed to conditions in India, since he had a similar experience later in Strasbourg. These events may perhaps be explained as the consequence of the natural reaction of entrenched forces to an outsider who came on a white horse with a mandate to sweep away the rubble and establish a new era.

The time of Weil's stay in India coincided with one of the most dramatic periods in her long struggle for independence from British rule. Mahatma Gandhi launched one of his greatest campaigns of *satyagraha*[4] against the British during the years 1930–32. Gandhi wanted it to be a movement that would involve the entire nation, which meant that the rationale had to be framed in a manner that would resonate with the masses. For this purpose Gandhi focussed on the salt tax which Britain had imposed so it could sell English salt at exorbitant prices. A natural consequence of this British policy of protection for their salt was a law that made it illegal for any Indian to make salt out of saltwater. The fact that a universal necessity like salt was controlled by the British in such a callous manner, when pointed out by Gandhi, galvanized the people. With characteristic brilliance and insight, Gandhi announced that he would march a few hundred kilometers from Ahmedabad, his normal place of residence, to a seaside village in the south and make salt there, daring the government to arrest him. This was the famous Salt March, arguably the single greatest campaign of *satyagraha* waged by Gandhi against the British, and the events springing out of it shook the British rule to its foundations and almost brought it to an end.[5] Weil was a full participant, emotionally and intellectually, in the events of this period in Indian history. He met almost all of the leading figures of the Indian independence movement, including Gandhi himself, and made deep friendships with some of them, like Zakir Husain, who was to become the president of India. This exposure to Gandhi's ideas was to prove fateful later when the time came for him to decide whether he was going to take part in a war that he did not feel was his war. But this is getting ahead of the story.

Strasbourg, Bourbaki, and More Mathematics

Weil returned to Paris and almost immediately got a position in the University of Marseilles as a lecturer. He held the position for a short time before going to Strasbourg, where his friend Henri Cartan was already in the faculty. From the fall of 1933 until 1939 he taught there, and these were happy and productive years for him.

There were at that time about ten young mathematicians, including Weil and Cartan, scattered in diverse parts of France, who were taking their teaching duties seriously and thinking about various pedagogical questions. Cartan himself often came to Weil and raised foundational questions, such as how best to formulate and prove a general form of Stokes' theorem to handle all applications. It was under the impulse of these questions from his friends that Weil had the idea that they should all get together and thrash out these problems once and for all. In retrospect this would turn out to be an important idea and mark the moment of conception of Bourbaki, which would dominate

[3]*The* Upanishads *are original texts containing Hindu speculative thought. There are 108 in all, dating back to between 1000 B.C. and 500 B.C., although some of them are thought to go back to even earlier times. Among the most famous ones are the* Chandogya Upanishad, *and the* Katha Upanishad. *The* Chandogya Upansihad *introduces the supreme reality that is the Universe* (Brahman) *and discusses the relation of the individual self* (Atman) *to this reality.*

[4]Satyagraha *literally means "insistence on truth". In Gandhi's hands it was transformed from a well-intentioned code of ethics into a dynamic instrument that energized a whole nation and led it to independence.*

[5]*The Salt March was from Ahmedabad to Dandi, a village on the west coast of India, several hundred miles to the south. It took Gandhi and his followers almost a month (from March 12, 1930, to April 6, 1930) to walk all the way. The march, with speculation (about British intentions toward the Mahatma) and the consequent tension mounting every day, attracted international attention. At the end of the march Gandhi and hundreds of his followers took sea water and distilled it to get salt. He was arrested a few days after this, but the* satyagraha *movement continued, paralyzing the country for months afterward. For a wonderful account see* On the Salt March, *by Thomas Weber, HarperCollins Publishers India, 1997, ISBN 81-7223-263-2.*

the mathematical instructional scene at its most advanced levels from then on. The founding members were Weil himself, Cartan, Delsarte, Chevalley, and Dieudonné. There were a few more who dropped out, but these five founders were the ones who continued till they were fifty, which was the age of retirement. Nowadays most mathematicians know the rituals and the history of the Bourbaki congresses and what became of them, so that there is no need to repeat the story here.[6]

However, there is one point that must be mentioned: it is not enough to create an author; one must have a publisher also. Bourbaki was fortunate to have the continued and unqualified support of Enrique Freymann, who ran the Hermann publishing company at that time. Mercurial, imaginative, and audacious, Freymann supported the young group wholeheartedly and gave them the financial support their efforts needed until they established themselves. Weil mentions many anecdotes in his brilliant sketch of Freymann's inimitable personality.

The War Years

Weil continued to travel, and among his travels was a visit to Russia, where he made the acquaintance of the principal Soviet mathematicians Alexandrov, Kolmogorov, Pontryagin, and others. But the times were slowly becoming ominous. War clouds were gathering in Europe. Moreover, these political developments were beginning to have an effect on his personal life. As a reserve army officer he was bound to serve in the French army when the draft call went up, and he was not willing to do it. Thus began the question within his own mind that tormented him all the time. Eventually he came to the decision that he would flee France and go to a neutral country if and when war broke out. He was aware that in all but technicalities this was desertion and that he would have to face grave consequences.

This was the beginning of his war experiences, which he calls "a comedy in six acts: prelude, Finnish fugue, arctic intermezzo, under lock and key, serving the colors, and a farewell to arms." His decision, which he learned later was not technically a desertion since he was not in the army, was taken only after the most elaborate arguments and counterarguments in his mind. He went to Finland to spend a few weeks there. But the march of events forced his wife to return to France, with no clear assurance in their minds as to when and how they would be united again. Then the Finnish-Russian war broke out while he was still in Helsinki. He was already under observation by the Finnish police because of his correspondence with Soviet mathematicians. As soon as war broke out between Finland and Russia, the Finnish police, certain that Weil was a spy for the Russians and acting with stupidity, scooped him up and put him in jail. He narrowly escaped being executed thanks to the fortuitous intervention of Nevanlinna. Weil recalls a conversation he had with Nevanlinna twenty years after these events in which Nevanlinna, recounting what took place, said that he (Nevanlinna) was at a state dinner where he met the chief of police of Helsinki and had the following exchange with him:

Weil in Brittany, about 1960.

Photograph courtesy of Sylvie Weil.

> C[hief]: Tomorrow we are executing a spy who claims to know you. Ordinarily I wouldn't have troubled you with such trivia, but since we are both here anyway, I am glad to have the opportunity to consult you.
>
> N: What is his name?
>
> C: André Weil.
>
> N (shocked): I know him. Is it really necessary to execute him?
>
> C: Well, what do you want us to do with him?
>
> N: Couldn't you just escort him to the border and deport him?
>
> C: Well, there is an idea: I had not thought of it.

Weil was thus deported to a prison in Sweden and from there shipped to France via England. Once he entered France he was arrested and put in jail in Le Havre. After a little while he was transferred to the military prison in Rouen pending his trial.

He spent about three months in the prison at Rouen before his trial. It was a time of profound introspection for him. The loss of freedom and enforced isolation made him retreat to his inner self. It was in the prison at Rouen that he did what is arguably his greatest work, the proof of the

[6] *See A. Borel's article in these* Notices, *Vol. 45, Number 3, 373–80, as well as an older article by P. R. Halmos, in the* Scientific American, *May 1957 (part of a book,* Mathematics in the Modern World, *published by W. H. Freeman and Company, 1968, pp. 77–81).*

Riemann hypothesis for smooth projective curves over a finite field. It was also from here that he wrote his famous letter to his sister outlining for her his ideas about number theory and his perspective of viewing it in a way that unifies number theory and the theory of Riemann surfaces, a viewpoint that started with Hilbert, came to maturity with Weil, and eventually reached its full development with Grothendieck.

It was also from here that he wrote some very touching letters to his wife. These letters, which capture vividly his emotional and physical isolation and his deeply philosophical state of mind during his imprisonment, are among the most moving parts of the whole book. When he was not thinking about or doing mathematics, he was reading the *Gita* and the *Chandogya Upanishad*. In his mind he had a vision of Krishna to guide him through the ordeal. Here are some extracts from these letters.

> (March 4) What can I say about myself? I am like the snail, I have withdrawn inside my shell; almost nothing can get through it, in either direction.
>
> (March 30) ...I am reading the *Gita*, in small doses as one ought to read this book. The more detail one absorbs, the more one admires it.
>
> (April 7) My mathematics work is proceeding beyond my wildest hopes, and I am even a bit worried—if it is only in prison that I work so well, will I have to arrange to spend two or three months locked up every year?
>
> I am sending Papa Cartan a note for the *Comptes Rendus*....I am very pleased with it, especially because of where it was written (it must be a first in the history of mathematics), and because it is a fine way of letting all my mathematical friends around the world know that I exist. And I am thrilled by the beauty of my theorems.
>
> Here are some lines from the *Gita* that I like very much: "A leaf, a flower, a fruit, some water, whoever dedicates it with love, this love offering I accept with the devotion of his soul."[7]
>
> If I get started on this topic, I won't finish for a year, and you may not find it terribly interesting—but I can hardly amuse you by describing the walls of my cell, which are the only landscape before my eyes now; and of everything in the *Gita*, all I have to offer Krishna is water, or now and then a fruit—an orange or banana that they give me for dessert; sometimes, these last few days, a young leaf, all crinkled up still, that the wind has blown onto the walk—but no flowers.
>
> (April 22)...I would much rather be sitting on that bench surrounded by ivy, near the yellow flowers smelling of honey, where I would speak to you of Krishna...."Of all the seasons," says Krishna, "I am the season of flowers." But he does not tell us which flowers....

For an intellectual, any stay in prison with an uncertain future looming in front is always a time for reflection and introspection. Weil's musings from the prison remind me of Jawaharlal Nehru's description of his life in a British prison in India.[8]

Weil's incarceration was succeeded by a trial which was a farce. The punishment was already determined before a single word was spoken at the trial. He was sentenced to five years' imprisonment (the maximum), to be suspended if he would submit to serve in the army, which he did. But by then the military situation was becoming chaotic for France. Crushed and humiliated in the battlefield, France had neither the military nor the political will to carry on. The front was changing constantly as the French forces were in retreat in confusion and panic, and his regiment was shipped to England to join other French forces in a camp. The troops had a choice either to join de Gaulle's army or be deported out of England. By sheer chance Weil's regiment was delayed getting to the rendezvous point and so had to stay behind. Moving from camp to camp, he came to London during the time it was bombed daily by the Luftwaffe. Eventually he boarded a hospital ship sent by Pétain to return to France. Using a card he had fabricated in England, Weil managed to get himself discharged. But his future was still uncertain, because no one was sure whether he would be asked to serve the remainder of his suspended sentence. Somehow he and his wife and her young son succeeded in getting visas to the United States and arrived there in the beginning of 1941.

United States and Brazil

His initial experiences in the United States were unpleasant and humiliating. He was on a grant from the Rockefeller Foundation and then later on a

[7]*Lines spoken by Krishna:* Bhagavad Gita, *IX: 26.*

[8]*See Nehru's book* The Discovery of India, *Meridian Books, London, 1956, especially the beginning.*

grant from the Guggenheim Foundation. These grants were just enough to get by, and the small colleges where he was given teaching positions exploited his circumstances and the fact that he was already being paid by these grants to obtain his services for a pittance. It was during these very difficult times that he wrote his famous letter to Artin, outlining his proof of the Riemann hypothesis for curves over a finite field. His approach required him to build a substantial amount of machinery, and since he was not sure when these preliminaries would be completed, he decided to communicate his results in the form of this letter. The machinery itself would be completed in the following two years and would appear as his famous *Foundations of Algebraic Geometry.*

He received an offer from the University of São Paulo to take up the position which was previously occupied by Albanese. He arrived in January of 1945 and spent two years there. He had the company of Zariski for a year and Dieudonné for another year, but he really missed the excitement of being in a stimulating atmosphere. As he was pondering what to do, his friend Marshall Stone offered him a professorship at the University of Chicago in 1947, which he accepted. His torments and difficulties were over, and he could look forward to a normal and peaceful life as a mathematics professor.

To Serve or Not To Serve

This review would not be complete without a discussion of the pivotal decision in his life, namely, his decision not to report to the French army when the Second World War started, although as a reserve army officer he was bound by his oath to do so. He offers an elaborate rationale for his decision, although admitting that his reasoning would appear confused and unconvincing to an outsider. There are two great episodes from Indian life and culture that provided him with the inspiration that led to his decision—one of them concerns Arjuna, the great warrior king on the eve of the epic battle of Kurukshetra, and the other relates to Gandhi and his interpretation of *satyagraha.*

Let me set the scene on the eve of the battle of Kurukshetra, the climactic battle in the Indian epic *Mahabharatha.* The dispute between rival factions of the same ruling family has gone out of control and has led to the brink of war; every king in the land has had to choose sides, and brothers and uncles and nephews are arrayed against each other to fight to the end, for a retreat is unthinkable, disgraceful, and against the warrior code of behavior. Arjuna, the greatest warrior of them all, with right on his side, as it is he and his brothers who have been deprived of their kingdom in a stacked gambling episode, is about to start the battle. His charioteer is Krishna himself.[9] Arjuna asks Krishna to drive the chariot to the middle of the battlefield, from where he surveys the two great armies. Then, overwhelmed by compassion for all the people who will be killed and the devastation to families that will ensue, he falters and tells Krishna that it is not worth doing this for the mere recovery of a kingdom and the worldly pleasures of being the king. Indeed, the battle would result in universal destruction exactly as Arjuna fears. And Arjuna, invincible because of the combination of his great prowess and the fact that the Lord himself is his charioteer, would emerge victorious in the end, but his triumph would be empty.

Photograph courtesy of Sylvie Weil.

The Weil family (Eveline, Sylvie, Nicolette, André) on the day of departure from Brazil, September 13, 1947, Santos, Brazil. The two men at the right are from the mathematics department at the Universidade de São Paolo.

Krishna does not respond directly to Arjuna's reasoning for not fighting, but instructs him on the ethics of living, on the mystery of life and death, and what is the right course of action for an individual. Krishna's advice constitutes what is known as the *Bhagavad Gita.* Krishna's injunction is that the individual should always act according to his or her *dharma,* which in Arjuna's case, as he is a member of the warrior caste, means that he should fight. That the fight would certainly cause universal devastation and grief is not an excuse to stay away from the fight, because the fight and its consequences as far as human beings are concerned are mere illusions; the soul is invincible and neither slays nor is slain.[10]

Dharma is a universally applicable code of behavior for the individual. It is not easy to define precisely because it is not a microcosmic concept but a macrocosmic one and might depend on the evolutionary state of the society. In ancient times it was determined by the individual's caste, and for Arjuna, as a member of the warrior caste, his *dharma* was to fight. However, in modern times where caste and other subdivisions have eroded,

[9]*Arjuna is also known as Partha, and so one of Krishna's names is Parthasarathy, Partha's charioteer.*

[10]Bhagavad Gita, *II: 19.*

Photograph courtesy of Sylvie Weil.

Weil in family apartment at 3 Rue Auguste Comte, Paris, in June 1993, with Nobuko Inaba, who did the Japanese translation of his autobiography.

it is more difficult to see clearly what one's *dharma* is. Weil chose in 1938 to define his *dharma* as the duty to be a scholar and teacher of mathematics. One might argue that this arbitrariness in defining one's *dharma* might lead to chaos. In the *Gita*, Krishna, who exists outside the *dharma* as divinity incarnate, says that if in the course of time the balance between right and wrong gets distorted, he will incarnate himself to redress the balance.[11]

The second inspiration for Weil came from his understanding of Gandhian *satyagraha,* gathered through his experiences in India during 1930–32. He was deeply impressed by Gandhi's insistence that when the laws governing a person's conduct are unjust, it is not merely the person's right but his duty to rise against these laws, regardless of the consequences.

Weil was also inspired by the example of Siegel, who deserted in 1918 when he decided that the war was not his war ("Dieser Krieg war nicht mein Kreig"). It is clear that Weil felt that no Frenchman could accept the war as his war, given the stupidity and shortsightedness of the French military and political bodies. Of course, he paid dearly for his decisions and actions.

The *Gita* is much more than what my brief remarks above can hope to convey. Its vision, its beauty, and its timeless relevance make it one of the great documents created by man. The doctrine of *satyagraha*, at least as can be understood from Gandhi's use of it, is a complex one, and this is not the place to go into it in any depth. That Weil, in the greatest crisis of his life, fell back on the *Gita* and the teachings of Gandhi to show him the light in the darkness is an indication of how profoundly he had been influenced by Indian culture and thought as well as by his long stay in India.

This elaborate explanation of his actions by Weil may perhaps appear self-serving to some, an unconvincing argument that cannot explain away the failure to do his duty, even raising questions of cowardice. Such an interpretation is too simplistic; the issues involved are emotional and complicated. Further, as he himself ruefully remarks, things turned out to be entirely different from what he had foreseen, and his life took completely unanticipated turns. We have already seen what these were.

Clearly there was no need for him to explain or justify his behavior—after all, he had faced the consequences of his actions, some of which were very traumatic. In my opinion this discussion by Weil should be seen as an attempt by him to throw open his mind and to invite the reader into its innermost chambers.

Concluding Remarks

Weil is a luminous figure in twentieth-century mathematics. The beauty of his discoveries and the clarity and consistency of his vision have been the sources of continued inspiration for two generations of mathematicians. But there is much more to him. His autobiography gives some wonderful insights into the mind of a profound thinker who was supremely creative, even when everything around him was collapsing, who had a full understanding of the world and yet stayed aloof from it. In his mind everything fitted perfectly—mathematics, philosophy, and politics. In this book he presents this world view with great forthrightness and eloquence. It will be a worthy addition to the personal library of every mathematician whose interests go beyond the merely mathematical.

[11] Bhagavad Gita, *IV: 7.*

1999 Steele Prizes

The 1999 Leroy P. Steele Prizes were awarded at the 105th Annual Meeting of the AMS in January 1999 in San Antonio. 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 (for 1999 limited to papers in analysis), 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 1999 Steele Prizes are SERGE LANG for Mathematical Exposition, JOHN F. NASH and MICHAEL CRANDALL for a Seminal Contribution to Research, and RICHARD V. KADISON 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, Bertram Kostant, H. Blaine Lawson Jr., Andrew J. Majda, Louis Nirenberg, Marc A. Rieffel, Jonathan M. Rosenberg, and John T. Tate.

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

Steele Prize for Mathematical Exposition: Serge Lang

Citation

The Leroy P. Steele Prize for Mathematical Exposition is awarded to Serge Lang of Yale University for his many mathematics books. Perhaps no other author has done as much for mathematical exposition at the graduate and research levels, both through timely expositions of developing research topics (e.g. Arakelov Theory, Complex Hyperbolic Geometry, Diophantine Geometry) and through texts with an excellent selection of topics. Among Lang's most famous texts are *Algebra* [Addison-Wesley, Reading, MA, 1965; Second edition, 1984; Third edition, 1993, ISBN 0-201-55540-9] and *Algebraic Number Theory* [Addison-Wesley, Reading, MA, 1970; Second edition, Graduate Texts in Mathematics, 110, Springer-Verlag, New York, 1994, ISBN: 0-387-94225-4]. Lang's *Algebra* changed the way graduate algebra is taught, retaining classical topics but introducing language and ways of thinking from category theory and homological algebra. It has affected all subsequent graduate-level algebra books. Lang's *Algebraic Number Theory* similarly changed the teaching of that subject. We quote briefly from the review of the second edition in *Mathematical Reviews* by M. Ram Murty, MR 95f:11085:

> This book is the second edition of Lang's famous and indispensable book on algebraic number theory...Lang's

> books are always of great value for the graduate student and the research mathematician. This updated edition of *Algebraic Number Theory* is no exception.

We also quote from a review of one of Lang's more specialized books, *Introduction to Arakelov Theory*, Springer-Verlag, New York-Berlin, 1988, ISBN: 0-387-96793-1. Here are the comments of Joseph H. Silverman (last year's Exposition Prize winner) in *Math. Reviews*, MR 89m:11059:

> The author has written an excellent book in a new, exciting, and very active area of research. It will undoubtedly become a standard reference in the field of arithmetic geometry, since it brings together in a coherent fashion the basic material which had previously only been available in the original journal articles. However, a potential reader should be warned that this is not a textbook for beginners...But for those with the necessary background, *Introduction to Arakelov Theory* provides a welcome entree to recent advances in arithmetic geometry.

The great diversity of Lang's books is not limited to his graduate textbooks and research-level monographs; he has written quite a number of undergraduate textbooks as well, especially at the junior-senior level. While they concentrate on the basics, Lang's textbooks do not talk down to the student. All of Lang's books display the mathematical taste of a first-class research mathematician.

Biographical Sketch

Serge Lang was born on May 19, 1927. He received his bachelor's degree at the California Institute of Technology in 1946. He served in the U.S. Army during 1946–47, after which he became a graduate student at Princeton University. He received his doctorate there in 1951 and served as an instructor for one year. He then went to the Institute for Advanced Study (1952–53) and to the University of Chicago (1953–55), where he served as an instructor. He spent fifteen years at Columbia University and held visiting positions at Princeton and Harvard Universities before going to Yale University in 1972, where he is currently professor of mathematics.

During 1957–58, Lang was a Fulbright Fellow. He received the AMS Cole Prize in 1959 and the Prix Carrière of the Académie des Sciences, Paris, in 1967. Lang has written 34 mathematics books ranging from elementary books—such as *Math! Encounters with High School Students, Geometry—A High School Course* (with Gene Murrow), *Basic Mathematics, The Beauty of Doing Mathematics* (talks at the Palais de la Découverte in Paris)—to advanced research monographs. He has also written three political books: *The Scheer Campaign* (Benjamin, 1967), *THE FILE* (Springer-Verlag, 1981), and *Challenges* (Springer-Verlag, 1998).

Response

I thank the Council of the AMS and the Selection Committee for the Steele Prize, which I accept. It is of course rewarding to find one's works appreciated by people such as those on the Selection Committee.

At the same time, I am very uncomfortable with the situation, because I resigned from the AMS in early 1996, after nearly half a century's membership. On the one hand, I am now uncomfortable with spoiling what could have been an unmitigated happy moment, and on the other hand, I do not want this moment to obscure important events which have occurred in the last two to three years, affecting my relationship with the AMS.

Indeed, the *Notices*, February 1996, published a 12-page article "Using Mathematics to Understand HIV Immune Dynamics" by Denise Kirschner, pp. 191–202. Having had occasion to be well informed on the issue of HIV pathogenesis and of strong objections (not only by me) against certain abuses of mathematical modeling in connection with HIV, I communicated an extensive file of documentation to AMS higher-ups at the time concerning the hypothesis that HIV is not pathogenic. This hypothesis of course is incompatible with the official orthodoxy. Readers can evaluate some of my documentation, published in a 114-page chapter of my recent book, *Challenges*.

I resigned from the AMS because of the way my documentation was handled in 1996, principally by the *Notices* editor, Hugo Rossi, in connection with the Kirschner article, and the way official responsibilities were met by those involved. Subsequently, about two years later on 5 January 1998, I submitted a 7-page piece for publication in the "Forum" of the *Notices*. The piece explained:

- encouraging events (see for example p. 714 of *Challenges*) which led me to submit a piece for publication in the *Notices*, rather than disengaging as I had done up to that point;
- my detailed objections to the responses which I got from AMS officials at the time in 1996;
- direct criticisms of the Kirschner piece per se.

I regard all three as important. Although the "Forum" editor, Susan Friedlander, told me she would have accepted the piece, it was rejected for publication by the 1998 editor-in-chief, Tony Knapp. Thus members of the AMS at large have not been informed through official channels of my resignation, nor of the very serious context of continued problems after the resignation, including the rejection of my "Forum" piece. I tried to inform some members by a direct mailing to 160 chairs of departments in January 1998, but such a mailing can reach only few among the total membership (nearly 30,000).

Torn in various directions, sadly but firmly, I do not want my accepting the Steele Prize to further obscure the history of my recent dealings with the AMS.

Steele Prize for a Seminal Contribution to Research: John F. Nash

Citation

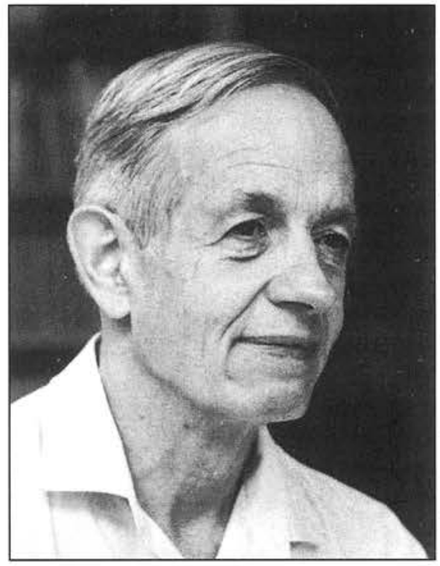
The award to John Nash is for his remarkable paper: "The embedding problem for Riemannian manifolds", *Ann. of Math.* (2) **63** (1956), 20–63.

This paper solved an old problem in Riemannian geometry, but the heart of it is Analysis. In it Nash cleverly reduces the question to a local perturbation problem for a system of nonlinear partial differential equations. If one tries to use the Implicit Function Theorem one fails because, though the linearized operator is invertible, the inverse loses some degree of differentiability; so the situation seems hopeless. But Nash devised a memorable iteration scheme coupled with a smoothing process to overcome the difficulty. It is a most original idea. Later Moser modified and generalized the idea, and we now have the "Nash-Moser" technique which is applicable to many problems. This is one of the great achievements in mathematical analysis in this century.

Biographical Sketch

John F. Nash Jr. was born June 13, 1928, in Bluefield, West Virginia. He went to the public schools in Bluefield from kindergarten through high school, and did supplementary study at Bluefield College. He entered Carnegie Tech (now Carnegie-Mellon University) as a George Westinghouse Scholar. Originally he was a chemical engineering major and later changed to chemistry and finally to mathematics. He obtained an "advanced standing" and received both B.S. and M.S. degrees at the time of graduation in 1948. He did his graduate study at Princeton University, 1948–50, where he stayed on for one year as an instructor after receiving his Ph.D. in mathematics in 1950. He arrived in the Boston area in summer 1951 and began teaching at the Massachusetts Institute of Technology. He was a C.L.E. Moore Instructor in the mathematics department of MIT and continued on the faculty until 1959. He was an occasional "member" of the Institute for Advanced Study. His honors include scholarships and foundation awards. He has received the Von Neumann Medal of the Operations Research Society, a share of the Nobel Prize in Economics (1994), and the *Business Week* award at Erasmus University in the Netherlands (1998). He was elected a Fellow of the Econometric Society and the American Academy of Arts and Sciences, and in 1996 was elected a Member of the National Academy of Sciences.

Response



John F. Nash Jr.

Photo by Robert P. Matthews, courtesy of Communications Dept., Princeton University.

It is indeed an honor to be awarded a share of the Leroy P. Steele Prize for 1999 for influential research.

Perhaps a few remarks about the context of my work, back in the 1950s, on the isometric representation of Riemannian manifolds are appropriate. Psychologically, I was influenced by the significant function of a metric tensor on the 4-continuum in the theory of general relativity and by the fact that I was a student in Princeton at a time when Einstein was still alive and resident in the town. This must have had an influence on my studies that related to manifolds, differentiable or Riemannian.

When I first studied the problem of obtaining an isometric embedding for an arbitrary given manifold with a Riemannian metric, I did not find a way to realize a smooth (highly differentiable when described by functions) realization of it as a subvariety of a Euclidean space, but instead I found the possibility of a C^1 embedding, so that the description of the embedding would be given by functions that would have continuous first derivatives but would not have any more smoothness than that.

But this result, although not really what one should hope for if the given Riemannian manifold were of high smoothness, had the nice property that it did not require a large number of dimensions for the Euclidean space of the representation. And moreover, the metric originally given did not need anything more than C^0 smoothness, merely to be describable by a metric tensor described by continuous functions.

In the context of the so-called Nash-Moser theory, the methods that were found to be effective for these C^1 embeddings were not of any direct relation to that. But for me the solution of the "embedding problem" in this first fashion provided a gateway to an approach to the problem in terms of desiderata of higher smoothness. It turned out to be possible to use the ideas involved in the study of low smoothness results to set up an initial approximation to a solution of the embedding problem with higher smoothness; then that problem became the problem of suitably perturbing an existing embedding so as to obtain a smooth embedding of isometric type. And this became a problem describable as one of finding an appropriate perturbation of small, but finite rather than infinitesimal, type which would realize the desired correction of a metric that was approximately already correct for isometry.

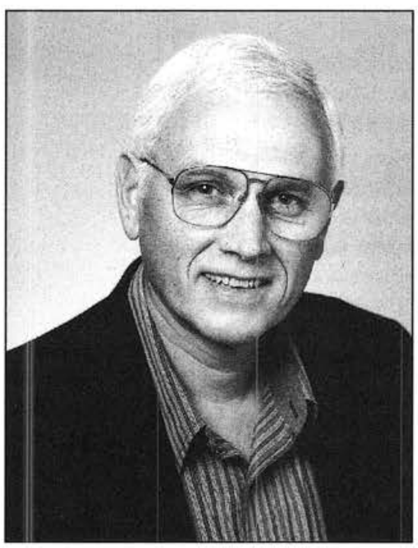
My work on the low smoothness embeddings was soon improved upon by N. H. Kuiper, who improved the technique and achieved consequentially that the maximum possibly needed dimensionality of the Euclidean space would be less than according to my results.

I feel that it is of interest to observe that at the present time there are still some simple questions that remain unanswered in the context of isometric representations. In particular, if a manifold is given with a Riemannian metric of C^2 differentiability, then the most that is known is that it can be embedded isometrically with the embedding functions (from the abstract manifold) being of C^1 type. But actually it would seem that the embedding should be at least of C^2 type and to achieve the C^3 level here would not be inconsistent and indeed simply parallel to achieving a C^1 imbedding when a C^0 Riemannian metric was given on the abstract manifold.

Steele Prize for a Seminal Contribution to Research: Michael G. Crandall

Citation

The award to Michael Crandall is for two seminal papers: "Viscosity solutions of Hamilton-Jacobi equations" (joint with P.-L. Lions), *Trans. Amer. Math. Soc.* **277** (1983), 1–42, and "Generation of semi-groups of nonlinear transformations on general Banach spaces" (joint with T. M. Liggett), *Amer. J. Math.* **93** (1971), 265–298.


Michael G. Crandall

Mike Crandall is one of the leaders in the world in applying abstract ideas to concrete applications. He is one of the inventors, in joint work with Pierre-Louis Lions, of the concept of "viscosity solution" for equations with rough solutions and of a formal comparison principle. This work has had wide ramifications in diverse applications, including control theory, image processing, phase field models, front propagation, and the Perron Procedure for degenerate fully nonlinear elliptic or parabolic equations. This joint work with Crandall is one of the main contributions in the citation for the Fields Medal which Lions was awarded in 1994 in Zürich.

Crandall is also world renowned for earlier work, beginning with the Crandall-Liggett Theorem, on characterizing contraction semigroups on nonreflexive Banach spaces. Crandall has played an important role in applying these results to concrete problems, such as scalar nonlinear conservation laws and their finite difference approximations, and degenerate equations for porous media.

Biographical Sketch

Michael Crandall was born November 29, 1940, in Baton Rouge, Louisiana. By the fifth grade he had attended five different elementary schools in Florida, Mississippi, Louisiana, and California as the family moved about following his father's work in construction. After graduating from Chula Vista High School in 1958 he supported himself via summer employment as a member of Hod Carriers and Laborers Local 89 in San Diego and part-time jobs during the academic year while attending the University of California, Berkeley, as an undergraduate, except for one fateful semester at the University of California, Los Angeles, where he met Sharon, his wife of thirty-six years.

After taking a bachelor's degree in engineering physics from UC Berkeley in 1962, Crandall reenrolled at Berkeley as a mathematics graduate student. He obtained his Ph.D. in 1965 under the direction of H. O. Cordes upon solving a problem in celestial mechanics posed by C. L. Siegel. Subsequently, he held an instructorship at Berkeley for a year followed by three years on a postdoctoral appointment at Stanford University. He then moved to UCLA, where he attained the rank of professor before accepting a professorship at the Department of Mathematics and Mathematics Research Center at the University of Wisconsin. Currently, Crandall is a professor at the University of California, Santa Barbara, where he has served a term as department chair. Crandall has also served the Society as a member at large of the Council, and he is currently on the Board of Trustees. He was also a managing editor of *Communications in Partial Differential Equations* for several years and a member of various editorial boards. He was an invited speaker at the 1974 Congress in Vancouver and has given an AMS invited hour address and an AMS Progress in Mathematics lecture.

Response

First, I would like to say that I am thrilled to be a recipient of the Steele Prize for publications of lasting impact. It was a bit subtle for the committee to award me the prize for two papers with three authors between them, but with me as the unique author on both. I thank the committee and salute my most excellent coauthors.

In this response I will follow my feelings, and what I feel is gratitude, not only for being awarded the prize, but for the circumstances and people who provided some of the backdrop for the cited works. I mention in particular Ralph Phillips, who put me and Amnon Pazy in contact with the lovely work of Y. Komura on generation of nonlinear semigroups in Hilbert spaces, and Tosio Kato, whose penetratingly clean mathematics is central to the theory of nonlinear evolution equations. Ralph passed away November 23; it was a privilege to know him.

Working with Amnon on the Hilbert space setting was exciting and satisfying. This start led to the work with Tom Liggett on generation in general Banach spaces. The application to scalar conservation laws brought the uniqueness proof of Kruzhkov into view, and this proof and Philippe Bénilan's abstract uniqueness theorem were both in the background when Pierre-Louis and I proved our first uniqueness results for viscosity solutions. Craig Evans's use of "Minty's trick in L^∞" to pass to limits in fully nonlinear equations was also part of the environment at the time. However, there is no doubt that the cited paper initiated a vigorous development by the many outstanding contributors to which the area owes its vitality. The outcome to date is a lot of beautiful mathematics, provided by a large community, for which the rest of the world has much use. I got to know Kato at Berkeley as a student, Ralph Phillips and Amnon Pazy at Stanford (and Paul Rabinowitz, but that is another story), Tom Liggett and Craig Evans at UCLA, and Pierre-Louis Lions at the former Mathematics Research Center (MRC) at Wisconsin; I wonder if people realize the enormous impact of MRC. In sum, I am a lucky man.

Steele Prize for Lifetime Achievement: Richard V. Kadison

Citation

The Leroy P. Steele Prize for Lifetime Achievement is awarded to Richard V. Kadison, Kuemmerle Professor of Mathematics at the University of Pennsylvania. For almost half a century, Dick Kadison has been one of the world leaders in the subject of operator algebras, and the tremendous flourishing of this subject in the last thirty years is largely due to his efforts. He was a key organizer of two major conferences on operator algebras—in Baton Rouge, Louisiana, in 1967, and in Kingston, Ontario, in 1980—which helped shaped the modern history of the subject. His students have included many world-class mathematicians not only in operator algebras but in other fields as well. And in mathematical exposition, Kadison's papers and his two-volume monograph with John Ringrose, *Fundamentals of the Theory of Operator Algebras* (originally published by Academic Press, now reprinted by the AMS), have been models of clarity and precision.

We quote from just a few of the many letters written in support of the nomination of Kadison for the Lifetime Achievement prize. Edward Effros of UCLA wrote that, "Quite simply, operator algebra theory would not exist as a subject today if it had not been for Dick." Fields Medalist Alain Connes wrote that Kadison's "global vision of the field was certainly essential for my own development." Isadore Singer of MIT wrote that "Dick is a most deserving candidate of a Steele Prize for Lifetime Achievement. I support the nomination with great enthusiasm because:

1) His many research papers are pathbreaking. They are a pleasure to read, combining clarity, power, and scholarship in a unique way.

2) His treatise with John Ringrose defines the field of operator algebras and is a source book for students and scholars alike.

3) Almost half a century of teaching the subject, encouraging graduate students and postdoctoral visitors at the University of Pennsylvania, and doing research at the cutting edge of the field have made Dick the leading light of operator algebras."

Richard V. Kadison

Biographical Sketch

Richard V. Kadison received his Ph.D. from the University of Chicago in 1950 and was a National Research Fellow that same year at the Institute for Advanced Study. He went to Columbia University as an assistant professor in 1952 and became an associate professor in 1956 and a full professor in 1960. In 1964 he took his present position as Kuemmerle Professor of Mathematics at the University of Pennsylvania. He was a Fulbright Research Fellow in Copenhagen (1954–55), a Sloan Fellow (1958–62), and a Guggenheim Fellow (1969–70). He received honorary doctoral degrees from the Université d'Aix-Marseille in 1986 and the University of Copenhagen in 1987. He is a member of the National Academy of Sciences, a foreign member of the Royal Danish Academy of Science and Letters, and a foreign member of the Norwegian Academy of Science and Letters.

Response

It is a great honor to receive the Steele Prize for Lifetime Achievement. I am very happy to accept it. This award is given occasionally, I'm sure, to people who can say that they did it all alone. That is certainly not the present case. I collaborated during much of my career with people who are splendid mathematicians as well as dear friends. My students, both graduate and postdoctoral, taught me much of what I know. My teachers during my graduate student days were a constant source of inspiration and support. To all of these people I owe a great debt of gratitude for whatever success I may have had.

The field in which I have worked for a large part of my life is the theory of operator algebras. I have had the good fortune to watch it flourish and make contact with most of mathematics and physics and a good many other subjects as well. Heisenberg and Schrödinger taught us that the analysis that goes with quantum physics is of a very special sort. Dirac and von Neumann formulated that *noncommutative* analysis in terms of operators on a Hilbert space and the algebraic interrelations among those operators. The physical observables of a quantum system are modeled by self-adjoint operators on such a space. With that as one of the principal grounds for Dirac and von Neumann's study, it was clear that the algebras of such operators are important mathematical constructs. It rapidly became clear as well that their structure was complicated and rich enough to keep an army of research mathematicians occupied for quite some time. The few of us at work on the subject fifty years ago knew that we would not be short of fascinating mysteries to occupy our thoughts.

It wasn't certain, however, that we would have much company on that journey of discovery. As it turned out, a formidable force of remarkably talented and dedicated researchers gathered and joined us. As with all the great fields of mathematics, this group included a small number of brilliant practitioners. They give the field much of its luster and direction. We are lucky to have our supply of such people. There are an encouraging number of very talented young mathematicians able and willing to join the ranks of serious researchers in all the great fields. They aren't expecting (nor will they find!) an easy life. A wise society would care for and make the best use of this precious resource.

It has been my privilege and joy to be among the workers in my field throughout most of my career. I'm hoping to continue working with them for some years to come.

1999 Bôcher Prize

The Maxime Bôcher Memorial Prize is awarded every five years for a notable research memoir in analysis which has appeared in the previous five years. The prize honors the memory of Maxime Bôcher (1867–1918), who was the Society's second Colloquium Lecturer (1896) and tenth president (1909–1910) and was also one of the founding editors of *Transactions of the AMS*. The recipient must be a member of the Society, or the memoir for which the prize is given must be published in a recognized North American journal. The prize carries a cash award of $4,000.

The eighteenth Bôcher Prize was awarded to Demetrios Christodoulou, Sergiu Klainerman, and Thomas Wolff at the 105th Annual Meeting of the AMS in January 1999 in San Antonio.

The prize was awarded by the AMS Council acting on the recommendation of a selection committeee, whose members at the time the 1999 prize was awarded consisted of James Glimm (chair), Peter Sarnak, and Leon Simon.

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

Demetrios Christodoulou

Citation

The Bôcher Prize is awarded to Demetrios Christodoulou for his contributions to the mathematical theory of general relativity. In particular, the prize is awarded for his remarkable memoir with S. Klainerman, *The Global Nonlinear Stability of the Minkowski Space*, Princeton Math Ser., vol. 41, Princeton University Press, 1993, which establishes the nonlinear stability of the Minkowski metric; and for his fundamental papers "Examples of naked singularity formation in gravitational collapse of a scalar field", *Ann. Math.* **140** (1994), 607–665, and "The instability of naked singularities in the gravitational collapse of a scalar field", *Ann. Math.* **149** (Jan. 1999), 183–217, which show, contrary to the widely held view, that naked singularities occur in the gravitational collapse of a scalar field; and for his analysis of the instability of these singularities.

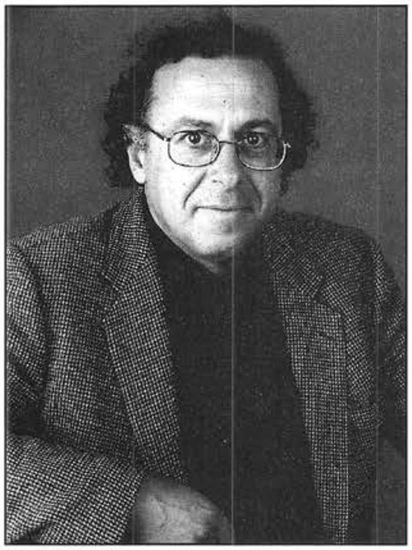
Biographical Sketch

Demetrios Christodoulou was born October 19, 1951, in Athens, Greece. He received his Ph.D. in physics from Princeton University in 1971. He held positions as a Humboldt fellow at the Max Planck Institute (1976–81), as a visiting member at the Courant Institute (1981–83), as an associate professor (1983–85) and professor (1985–87) at Syracuse University, and as professor of mathematics (1988–92) at the Courant Institute. Since 1992 he has been professor of mathematics at Princeton University.

Christodoulou was awarded the Otto Hahn Medal in mathematical physics in 1981, the Xanthopoulos Award in relativity in 1991, and a MacArthur Fellowship in 1993. He also received the Excellence in the Sciences Award from the Academy of Athens in 1996, an Honorary Doctorate in the Sciences from the University of Athens in 1996, and a Guggenheim Fellowship in 1998.

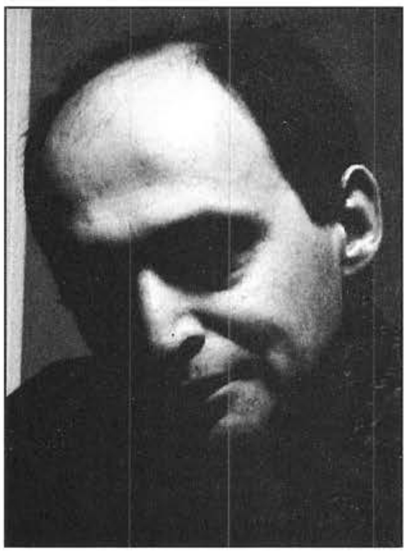
Response

It is a great honor for me to be awarded the 1999 Bôcher Prize. I would like to express my gratitude



Pryde Brown Photographs

Demetrios Christodoulou



Photograph courtesy of Anca Niculin.

Sergiu Klainerman

Thomas Wolff

to the Bôcher Prize Committee and the AMS for recognizing my work.

My mathematical research has centered on the study of global problems associated to nonlinear systems of partial differential equations of hyperbolic type, i.e., the global existence and regularity of solutions to the initial value problem, the formation and structure of singularities, and the long-time asymptotic behavior. I have given particular attention to the Einstein equations of general relativity where the solution of problems requires a combination of purely analytic and differential-geometric methods.

The joint work with Sergiu Klainerman demonstrated that any asymptotically flat initial data for the vacuum Einstein equations which is suitably close to trivial data gives rise to a global solution, a geodesically complete spacetime tending to flatness at infinity along any geodesic, thus establishing the stability of the Minkowski space of special relativity in the framework of the general theory and providing the basis for a rigorous theory of gravitational radiation.

Another work, involving several steps completed over the years, concerns the initial value problem in the large under the assumption of spherical symmetry, for the Einstein equations with matter, the energy-momentum-stress tensor being that corresponding to a scalar field. One of the principal results of that work was that if the initial data verifies a certain largeness condition, then catastrophic gravitational collapse must occur. This is signaled by the formation of a trapped region, that is, a spacetime region where the future light cones have cross-sectional areas decreasing with time. The formation of a trapped region is preceded by that of an event horizon, namely, of a future boundary of the set of points which are causally connected to infinity. The trapped region ends at a singular boundary, whose structure was analyzed in detail. Another, unexpected result of the work was that naked singularities, namely, singular points which are not preceded by a trapped region and which are causally connected to infinity, also occur. The work culminated in a paper which shows that in the space of initial data the subset leading to the formation of naked singularities has positive codimension, hence must be viewed as being exceptional, and initial data belonging to the complement of this subset leads either to a complete regular solution or to the formation of a trapped region.

Despite the fact that some progress has been achieved, our subject is still very much in its infancy. The global stability of the Kerr family of nontrivial stationary solutions of the vacuum Einstein equations has not yet been investigated. The simultaneous removal of symmetry assumptions as well as restrictions on the size of the initial data leads us to a territory which is at present almost completely unexplored. Moreover, the general framework of nonlinear systems of partial differential equations of hyperbolic type offers many additional problems of fundamental significance, such as the development of a general theory of shock formation and evolution in 3-dimensional continuous media.

Sergiu Klainerman

Citation

The Bôcher Prize is awarded to Sergiu Klainerman for his contributions to nonlinear hyperbolic equations. In particular, the prize is awarded for his remarkable memoir, joint with D. Christodoulou, *The Global Nonlinear Stability of the Minkowski Space,* Princeton Math Ser., vol. 41, Princeton University Press, 1993, which establishes the nonlinear stability of the Minkowski metric; and for his fundamental papers, joint with M. Machedon, "Space-time estimates for null forms and the local existence theorem", *Comm. Pure Appl. Math.* **46** (1993), 1221–1268, and "Smoothing estimates for null forms and applications", *Duke Math. J.* **81** (1995), 99–133, on well posedness and global existence for nonlinear wave equations and the crucial "null form" condition central to these works.

Biographical Sketch

Sergiu Klainerman was born in Bucharest, Romania, in 1950. He received his Ph.D. from New York University and was a Miller Fellow at Berkeley from 1978 to 1980. He was assistant, associate, and full professor at New York University from 1980 to 1987. Since 1987 he has been a full professor at Princeton University.

He has held visiting positions at various institutions, including the Institute for Advanced Study in Princeton, the Institut des Hautes Études Scientifiques in Bures-sur-Yvette, France, the Eidgenössische Technische Hochschule in Zürich, and Stanford University, as well as in Jerusalem, Bonn, and Kyoto. Last year he held the position of Blaise Pascal International Chair at Université de Paris VI.

Klainerman's honors include a MacArthur Fellowship; Miller, Sloan and Guggenheim Fellowships; and the Le Conte Prize of the French Academy of Sciences. He is a Fellow of the American Academy of Arts and Sciences. His research interests are partial differential equations of mathematical physics and their connections to Fourier analysis and geometry.

Response

I am greatly honored to share the 1998 Bôcher Prize with my colleagues D. Christodoulou and T. Wolff and grateful to the selection committee for their kind recognition of my work and the field I represent. Before commenting on the citation, I would like to thank various people for the special role they have played in my scientific career. I will mention only a select few. On a personal level my parents, brother, uncle Hers, and my wife, Anca, have given me unconditional love and support. O. Liess was my enthusiastic mentor during my undergraduate education in Romania; I owe him a lot. I am also greatly indebted to my former thesis advisor, L. Nirenberg, whose insight and generosity helped me to find my own research path. F. John was a great source of inspiration, a role model, and a personal friend. As a graduate student I was also influenced, in a broad scientific sense, by many stimulating conversations with J. Moser. A. Majda influenced my scientific tastes a great deal during the two-year period of my Miller Fellowship at Berkeley. I am especially indebted to my collaborators, foremost among them D. Christodoulou and M. Machedon.

As mentioned in the citation, most of my work has to do with nonlinear hyperbolic equations. This is a difficult subject, with its roots in the many examples of such systems appearing in continuum mechanics, general relativity, relativistic field theory, and geometry. The modern theory of hyperbolic equations, with its emphasis on qualitative features rather then explicit solutions, goes back to the beginning of the century. To Hadamard we owe the very distinction between well-posed and ill-posed problems and thus the first meaningful characterization of hyperbolicity. The linear theory was later developed by people like H. Lewy, K. Friedrichs, I. G. Petrowsky, S. Sobolev, J. Leray, etc. They were also responsible for developing the methods to prove the classical theorem of, local in time, existence and uniqueness for large classes of nonlinear hyperbolic equations. The one-dimensional theory for systems of hyperbolic laws goes back to Riemann. It had a very productive period from the mid 1940s to the late 1960s due to the eminent efforts of people like R. Courant, K. Friedrichs, J. von Neumann, P. Lax, S. Kruzkov, J. Glimm, and others. It has recently made important advances due to the work of Bressan.

The progress on higher-dimensional nonlinear equations was very slow, however, and by the early 1960s almost all results, which went beyond local in time existence and uniqueness, were restricted to one space dimension. The situation started to change in the 1960s and 1970s through the pioneering works of K. Jorgens, F. John, I. E. Segal, C. Morawetz, and W. Strauss. Today the subject of nonlinear hyperbolic equations is going through an exciting period of both broadening of scope and deepening of its methods and results. I can mention two developments which I consider most significant for higher-dimensional problems: the first is the emergence of methods tied to the geometric structure of nonlinear wave equations, and the second is the development of spacetime estimates based on Fourier analysis.

Geometric methods, by which I mean the use of the special symmetries of the equations in physical space, have allowed us to prove small data global regularity results for large classes of nonlinear wave equations, including quasilinear. They have played a fundamental role in my work in collaboration with D. Christodoulou on the *The Global Nonlinear Stability of the Minkowski Space*, mentioned in the citation. Geometric methods, in a somewhat different way, also played an important role in the beautiful global regularity result for the Yang-Mills equations in $\mathbb{R}^{3+1}$ due to Eardley and Moncrief.

The role of spacetime estimates was first pointed out by I. E. Segal, and it was then discovered by R. S. Strichartz that such estimates are intimately tied to the restriction theorems in Fourier analysis pioneered by E. Stein. Strichartz type estimates, as later developed by H. Pecher, Ginibre-Velo, and Keel-Tao, have found important applications, the most notable among them being the global regularity result for critical, scalar, nonlinear wave equations due to M. Struwe and M. Grillakis.

My work with M. Machedon builds on the latter development, based on Fourier analysis, but attempts also to take advantage of the nonlinear structure of special geometric equations such as Yang-Mills and Wave-Maps. Our main achievement was to develop a class of bilinear and some multilinear estimates intimately tied to the specific "null form" structure of these equations. One can thus obtain a lot more regularity than is possible with Strichartz type estimates alone. In the case of the $3+1$ dimensional Yang-Mills equations, these new estimates have allowed us to prove global regularity in the energy class, thus extending and giving a new proof of the above-mentioned result of Eardley-Moncrief. In the case of Wave-Maps in $2+1$ dimensions, our new estimates go quite a long way but still fall short of proving the expected regularity result. New ideas are certainly needed.

Despite the remarkable progress made during this past century, the subject of hyperbolic equations is still in its infancy. Most of the fundamental questions concerning the regularity and asymptotic behavior of solutions to the important physical equations remain wide open. The methods which have been used so far are still crude by comparison to the powerful tools of elliptic theory, and this reflects in the very incomplete nature of our results. Yet there lies the great attraction of the field to me: the basic rules of the game are still to be uncovered.

Thomas Wolff

Citation

Tom Wolff is awarded the Bôcher Prize for his work in harmonic analysis, notably the work presented in his papers "A Kakeya type problem for circles", *Amer. J. Math.* **119** (1997), 985–1026, and "An improved bound for Kakeya type maximal functions", *Rev. Mat. Iberoamericana* **11** (1995), 651–674. The techniques presented there represent an important contribution to our understanding of the structure of subsets of Euclidean space, involving the interplay between geometric measure theory and harmonic analysis. The award is also made in acknowledgement of Wolff's work on harmonic measure and unique continuation, including in particular *Counterexamples with harmonic gradients in* R^3, Princeton Math. Ser., vol. 42, Princeton University Press, 1995, 321–384.

Biographical Sketch

Thomas Wolff was born in New York City, July 14, 1954, and received his A.B. degree from Harvard in 1975 and his Ph.D. from the University of California, Berkeley, in 1979, under Donald Sarason. He was a National Science Foundation Postdoctoral Fellow at the University of Chicago (1980–82) and has held teaching positions at the University of Washington; New York University; University of California, Berkeley; and California Institute of Technology, where he is now professor of mathematics.

Response

The Bôcher Prize is truly a great honor, and I am most grateful to the committee for recognizing my work in this manner. Many people have contributed in an essential way to the circle of ideas around the Kakeya problem and to the other topics mentioned in the citation, both before me and also recently, and I take this as a tribute to all of them.

Mathematics often develops in an incremental way, and most of the things I have done have been motivated by related results in the literature. For the two papers in geometric measure theory, I started from some of Bourgain's papers on the Kakeya problem and was then able to incorporate some ideas from the combinatorics literature, especially the paper of Clarkson, Edelsbrunner, Guibas, Sharir, and Welzl, "Combinatorial complexity bounds for arrangements of curves or spheres". Much remains to be done in this area, and my hope is that these ideas may continue to prove useful.

I first learned about the power of combinatorial ideas in analysis twenty years ago as a graduate student by reading the proof of the corona theorem and other related papers in function theory. The construction in my paper on harmonic gradients was suggested by the work that had been done on the analogous snowflake domains in the plane by Carleson, and by Kaufman and Wu.

Finally, it's never been easy for me, and I would like to thank several people for encouragement at the beginning of my career—Alice Chang, John Garnett, Jürgen Moser, Don Sarason, and Nick Varopoulos.

1999 Satter Prize

The Ruth Lyttle Satter Prize was established in 1990 using funds donated by Joan S. Birman in memory of her sister, Ruth Lyttle Satter. Professor Satter earned a bachelor's degree in mathematics and then joined the research staff at AT&T Bell Laboratories during World War II. After raising a family, she received a Ph.D. in botany at the age of forty-three from the University of Connecticut at Storrs, where she later became a faculty member. Her research on the biological clocks in plants earned her recognition in the U.S. and abroad. Professor Birman requested that the prize be established to honor her sister's commitment to research and to encouraging women in science. The prize is awarded every two years to recognize an outstanding contribution to mathematics research by a woman in the previous five years. The amount of the prize is $1,200.

At the 105th Annual Meeting of the AMS in January 1999 in San Antonio, the 1999 Satter Prize was awarded to Bernadette Perrin-Riou. The prize was awarded by the AMS Council on the recommendation of a selection committee consisting of Sun-Yung Alice Chang, Peter Sarnak, and Carol Wood.

The text that follows contains the committee's citation for the award, a brief biographical sketch, and a response from Bernadette Perrin-Riou upon receiving the award.

Citation

The 1999 Satter Prize is awarded to Bernadette Perrin-Riou in recognition of her number theoretical research on p-adic L-functions and Iwasawa theory. Her results on the p-adic Gross-Zagier Formula and the related Birch and Swinnerton-Dyer Conjectures have striking applications to the arithmetic of elliptic curves. Moreover, her foundational papers on p-adic representations and motives and on the Bloch-Kato Conjectures provide a framework and route to these basic general problems about L-functions of motives. In particular, her work provides the link between Kato's Euler System and p-adic L-functions. Her works have had a profound impact on the study of p-adic L-functions and Iwasawa theory, both in shaping it at present and in determining the direction in which it is moving.

Photo Michel

Bernadette Perrin-Riou

Biographical Sketch

Bernadette Perrin-Riou was born on August 1, 1955, at Les Vans, Ardèche, France. She was a student at the École Normale Supérieure de Jeunes Filles in 1974 (since then it has been unified with the men's École Normale d'Ulm). She did her Thèse de 3ème cycle with G. Poitou (1979) and her Thèse d'État with J. Coates (1983) in France. Starting in 1978, she was assistant, then Maître de Conférences, and finally professor at Université Pierre et Marie Curie. In 1994 she moved to the Université de Paris, Orsay. She was a speaker at the International Congress of Mathematicians (Zürich, 1994) and received the 1998 Charles-Louis de Saulses de Freycinet Prize of the French Académie des Sciences.

Response

I am very grateful to the AMS for awarding me the 1999 AMS Ruth Lyttle Satter Prize, and I am both very happy and honored.

On this occasion I cannot help but think of some of the people who taught me mathematics: Pascal Monsellier, my high school teacher, with whom I discovered vector spaces, abstract algebraic structures, concrete plane and space isometry groups, as well as the epsilons and etas; and later Roger Godement and his course "Le jardin des délices modulaires". Georges Poitou and John Coates then introduced me to number theory, Galois cohomology, and elliptic curves. Eventually, I tried to extend the framework of elliptic curves using p-adic representations, which naturally led me to use Jean-Marc Fontaine's ring of periods.

I was not aware that my work has had the influence stated in the citation, but I certainly had great pleasure in discovering and understanding mathematical objects and becoming "intimate" with them. On the other hand, sometimes I found it was rather frustrating not to be able to share this mathematics with more people. This may be because of the subject; not everyone in number theory can prove a theorem at the same time deep and easy to state!

Since this is a prize for women, I should probably add a few words without any claim to generality. My parents both had a scientific education, and I never thought of any other studies. I never felt a serious difference with men during my professional career, but this may be just because I was too innocent and unaware of the problem. However, I am still shocked by the small number of girls—about one-third—in my son's high school science class.

1999 AMS-MAA-SIAM Morgan Prize

Today undergraduate students are working on problems of current research interest, proving theorems, writing up results for publication, and giving talks on their work. There is undergraduate research today at the highest standards of professional excellence. The Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student is intended to recognize and encourage outstanding mathematical research by undergraduate students. The prize was endowed by Mrs. Frank Morgan and also carries the name of her late husband.

At the Joint Mathematics Meetings in San Antonio in January 1999, the 1998 Morgan Prize was awarded to DANIEL BISS. An Honorable Mention was presented to AARON F. ARCHER.

The prize selection committee consisted of George Andrews, Kelly J. Black, Catherine A. Roberts, Robert O. Robson, Martha J. Siegel, and Trevor Wooley.

The text that follows contains the committee's citation, a brief biographical sketch of Daniel Biss, and his response upon receiving the award. The same material is also presented for Aaron Archer.

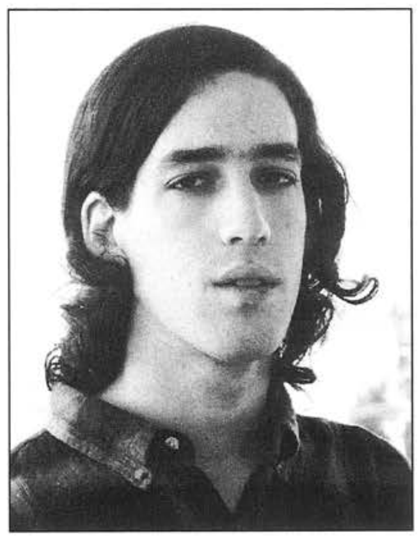
Daniel Biss

Citation

The 1998 winner of the Morgan Prize for outstanding research by an undergraduate is Daniel Biss, whose undergraduate studies were conducted at Harvard University. His submission for the prize included results in combinatorics, topology, group theory, and graph theory.

The committee was most impressed by Biss's remarkable breadth as well as depth. The most exciting aspect of his submission was his extension of a category which more closely binds the associations between combinatorial group theory and combinatorial topology. Overall, Biss's submission included four solid research papers, two of which have been accepted for publication.

The strength of his research, coupled with outstanding letters, insured that he is a truly outstanding candidate, and the committee is proud to give the 1998 Frank and Brennie Morgan Prize to Daniel Biss.



Daniel Biss

Biographical Sketch

Daniel Biss was born in Akron, Ohio, in 1977 and brought up in Bloomington, Indiana. His mathematical education began in 1992 under the guidance of Ciprian Foias, Distinguished Professor of Mathematics at Indiana University, who taught him analysis and measure theory. Around the same time, Biss began taking graduate-level courses at Indiana.

In the summer of 1994 he attended the Research Science Institute at the Massachusetts Institute of Technology, where he won the H. G. Rickover Medal, awarded to the outstanding student at the Institute. There he began working on a problem in algebraic combinatorics. This work was continued under the guidance of Professor Foias, as well as Kent Orr, also a professor at Indiana. It resulted in a paper for which Biss was named a finalist in the Westinghouse Science Talent Search, a winner of the Naval National Science Award, and a winner of the *USA Today* All-USA Academic Team competition.

In 1995 Biss went to Harvard University to pursue an undergraduate degree in mathematics. The following summer he was a student at the Duluth Summer Mathematics Research Experience for Undergraduates, under the direction of Joseph A. Gallian. Biss returned each of the following two years as a research advisor. During his second year at Harvard he was a course assistant for an honors freshman multivariable calculus course and later for a representation theory course. He has twice received a Certificate of Distinction in Teaching. In 1997 he was awarded the Barry M. Goldwater Scholarship in Mathematics, Science, and Engineering. In the spring of 1998 Biss graduated summa cum laude and received the Thomas Wendell Hoopes prize for his undergraduate thesis "Homotopy theory with a view toward stable computations", written under the direction of Raoul Bott and Michael Hopkins, professors at Harvard and MIT respectively.

Response

I am very honored to have been awarded the Morgan Prize. I would like to thank the AMS, MAA, and SIAM for instituting this award. Also, I would like to give my thanks for the opportunity to attend a summer Research Experience for Undergraduates in Duluth, MN. Without the existence of such a program and without the guidance of the program's founder and director, Joseph A. Gallian, I would never have been able to do most of the work for which the prize was awarded. I'd also like to point out that some of the work was done in collaboration with Samit Dasgupta, and without his ideas and commitment that could never have come about. Lastly, I'd like to thank the many other people who have been tremendous mathematical influences, particularly Kent Orr and Ciprian Foias, who have always been able to point me in the right direction, both inside and outside of mathematics.

Honorable Mention: Aaron F. Archer

Citation

An Honorable Mention is awarded to Aaron F. Archer for his nomination to the 1998 Frank and Brennie Morgan Prize. Archer's undergraduate studies were conducted at Harvey Mudd College. His submission for the prize included two solid papers on graph theory, introducing new chromatic interpretations for a graph.

Archer also has two applied mathematics papers in preparation and is a coauthor on a third paper that was awarded the SIAM Prize from the Mathematical Modeling Contest. All of his references painted a picture of a multitalented mathematician with demonstrated problem-solving ability, proven research ability, excellent communication skills, and an aptitude for working with others. As one of his letters stated, "Everything he does, he does well."

This outstanding young researcher has been recognized by an Honorable Mention in this year's Morgan Prize competition.

Biographical Sketch

Aaron Archer grew up in Tucson, Arizona. Last May he earned his B.S. in mathematics, graduating with high distinction from Harvey Mudd College in Claremont, California. Aaron's experience as a high school student at the 1992 Hampshire College Summer Studies in Mathematics summer camp strongly influenced him to study mathematics in college, and he returned to teach at the program in 1995 and 1998. He is also an alumnus of the Budapest Semesters in Mathematics and the Research Experiences for Undergraduates programs at Indiana University and the University of Minnesota, Duluth. He has done work in chromatic graph theory, computational geometry, discrete dynamical systems, and recreational mathematics. He received a Barry M. Goldwater Scholarship for his undergraduate studies. He initiated and led a fundraising effort last spring to establish a merit scholarship for promising incoming math students at Harvey Mudd, named after his classmate Andrew "Rif" Hutchings.

Archer is currently a Hertz Fellow in the Department of Operations Research and Industrial Engineering at Cornell University, where he is concentrating on discrete optimization.

Response

I am greatly honored to receive this recognition for my undergraduate work. I would like to thank all those who have helped guide my research or given me valuable advice and encouragement, particularly Professors Joseph Gallian of the University of Minnesota, Duluth; Maynard Thompson of Indiana University; and Michael Moody, Arthur Benjamin, and Francis Su of Harvey Mudd College.

Mathematics Opportunities

IMA Announces Spring and Summer Programs

The 1998-99 program of the Institute for Mathematics and its Applications, "Mathematics in Biology", will devote several workshops during the spring to the topic "Dynamic Models of Ecosystems and Epidemics". The date, title, and a brief description of each workshop follow.

April 19-23: Local Interaction and Global Phenomena in Vegetation and Other Systems. This workshop explores the effects of small-scale spatial interactions on the large-scale structure of communities. It addresses issues in scaling, renormalization, the interactions between levels of organization, and the interface between physical and biological processes.

April 24-27: Challenges and Opportunities in Genomics: Production, Storage, Mining, and Use. This is a Hot Topic workshop that focuses on scientific and mathematical issues that arise in production, storage, and mining of genomic data and use of the knowledge in applications.

May 17-21: Mathematical Approaches for Emerging and Reemerging Infectious Diseases. This workshop focuses on the study of ecological and evolutionary models in epidemiology and immunology using dynamical systems and stochastic analysis. A tutorial on the use of deterministic models in epidemiology and immunology will be held prior to the workshop on May 13-14.

June 17-11: From Individual to Aggregation: Modeling Animal Grouping. This workshop explores how striking animal aggregation patterns arise from decisions taken at the level of individuals.

July 20-24: Decision Making under Uncertainty: Energy and Environmental Models. This Hot Topic workshop is intended to create a dialogue between industry and academia about modeling issues and mathematical methodology that could be helpful in dealing with uncertainty in decision making.

The theme of the 1999 summer program is "Codes, Systems, and Graphical Models". The program is divided into two weeks: the first, August 2-6, covers codes on graphs and iterative decoding; the second, August 9-13, covers connections among coding theory, system theory, and symbolic dynamics.

For more details on these and other IMA programs, consult the Web site `http://www.ima.umn.edu/programs2.html`, or contact the Institute for Mathematics and its Applications, University of Minnesota, 400 Lind Hall, 207 Church Street, Minneapolis, MN 55455; telephone 612-624-6066; e-mail to Fred Dulles, Associate Program Director, at `dulles@ima.umn.edu`.

—From an IMA announcement

International Center for Mathematical Sciences 1999 Scientific Program

The International Center for Mathematical Sciences (ICMS) is organizing the following workshops and events for the spring and summer of 1999.

April 16: Lecture on Mathematics in Medicine by Jonathan Sherratt, Edinburgh International Science Festival.

May 16-23: Workshop, New Directions in the Model Theory of Henselian Valued Fields. Scientific Committee: H. D. Macpherson and D. Haskell.

May 23-June 4: Workshop, Hamiltonian Mechanics and Small Divisors in PDEs. Scientific Committee: W. Craig, J. Carr, K. Khanin, S. Kuksin, and E. Wayne.

July 5-9: The Fourth International Congress on Industrial and Applied Mathematics. A series of popular lectures and an exhibition will be held in association with the Congress. Details are available from the ICIAM99 Web site, `http://www.ma.hw.ac.uk/iciam99/`.

July 11-14: Workshop, The Dynamics of Thin Fluid Films. Scientific Committee: S. K. Wilson, B. Duffy, M. Grinfeld, L. Hocking, O. Jensen, J. King, J. Ockendon, D. Parker, M. Savage, and S. D. R. Wilson.

August 24-September 4: Workshop, The Geometry and Physics of Monopoles. Scientific Committee: J. Gauntlett, N. Hitchin, N. Manton, and M. Singer.

Full details on these programs can be obtained from the ICMS Web site at `http://www.ma.hw.ac.uk/icms/1999/index.html`, or contact the International Center for Mathematical Sciences, 14 India Street, Edinburgh EH3 6EZ, Scotland.

—From an ICMS announcement

Mathematical Sciences and Their Applications Throughout the Curriculum

Mathematical Sciences and their Applications Throughout the Curriculum (MATC) is a major initiative of the National Science Foundation intended to promote systemic improvements in undergraduate education by increasing student understanding of and ability to use the mathematical sciences. Seven institutions, each one with five to ten affiliates, are engaged in the initiative. MATC mathematicians join with faculties of other departments to develop multidisciplinary courses, modules, and other materials, as well as new teaching approaches, that include the use of computer-based technologies and the Internet.

Indiana University, Bloomington, one of the lead MATC institutions, will host a workshop July 8-10, 1999. The workshop will feature "minicourse presentations" of many of the courses and teaching approaches that have been developed over the past three years. Faculties in all disciplines who have an interest in improving student understanding of mathematics and its applications are invited to attend the workshop. The registration fee is $45 per person. Financial support is available to qualifying individuals who participate in two-person teams, one from mathematics and one from another discipline.

A sample of the program and further details are available at the MATC Web site at `http://matc.siam.org/workshop4/`.

—From a SIAM announcement

National Medal of Science Nominations Sought

The National Medal of Science is the United States's highest honor for scientific accomplishment. The National Science Foundation (NSF) administers the program on behalf of the president. Any U.S. citizen or permanent resident who has applied for citizenship within the preceding twelve months is eligible to be nominated. A distinguished 12-member committee appointed by the president reviews the nominations and sends its list of recommendations to the president for final selection. The committee consists of outstanding scientists and engineers from a variety of disciplines in the natural and social sciences. The president of the National Academy of Sciences and the assistant to the president for Science and Technology Policy serve as ex officio members of the selection committee.

For information on submitting nominations for the National Medal of Science, contact Susan Fannoney, Program Officer for the National Medals of Science, National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230; telephone 703-306-1096; fax 703-306-0181; e-mail `sfannone@nsf.gov`. The forms for electronic submission of nominations and references may be found on the Web at `www.fastlane.nsf.gov/` and in PDF and Word format at `www.nsf.gov/nsb/awards/hold.htm`. The deadline for nominations for this year is **May 31, 1999.**

—From NSF announcement

AWM Announces Mentoring Travel Grants for Women

The Association for Women in Mathematics announces a new Mentoring Travel Grant program, supported by the National Science Foundation. The objective of this program is to help junior women develop a long-term working and mentoring relationship with a senior mathematician. This relationship should help the junior mathematician to establish her research program and eventually receive tenure. In 1999 AWM expects to award as many as three grants, in amounts of up to $4,000 each. Each grant would fund travel, subsistence, and other required expenses for an untenured woman mathematician to travel to an institute or a department to do research with a specified individual for one month. Any unexpended funds could be used for further travel to work with the same individual during the following year. (Applicants for mentoring travel grants may in exceptional cases receive up to three such grants throughout their careers, possibly in successive years; each such grant would require a new proposal and would go through the usual competition.)

Applicants must be women holding a doctorate or equivalent experience and with a work address in the USA (or home address if unemployed). The applicant's research may be in any field which is funded by the Division of Mathematical Sciences of the National Science Foundation.

Each applicant should submit FIVE COPIES of each of the following: a cover letter; a curriculum vitae; a research proposal approximately five pages in length which specifies why the proposed travel would be particularly beneficial; a supporting letter from the proposed mentor (who must promise to be available at the time of the proposed travel and may be either a man or a woman), together with the curriculum vitae of the proposed mentor; an approximate budget; and information about other sources of funding available to the applicant. A final report will be required from each awardee. All awards will be determined on a competitive basis by a selection panel consisting of distinguished mathematicians appointed by the AWM.

Send FIVE complete copies of the application materials (including the cover letter) to: Mentoring Travel Grant Selection Committee, Association for Women in Mathematics, 4114 Computer & Space Sciences Building, University of Maryland, College Park, MD 20742-2461. Applications via e-mail or fax are not acceptable. Deadline for applications is **April 1, 1999.**

Further information may be obtained by telephone (301-405-7892) or e-mail (`awm@math.umd.edu`).

—From AWM announcement

For Your Information

Philippe Tondeur Appointed DMS Director

Philippe Tondeur of the University of Illinois, Urbana-Champaign, has been appointed director of the Division of Mathematical Sciences (DMS) of the National Science Foundation (NSF). He will assume his new position in July 1999. He succeeds Donald J. Lewis, who has been director of the DMS since 1995.

"We are delighted that Philippe Tondeur will be the new Division Director for Mathematics at the NSF," said Robert Eisenstein, NSF's assistant director for Mathematical and Physical Sciences. "Like many areas of science and engineering these days, mathematics has entered a golden age. What makes the case for mathematics so central is that, in addition to the discovery potential for new fundamental mathematics, there is the pivotal role that math plays in all areas of science and engineering and business, as well as general education. The responsibilities of the DMS are thus very large, and Philippe Tondeur is a person with the necessary wide and deep vision that will be necessary to accommodate both the excitement and the responsibilities of the field."

Born in Switzerland, Tondeur received his Ph.D. from the University of Zürich in 1961. He has been at Illinois since 1970 and has served as chair of the Department of Mathematics since 1996. His mathematical research has centered on differential geometry and topology and their interactions with mathematical physics. Tondeur is the author of nearly fifty publications, including the book *Foliated Bundles and Characteristic Classes*, written with F. Kamber and published in 1975 in the Springer series Lecture Notes in Mathematics.

—*Allyn Jackson*

Association for Research in Undergraduate Mathematics Education Formed

The Association for Research in Undergraduate Mathematics Education (ARUME) was formed at the Joint Meeting of the AMS and the Mathematical Association of America (MAA) in San Antonio, Texas, on January 14, 1999. The purpose of ARUME is to foster basic research in undergraduate mathematics education and its application to improving teaching practice. ARUME will provide organizational support for the conduct of research in undergraduate math education and its dissemination through talks, conferences, and publications. It will also interact with teachers of postsecondary mathematics to provide a firm grounding for research efforts within undergraduate teaching. ARUME will maintain a close relationship with the MAA and seek to build relationships with other organizations concerned with the learning and teaching of mathematics.

During the San Antonio meeting, paper and poster sessions addressed a variety of topics, such as students' intuitive number theory rules, preservice teachers' conceptions of variable, the effects of writing on calculus students' understandings of limit, and graduate students' mathematical beliefs.

ARUME will sponsor paper sessions and an expository talk at the MathFest in Providence, Rhode Island, July 31–August 2, 1999. In addition, it is helping to organize the Fourth Annual Conference on Research in Undergraduate Mathematics Education (RUME), to be held September 16–19, 1999, in Chicago, Illinois, sponsored by the Exxon Education Foundation.

Membership in ARUME is open to anyone interested in the pursuit of its goals. For information about membership, contact David Meel (meel@bgnet.bgsu.edu). Further information on the conference can be found at the Web site http://galois.oxy.edu/mickey/rume99.html or by contacting Mickey McDonald, Mathematics Department, Occidental College, Los Angeles, CA 90041; telephone 323-259-2504.

—From an ARUME announcement

NSF Report Examines Foreign Doctorates' Plans to Remain in United States

A study conducted by the National Science Foundation (NSF) has found that the majority of foreigners receiving science and engineering doctorates in the United States plan to remain in the country. This trend holds across all fields, including the mathematical sciences. The study, entitled "Statistical Profiles of Foreign Doctoral Recipients in Science and Engineering: Plans to Stay in the United States", was released last November.

Between 1988 and 1996, 55,000 students from the major countries of Asia, Europe, and North America (excluding the United States) earned doctoral degrees in science and engineering at United States institutions; the analogous figure for the mathematical sciences is 3,490. (It is useful to keep in mind that, according to the AMS-IMS-MAA Annual Survey, U.S. institutions awarded a total of 8,737 mathematical sciences doctorates from 1988 to 1996.) Of these 55,000 individuals, 63 percent planned to remain in the United States, and 39 percent had firm plans (that is, could provide the name and address of an employer) to stay in the United States; in the mathematical sciences, the figures are 61 percent and 37 percent respectively.

China was the source of many of these doctorates, as well as the source of many of those with plans to stay in the United States. During 1988–96, 1,354 students from China earned doctoral degrees in the mathematical sciences from United States institutions, and of these, 83 percent planned to stay in the United States. Four hundred had firm job offers, 70 percent of them from educational institutions and 26 percent from business or industry.

These trends did not hold for other Asian countries. During this same period, 377 students from South Korea and 376 students from Taiwan received mathematical sciences doctorates in the United States, but only 25 percent and 36 percent respectively planned to remain in the United States. "The trend in the 1990s has been for fewer doctoral recipients from South Korea and Taiwan to remain in the United States because of improved employment opportunities in their home countries," the report states. "However, these trends could change because of deteriorating financial conditions in Asia in 1998."

After China, South Korea, and Taiwan, the countries of Eastern Europe were the largest source of foreign doctorates in the mathematical sciences, accounting for 318, or 9 percent of the total. Of these, 219 planned to remain in the United States, and of the 79 with firm plans to stay, 85 percent had employment offers from educational institutions and 15 percent from business and industry. The picture in Western Europe was quite variable. France accounted for the fewest number of the mathematical sciences doctorates, just 29, whereas Germany had the largest number, 123. The percentage with firm plans to remain in the United States ranged from 6 percent of those from Italy to 37 percent of those from the United Kingdom.

The study found that across all fields of science and engineering the majority of United States employment offers received by foreign science and engineering doctoral recipients was from industry. However, in two fields, biological sciences and mathematical sciences, more job offers were made by educational institutions than by industry. In the mathematical sciences, 75 percent of the job offers were from educational institutions. After noting that 38 percent of foreigners receiving doctorates in computer science had firm job offers from educational institutions, the report states: "Those earning Ph.D.s in mathematics also seemed to be in high demand in the United States; most of their employment offers came from universities."

The report is available on the NSF Web site at http://www.nsf.gov/sbe/srs/nsf99304/.

—Allyn Jackson

Draft NCTM Standards Discussed

In October 1998 the National Council of Teachers of Mathematics (NCTM) released the first draft of the revision of its school mathematics standards, *Principles and Standards for School Mathematics: Discussion Draft.* A session held at the Joint Mathematics Meetings in San Antonio in January 1999 on the new draft document made it clear that many divisions remain over various aspects of the Standards.

When the original NCTM Standards appeared in 1989, their impact was enormous. Not only did they lead to substantial rethinking of school mathematics curricula across the country, but they also led to development of standards for other academic subjects. At the same time, the NCTM Standards ignited a searching debate among mathematicians, K–12 teachers, school administrators, and educational policymakers about what kind of mathematics should be taught at the school level and how it should be taught.

The 1989 Standards addressed mathematics curricula; in subsequent years the NCTM issued two more sets of standards, on assessment and the teaching profession. These three sets of standards are now being revised, updated, and unified in the new document, informally known as Standards 2000. Copies of the draft standards were handed out to the perhaps 100 attendees at the session at the Joint Meetings. It seemed that few had seen the 342-page document before attending the session. The draft may be enjoying wider visibility now that it has been posted on the NCTM Web site.

Joan Ferrini-Mundy opened the session with some general remarks about the standards revision process. Ferrini-Mundy, who is on the faculty of the University of New Hampshire, is the director of the Mathematical Science Education Board of the National Research Council and serves as chair of the Writing Group for Standards 2000. The NCTM has gone to great lengths to collect commentary and ideas from a wide variety of individuals and groups having an interest in mathematics education. Ferrini-Mundy mentioned in particular the Association Review Groups, formed within professional societies and other organizations for the purpose of contributing to the standards revision. The AMS Association Review Group was originally chaired by Roger Howe of Yale University (see "The AMS and Mathematics Education: The Revision of the NCTM Standards", by Roger Howe, and "Reports of AMS Association Resource Group", edited by Howe, both in the February 1998 issue of the *Notices*). The new chair is John Polking of Rice University. Some members of the Standards 2000 writing teams—Judith Roitman of the University of Kansas, Kathleen Heid of Pennsylvania State University, and Alan Schoenfeld of the University of California, Berkeley—also made brief presentations during the session.

The heart of the session was a small group discussion period, during which the audience broke up into groups, each of which focused on a different standard. After the discussion was called to a close, a spokesperson for each group described briefly the group's discussion. For example, Tony Gardiner of the University of Birmingham, United Kingdom, was the spokesperson for a group that discussed the "patterns, functions, and algebra" standard. He commented that the wording seemed to advocate the use of patterns to introduce the concept of a function. For example, students can be given tables or sequences of numbers and asked to guess what the pattern is; in later grades, such patterns would be encapsulated in functional notation. According to Gardiner, this approach was used in the mathematics curriculum adopted in the United Kingdom in 1988, and it backfired. He said that it tended to reinforce the idea that all variables stand for small, positive integers and that it also encouraged students to see an algebraic expression as a kind of "guessed shorthand" for a rule rather than a precise expression with which one can calculate.

Susanna Epp of DePaul University was the spokesperson for the group looking at the standard concerning mathematical proof. She said that clearer distinctions needed to be made between valid and invalid justifications. Consider the difference between a valid informal argument that justifies a statement and a set of examples that illustrates the statement: the first can be extended to a formal proof; the second, perhaps not. She also pointed out the value of open-ended questions in which students are presented with a statement and asked to explain whether the statement is always, sometimes, or never true.

One question raised in the discussion is that of the audience for Standards 2000. As Ferrini-Mundy explained, the Standards are used by many different groups: classroom teachers, curriculum developers, textbook publishers, and policymakers at the local, state, and federal levels, to name just a few. It is difficult to create a set of standards that will suit so many different uses, and as Ferrini-Mundy noted, this is a difficult question the Writing Group has struggled with.

Even if the NCTM succeeds in producing standards that would be useful to such a wide audience, another hard question remains: Are mathematics teachers ready for the changes Standards 2000 calls for? To Howe, this is one of the central problems. After the original NCTM Standards appeared, he asserted, "major errors" were made as school districts adopted new curricula without knowing whether teachers had sufficient background in mathematics to use the new curricula. This problem contributed to the demise of the "New Math" of the 1960s, he pointed out, and has been a significant factor in the rejection in recent years of new curricula introduced in California.

The 80-minute session did not allow for deep or substantive discussion, but interest was clearly high as many remained in the room afterward, engaged in individual discussions. The NCTM has designated the 1998–99 academic year as a "Year of Dialogue" about Standards 2000. In the summer of 1999 the writing teams will meet again to revise the document on the basis of comments received. The final version is scheduled to be released in April 2000. To obtain further information or a copy of the draft revision, write to: Standards 2000 Project, National Council of Teachers of Mathematics, 1906 Association Drive, Reston, VA 22091; e-mail: `future@nctm.org`. Standards 2000 is available on the World Wide Web at `www.nctm.org/standards2000/`.

—*Allyn Jackson*

Correction

Due to receipt of incorrect information, misspellings occurred in two dissertation titles appearing in "Doctoral Degrees Conferred", *Notices*, February 1999, p. 255, under Western Michigan University. The corrected entries are:

Crawford, Pamela, Fostering reflective thinking in first-semester calculus students.

Wahlberg, Melanie, The effects of writing assignments on second-semester calculus students' understanding of the limit concept.

Reference and Book List

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

Upcoming Deadlines

April 1, 1999: Deadline for applications for AWM Mentoring Travel Grants (see page 473 this issue). For more information: telephone 301-405-7892, e-mail awm@math.umd.edu.

April 5, 1999: Deadline for submission of proposals for Short-Term Project Development Grants from the Office of International Affairs of the National Research Council. For more information, contact the Office of International Affairs, National Research Council, 2101 Constitution Avenue, NW (FO 2060), Washington, DC 20418; telephone 202-334-3680; fax 202-334-2614; e-mail ocee@nas.edu; World Wide Web http://www2.nas.edu/oia/22da.html.

April 12, 1999: Deadline for proposals for the 2000 NSF-CBMS Regional Conferences. For more information, contact the Conference Board of the Mathematical Sciences, 1529 18th Street, NW, Washington, DC 20036; telephone 202-293-1170; fax 202-265-2384; World Wide Web http://www.maa.org/cbms/nsf/2000nsf.html; e-mail kolbe@math.georgetown.edu or rosier@math.georgetown.edu. See also the announcement of the upcoming NSF-CBMS Regional Conferences, to be held in the summer of 1999, which appeared in the February 1999 *Notices*.

April 16, 1999: Deadline for applications for Project NExT Fellowships. For more information, see the Project NExT home page (http://archives.math.utk.edu/projnext/), or contact one of the following: T. Christine Stevens (Director, Project NExT), Department of Mathematics and Computer Science, Saint Louis University, 221 North Grand Blvd., St. Louis, MO 63103; telephone 314-977-2444; e-mail stevensc@slu.edu; Joseph Gallian (Codirector), Department of Mathematics and Statistics, University of Minnesota-Duluth, Duluth, MN 55812; telephone 218-726-7576; e-mail jgallian@d.umn.edu; or Aparna Higgins (Codirector), Depart-

Where to Find It

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

ment of Mathematics, University of Dayton, Dayton, OH 45469; telephone 937-229-2103; e-mail `higgins@saber.udayton.edu`.

July 19, 1999: Deadline for proposals for the second VIGRE Grant competition. For more information, consult the NSF Web site at `http://www.nsf.gov/cgi-bin/getpub?nsf9916/`.

July 30, 1999: Deadline for submission of proposals for Long-Term Project Development Grants from the Office of International Affairs of the National Research Council. For more information, contact the Office of International Affairs, National Research Council, 2101 Constitution Avenue, NW (FO 2060), Washington, DC 20418; telephone 202-334-3680; fax 202-334-2614; e-mail `ocee@nas.edu`; World Wide Web `http://www2.nas.edu/oia/22da.html`.

Board on Mathematical Sciences, National Research Council

John Tucker (Director, BMS), National Academy of Sciences

Robert MacPherson (chair), Institute for Advanced Study

Lynne Billard, University of Georgia

George Casella, Cornell University

Jennifer Chayes, Microsoft Research

Ronald R. Coifman, Yale University

Robert Fefferman, University of Chicago

C. William Gear, NEC Research Institute

Fan Chung Graham, University of Pennsylvania

Dianne P. O'Leary, University of Maryland

Alan S. Perelson, Los Alamos National Laboratory

William R. Pulleyblank, IBM T. J. Watson Research Center

Donald St. P. Richards, University of Virginia

Karen E. Smith, University of Michigan

Daniel W. Stroock, Massachusetts Institute of Technology

DeWitt L. Sumners, Florida State University

Peter J. Bickel (ex officio), University of California, Berkeley

The postal address for BMS is: Board on Mathematical Sciences, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; World Wide Web `http://www2.nas.edu/bms/`.

Book List

The **Book List** *highlights books that have mathematical themes and hold appeal for a wide audience, including mathematicians, students, and a significant portion of the general public. When a book has been reviewed in the* Notices, *a reference is given to the review. Generally the list will contain only books published within the last two years, though exceptions may be made in cases where current events (e.g., the death of a prominent mathematician, coverage of a certain piece of mathematics in the news) warrant drawing readers' attention to older books. Suggestions for books to include on the list may be sent to the Managing Editor,* e-mail: `notices@ams.org`.

Abraham Robinson: The Creation of Nonstandard Analysis, a Personal and Mathematical Odyssey, by Joseph Warren Dauben. Princeton University Press, 1998. ISBN 0-691-05911X.

The Algorithmic Beauty of Sea Shells (Virtual Laboratory), by Hans Meinhardt, Przemyslaw Prusinkiewicz, and Deborah R. Fowler. Springer-Verlag, 1998. ISBN 3-540-63919-5.

The Apprenticeship of a Mathematician, by André Weil, translation by Jennifer Gage, Birkhaüser Boston, 1992. ISBN 0-817-62650-6. (Reviewed in this issue.)

A Beautiful Mind: A Biography of John Forbes Nash, Jr., by Sylvia Nasar, Simon & Schuster, 1998. ISBN 0-684-81906-6. (Reviewed November 1998.)

Challenges, by Serge Lang. Springer-Verlag, 1998. ISBN 0-387-94861-9.

Drawbridge Up: Mathematics—A Cultural Anathema (Zugbrücke ausser Betrieb: Die Mathematik im Jenseits der Kultur), by Hans Magnus Enzensberger. A. K. Peters, 1999. ISBN 1-56881-099-7.

e: The Story of a Number, by Eli Maor. Paperback edition, Princeton University Press, 1998. ISBN 0-691-05854-7.

Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science, by Alan Sokal and Jean Bricmont. English version of *Impostures Intellectuelles* (reviewed August 1998). St. Martin's Press, 1998. ISBN 0-312-19545-1.

The Feynman Processor, by Gerard J. Milburn and Paul Davies. Helix Books, Perseus, 1998. ISBN 0-738-20016-6.

Geometry Civilized: History, Culture, and Technique, by John Heilbron, Oxford University Press, 1998. ISBN 0-19-850078-5.

Goodbye, Descartes: The End of Logic and the Search for a New Cosmology of the Mind, by Keith Devlin. John Wiley & Sons, 1998. ISBN 0-471-14216-6.

An Imaginary Tale: The Story of $\sqrt{-1}$, by Paul J. Nahin. Princeton University Press, 1998. ISBN 0-691-02795-1.

The Jungles of Randomness: A Mathematical Safari, by Ivars Peterson. Paperback edition, John Wiley & Sons, 1998. ISBN 0-471-29587-6.

The Language of Mathematics: Making the Invisible Visible, by Keith Devlin. W. H. Freeman and Company, 1998. ISBN 0-716-73379-X.

Life by the Numbers, by Keith Devlin. John Wiley & Sons, 1998. ISBN 0-471-24044-3.

The Man Who Loved Only Numbers: The Story of Paul Erdős and the Search for Mathematical Truth, by Paul Hoffman. Hyperion, 1998. ISBN 0-786-86362-5. (Reviewed October 1998.)

Mathematical Reasoning: Analogies, Metaphors, and Images, edited by Lyn English. Lawrence Erlbaum Associates. ISBN 0-8058-1979-7.

Mathematics for the Curious, by Peter M. Higgins. Oxford University Press, 1998. ISBN 0-192-88072-1.

Mathematics: From the Birth of Numbers, by Jan Gullberg, Peter

Hilton. W. W. Norton and Company, 1997. ISBN ISBN 0-393-04002-X.

Modern Mathematics in the Light of the Fields Medals, by Michael Monastyrsky. AK Peters, 1997. ISBN 1-568-81065-2.

Moral Calculations: Game Theory, Logic, and Human Frailty, by László Mérő. Copernicus-Springer Verlag, 1998. ISBN 0-387-98419-4.

My Brain is Open: The Mathematical Journeys of Paul Erdős, by Bruce Schecter. Simon & Schuster, 1998. ISBN 0-684-84635-7.

The Number Devil, by Hans Magnus Enzensberger. Metropolitan Books, 1998. ISBN 0-805-05770-6.

Once Upon a Number: A Mathematician Bridges Stories and Statistics, by John Allen Paulos. Basic Books, 1998. ISBN 0-465-05158-8.

Paul Dirac: The Man and His Work, by Abraham Pais, Maurice Jacob, David Olive, and Michael Atiyah. Cambridge University Press, 1998. ISBN 0-521-58382-9. (Reviewed October 1998.)

Philosophy of Mathematics: An Introduction to a World of Proofs and Pictures, by James Robert Brown, Routledge, 1998. ISBN 0-415-12274-0.

The Pleasures of Counting, by T. W. Körner. Cambridge University Press, 1997. ISBN 0-521-56087-X; 0-521-56823-4. (Reviewed March 1998)

Polyhedra, by Peter Cromwell. Cambridge University Press, 1997. ISBN 0-521-55432-2. (Reviewed September 1998)

Privacy on the Line: The Politics of Wiretapping and Encryption, by Whitfield Diffie and Susan Landau. MIT Press, 1997. ISBN 0-262-04167-7. (Reviewed June/July 1998)

Proofs from the Book, by Martin Aigner and Günter Ziegler. Springer-Verlag, 1998. ISBN 3-540-63698-6.

Randomness, Deborah Bennett. Harvard University Press, 1998. ISBN 0-674-10745-4.

Reasoning with the Infinite: From the Closed World to the Mathematical Universe, by Michel Blay (translated by M. B. DeBevoise). University of Chicago Press, 1998. ISBN 0-226-05834-4.

Strength in Numbers, by Sherman Stein. John Wiley & Sons, 1996. ISBN 0-471-152528-8.

Tracking the Automatic Ant, and Other Mathematical Explorations, by David Gale, Springer-Verlag, 1998. ISBN 0-387-98272-8.

The Universe and the Teacup: The Mathematics of Truth and Beauty, by K.C. Cole. Hartcourt Brace, 1998. ISBN 0-151-00323-8. (Reviewed March 1999.)

Visual Explanations—Images and Quantities, Evidence and Narrative, by Edward R. Tufte, Graphics Press, 1997. ISBN 0-961-39212-6. (Reviewed January 1999.)

What is Mathematics, Really?, by Reuben Hersh, Oxford University Press, 1997. ISBN 0-19-511368-3.

Women in Mathematics: The Addition of Difference, by Claudia Henrion. Indiana University Press, 1997. ISBN 0-253-33279-6. (Reviewed May 1998.)

REFERENCE & BOOK LIST

Call for Nominations

Distinguished Public Service Award

Frank Nelson Cole Prize in Algebra

Norbert Wiener Prize

The selection committees for these prizes request nominations for consideration for the 2000 awards, which will be presented at the Joint Mathematics Meetings in Washington, D.C. in January 2000. Information about these prizes may be found in the November 1997 *Notices*, pp. 1347–1353. (Also available at http://www.ams.org/ams/prizes.html).

The *Award for Distinguished Public Service* is presented every two years to a research mathematician who has made a distinguished contribution to the mathematics profession during the preceding five years.

The *Frank Nelson Cole Prizes* are awarded at five-year intervals for contributions to algebra and number theory, respectively.

The *Norbert Wiener Prize* is normally awarded every five years and is made jointly by the American Mathematical Society and the Society for Industrial and Applied Mathematics for an outstanding contribution to "applied mathematics in the highest and broadest sense".

Nominations should be submitted to the Secretary, Robert J. Daverman, American Mathematical Society, 312D Ayres Hall, University of Tennessee, Knoxville, TN 37996-1330, and should include supporting material. For the Public Service Award, include a short description of the pertinent activities of the nominee; for the Cole Prize and Wiener Prize, include a short description of the work that is the basis of the nomination, including complete bibliographic citations. A curriculum vitae should be included for all nominees. The nominations will be forwarded by the secretary to the appropriate prize selection committee which will, as in the past, make the final decisions on the awarding of the prizes.

Deadline for Nominations is April 30, 1999

(Note the extension of the deadline for the Public Service Award.)

Mathematics Calendar

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

April 1999

*29–May 1 **Workshop on Combinatorial Methods for Statistical Physics Models**, Georgia Institute of Technology, Atlanta, Georgia.

Sponsors: Georgia Institute of Technology; The Center for Discrete Mathematics and Theoretical Computer Science (DIMACS); The Southern Applied Analysis Center (SAAC); The Algorithms, Combinatorics and Optimization Program (ACO).

Organizers: D. Randall (Georgia Institute of Technology) and P. Tetali (Georgia Institute of Technology).

Focus: This workshop will focus on recent developments at the interface between combinatorics, statistical physics, and theoretical computer science.

Topics: Topics include Gibbs measures and phase transitions in various models (such as the Potts model, hardcore lattice gases and dimer systems), percolation theory, and mixing rates of finite Markov chains. There will be introductory lectures intended for a wide audience as well as more focused talks highlighting recent research trends; beginners to the topic with a background in basic combinatorics and probability are encouraged to attend.

Information: D. Randall, Georgia Institute of Tech., randall@math.gatech.edu; WWW: http://dimacs.rutgers.edu/Workshops/index.html.

*30–May 2 **Nonlinear Partial Differential Equations and Applications to Materials**, University of Minnesota, Minneapolis, Minnesota.

Focus: This workshop will bring together researchers in materials science, applications of PDEs, analysis of PDEs and numerics in a setting which will allow informal interaction as well as a selection of hour talks by leaders in the respective fields. In this manner, issues of intense interest in materials science will be brought to the attention of modelers, theoretical analysts, and numerical analysts for discussion, with the expectation that they will provide ideas and insight useful for the challenges offered by materials research. At the same time, new concepts and methods currently being brought to bear on the fundamental issues in the analysis of PDEs (numerical and theoretical) will be presented in a way which may open new paths of inquiry for modelers and for materials scientists.

Topics: Topics which will be discussed include level-set methods, viscosity solutions of scalar PDEs and of systems, nonlinear homogenization, multiple time scales, widely varying length scales, fast numerical methods, and mesoscale models derived from microscale with their relations with the macroscale viewpoint.

Speakers: O. Bruno (Caltech), A. Friedman (Univ. of Minnesota), R. James (Univ. of Minnesota), R. Kohn (Courant Institute), J. Lowengrub (Univ. of Minnesota), M. Luskin (Univ. of Minnesota), G. McFadden (National Inst. of Standards & Technology), G. Milton (Univ. of Utah), M. Ortiz (Caltech), S. Osher (UCLA), G. Papanicolaou (Stanford Univ.), M. Soner (Princeton Univ.), V. Sverak (Univ. of Minnesota).

Funding: Funding has been made available to defray workshop expenses for a number of graduate students. If you are a registered graduate student and are interested in applying for these funds, please check the appropriate box on the registration form and have one letter of recommendation, addressing your qualifications, sent from your advisor or department chairman to R. Gulliver, School of Mathematics, Univ. of Minnesota, Minneapolis, MN 55455, or by e-mail to gulliver@math.umn.edu. The deadline for application for support of graduate students is Friday, February 5, 1999. Mathematicians from the twenty-nine Participating Institutions of the IMA are eligible to receive IMA/PI funding, where available, to come to the workshop. Application to use IMA/PI funds for the workshop should be made directly to the mathematics depart-

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.)

ment chair. Faculty from other departments are sometimes also eligible.
Organizers: R. Gulliver (gulliver@math.umn.edu) and F. Reitich (reitich@math.umn.edu).
Registration: Deadline for registration (to ensure hotel space): Friday, March 5, 1999.
Information: For further information and registration form, see http://www.ima.umn.edu/~gulliver/confs/pdemat.html.

May 1999

*20-24 **Twenty-seventh Canadian Operator Theory and Operator Algebras Symposium**, University of Prince Edward Island, Charlottetown, PEI, Canada.
Speakers: K. Davidson (Univ. of Waterloo), G. Elliott (Univ. of Toronto), L. Ge (Univ. of New Hampshire), D. Hadwin (Univ. of New Hampshire), D. Handelman (Univ. of Ottawa), D. Larson (Texas A&M Univ.), S. Power (Univ. of Lancaster), I. Putnam (Univ. of Victoria), H. Radjavi (Dalhousie Univ.), M. Rordam (Univ. of Copenhagen).
Information: G. MacDonald, Dept. of Math. & CS, Univ. of Prince Edward Island, Charlottetown, PEI, Canada, C1A 4P3; e-mail: gmacdonald@upei.ca; Web page: http://www.math-cs.upei.ca/people/gmacdon/cosy/.

*26-28 **Crystallographic Groups and Their Generalizations II**, K. U. Leuven (Campus Kortrijk), Kortrijk, Belgium.
Scientific Committee: H. Abels (Bielefeld), Y. Felix (Louvain la Neuve), F. Grunewald (Duesseldorf), P. Igodt (Leuven/Kortrijk).
Invited Speakers: Y. Benoist (E.N.S.), M. Bridson (Oxford), C. Casacuberta (Barcelona), K. Dekimpe (Leuven/Kortrijk), B. Farb (Chicago), W. Goldman (College Park), G. Margulis (Yale).
Topics: Recent developments concerning crystallographic groups and all concepts which can be seen as generalizations of them are the subjects of this workshop. A nonexhaustive list of possible topics includes: Affine crystallographic groups and affine manifolds; almost crystallographic groups and infra-nilmanifolds; polynomial structures on polycyclic-by-finite groups and polynomial manifolds; discrete subgroups of Lie groups and homogeneous spaces; localisation problems for groups; finitely generated groups, quasi-isometry and rigidity; geometric group theory.
Call for Abstracts: Interested researchers will be offered an opportunity to present a short talk (25 minutes) on their work. For this they should send a title and abstract (in LaTeX-format) to the scientific committee, via the e-mail address: Paul.Igodt@kulak.ac.be. For those talks which eventually cannot be scheduled, the authors/participants will get an opportunity to present a poster (max. two A3-size documents).
Information: Registration documents and all practical information are found at the Web site http://www.kulak.ac.be/workshop/.

*29-June 1 **CMS Summer 1999 Meeting**, Memorial University of Newfoundland, St. John's, Newfoundland.
Program: This meeting will feature plenary speakers from a broad spectrum of mathematics by top mathematicians. It will also feature sessions in various areas of mathematics.
Plenary Speakers: E. Barbeau (Toronto), R. K. Brylinski (Pennsylvania State), M. van den Bergh (Limburg/Belgium) and T. Korner (Cambridge).
Prize Lectures: The Jeffery-Williams Lecture will be given by J. Friedlander (Univ. of Toronto). The Krieger-Nelson Prize will be given by N. Tomczak-Jaegermann (Univ. of Alberta).
Sessions: Session titles and speakers are: **Combinatorics and Its Applications** (N. Shalaby and D. Stinson, organizers): F. Bennett (Halifax), C. Colbourn (Maine), K. Heinrich (SFU), A. Rosa (McMaster), D. Stinson (Waterloo), L. Vinet (Montreal); **Education: What Mathematical Competitions Do for Mathematics** (B. Shawyer and E. Williams, organizers): E. Barbeau (Toronto), R. Dunkley (Waterloo), T. Gardiner (Birmingham), R. Janes (Director of NCTM), and S. Sullivan (MUN student); **Graduate Student Seminar**: A special session is being organized for graduate students. Anyone interested in participating in the organization of this program should contact H. Brunner, e-mail: cms99@math.mun.ca; **Joint CMS-CRM Session on Harmonic Analysis** (K. Hare, organizer): J. Benedetto (Maryland), B. Forrest (Waterloo), J.-P. Gabardo (McMaster), E. Granirer (UBC), H. Henig (McMaster), Z. Hu (Windsor), R. Kerman (Brock), T. Korner (Cambridge), T. Lau (Alberta), D. Oberlin (Florida), J.-O. Ronning (Skode U.), G. Sinnamon (UWO), S. Wainger (Wisconsin); **Nonlinear Analysis and Its Applications** (S. Singh and B. Watson, organizers): G. Allasia (Torino), J. Borwein (SFU), P. Gauthier (Montreal), K. Goebel (Lublin), W. A. Kirk (Iowa), W. Light (Leicester), S. Park (Seoul), B. Rhoades (Indiana), W. Takahashi (Tokyo), E. Tarafdar (Australia), J. Whitfield (Lakehead); **Perspectives in Ring Theory** (E. Goodaire and E. Jespers, organizers): Y. Bahturin (Moscow), M. van den Bergh (Limburg/Belgium), J. Okninski (Warsaw), D. S. Passman (Wisconsin), M. Putcha (North Carolina State), L. Renner (UWO), S. K. Sehgal (Edmonton); **Joint CMS-Fields Institute Session on Representation Theory** (A. Broer, organizer): J. Brundan (Oregon at Eugene), R. K. Brylinski (Pennsylvania State), C. Cunningham (Massachusetts), S. R. Evens (Arizona at Tucson), L. Helminck (North Carolina State), M. Hunziker (Brandeis), A. S. Kleshchev (Oregon at Eugene), F. Knop (Rutgers), V. Lakshmibai (Northeastern), W. M. McGovern (Seattle), G. McNinch (Notre Dame), F. Murnaghan (Toronto), M. Nevins (Alberta), M. Reeder (Boston College), Y. Sanderson (Rutgers), G. Savin (Utah), E. Sommers (Harvard), P. Trapa (Institute for Advanced Studies); **Surveys in Mathematics** (K. Murty, organizer): Speakers to be announced.
Submission of Abstracts: The CMS publishes abstracts for all scheduled talks. Titles for plenary speakers, prize lecturers, and invited special sessions for the scientific and education program will appear in the **April** issue of the *CMS Notes*. Titles for contributed papers will appear in the **May** issue of the *CMS Notes*. All abstracts will be published in the meeting program and will be available on the Canadian Mathematical Electronics Services (Camel): http://camel.math.ca/CMS/Events/summer99/ and on the CMS99 Summer Meeting Web site: http://www.math.mun.ca/~cms99/.

June 1999

*11-13 **20th Annual Meeting of the Canadian Applied and Industrial Mathematical Society (CAIMS-99)**, Université Laval, Quebec, Canada.
Supported by: The Canadian Applied and Industrial Mathematical Society (CAIMS), Le Centre de Recherche Mathematiques de Montréal (CRM), The Field Institute for Research in Mathematics, SIAM, GAMM.
Scientific Committee: J. Bélair (Univ. de Montréal), F. Bergeron (UQAM), J. Clements (Dalhousie Univ.), M. Fortin (chair), H. Manouzi (Univ. Laval), R. Miura (UBC), B. Moodie (Univ. of Alberta), B. Simpson (Univ. of Waterloo).
Invited Keynote Speakers: G. Alefeld, O. Diekeman, M. Gunzburger.
Local Organization Committee: M. Beauchamp, M. Fortin, J. J. Gervais, H. Manouzi, R. Pierre.
Minisymposia Themes: Dynamical systems in physiology; bifurcation theory; population dynamics; control problems for nonlinear partial differential equations; numerical methods and simulations for nonlinear partial differential equations; interval arithmetic: algebraic problems; interval arithmetic: continuous problems; quantum computic; combinatorics and symbolic computations; fluid mechanics. The meeting will be held concurrently with the "Journee des Elements Finis", a one-day industrial mathematics workshop, the subject of which will be "Numerical Methods in Biomechanics".
Deadlines: Deadline for receipt of abstracts: Friday, April 30, 1999; deadline for registration (on site): Thursday, June 10, 1999.
Information: Further information on fees, etc., is available at the conference Web site: http://www.mat.ulaval.ca/caims99/, where it is possible to register electronically; get the material for abstract submission. Contact (e-mail preferred) R. Pierre, CAIMS-99, Departement de Mathematiques et Statistique, Université Laval, Quebec, QC, G1K 7P4, Canada; tel: 1-418-656-2972; fax: 1-418-656-2817; e-mail: rpierre@mat.ulaval.ca.

*19-23 **NSF-CBMS Regional Conference**

on Mathematical Analysis of Viscoelastic Flows, University of Delaware, Newark, Delaware.
Principal Lecturer: M. Renardy (Virginia Tech).
Organizers: D. O. Olagunju (Univ. of Delaware), olagunju@math.udel.edu; and Y. Renardy (Virginia Tech.), renardyy@math.vt.edu.
Information: Visit the Web site: http://www.math.udel.edu/~olagunju/cbms/, or contact the organizers.

*21-26 **Conference on Symplectic Geometry**, Instituto Superior Tecnico, Lisboa, Portugal.
Confirmed Speakers: M. Audin (Strasbourg), P. Biran (Stanford), Y. Eliashberg (Stanford), H. Geiges (Leiden), V. Ginzburg (Santa Cruz), E. Giroux (Lyon), V. Guillemin (MIT), Y. Karshon (Jerusalem), D. McDuff (Stony Brook), L. Polterovich (Tel-Aviv), S. Tolman (Illinois), A. Weinstein (Berkeley), J. Weitsman (Santa Cruz).
Program: There will be about 20 one-hour lectures on symplectic geometry and symplectic topology. The conference will start in the morning of Monday, June 21, and will finish in the afternoon of Saturday, June 26, with two half-days for sightseeing. A two-week course on algebraically integrable systems by M. Audin will take place in the weeks before and after the conference (June 14-18 and June 28-July 2).
Deadlines: Application for partial funding: April 1, 1999; application for local arrangements: May 1, 1999.
Information: URL: http://www.math.ist.utl.pt/omega99.html; e-mail: omega99@math.ist.utl.pt; tel: +351-1-841-7113; fax: +351-1-841-7598; postal address: Conference on Symplectic Geometry, a/c A. Cannas da Silva, Departamento de Matematica, Instituto Superior Tecnico, 1049-001 Lisboa, Portugal.

July 1999

*2-5 **VIIIth Oporto Meeting on Geometry, Topology and Physics**, Dep. Matematica Pura, Fac. Ciencias, Oporto University, Oporto, Portugal.
Aim: The aim of the Oporto meetings is to bring together mathematicians and physicists interested in the interrelationship between geometry, topology and physics and to provide them with a pleasant and informal environment for scientific interchange.
Topics: The focus themes for this year are: 1. spinors and geometry, 2. integrability & algebraic geometry and, 3. topological quantum field theory. The meeting will consist largely of four short courses, of approximately three lectures each, given by the main speakers, supplemented by a limited number of seminars (more details later). The talks are at the advanced graduate or postdoctoral level, and should be of interest to all researchers wishing to learn about recent developments in the overlap between geometry, topology, and physics.
Main Speakers: R. Donagi (Univ. of Pennsylvania): Spectral curves, integrable systems, and moduli; J. Froehlich (Institut fur Theoretische Physik): Supersymmetry and noncommutative geometry; E. Getzler (Northwestern Univ.): The Virasoro conjecture for Gromov-Witten invariants: A status report; I. Krichever (Columbia Univ.): Moduli spaces of Riemann surfaces and 2D integrable systems.
Information: WWW: http://fisica.ist.utl.pt/~jmourao/om/omviii/textoom99b.html.

*5-August 21 **Summer Semester on Complex Potential Theory and its Applications**, Feza Gursey Institute, Istanbul, Turkey.
Emphasis: Feza Gursey Institute will host a research-teaching semester (July 5-August 6 and August 16-21, 1999) on Complex Potential Theory (CPT) and its applications. There will be a workshop in Edirne (Linear Topological Spaces and Complex Analysis III) August 9-August 13, emphasizing, mainly, the connection between complex analysis and functional analysis.
Organizers: A. Aytuna (Middle East Technical Univ.), T. Terzioglu (Sabanci Univ.) and V. Zahariuta (Feza Gursey Institute & Rostov State Univ.).
Purpose: CPT is a relevant potential theory for the multidimensional complex analysis that deals with plurisubharmonic functions and maximal plurisubharmonic functions; it is strongly connected with the study of the complex Monge-Ampère equation. CPT is an active area of research in mathematics with applications in approximation and interpolation theory, partial differential equations, complex dynamical systems, differential geometry, number theory and so on. The aim, during the semester, is to impart the main ideas of CPT to advanced graduate students and other interested mathematicians through a series of lectures by leading researchers in the field as well as to proceed scientific discussions of the advanced results and some open problems in CPT.
Lecturers: The semester will consist largely of courses taught by invited lecturers. The following specialists will provide 10-15 hour courses of lectures each: A. Aytuna (METU, Turkey): Introduction to the classical potential theory in the complex plane; S. Kolodzej (Jagellonian Univ., Kracow, Poland): The main aspects of CPT and Monge Ampére equations; E. Poletsky (Syracuse Univ., USA): Plurisubharmonic currents and pluripotentials; J. Siciak (Jagellonian Univ., Kracow, Poland): Pluripotentials and their applications in interpolation and approximation theory; D. Vogt (Wuppertal Univ., Germany): CPT, Phraghmen-Lindelof Principles and applications to partial differential equations; V. Zahariuta (Rostov State Univ., Russia & Feza Gursey Institute): Plurisubharmonic functions and analytic functions of several complex variables.
Participation: Candidates should send in their request for participation directly to the Feza Gursey Institute (http://www.gursey.gov.tr/complex.html). TUBITAK will fully support those participants from the outlying universities within Turkey. Those institutions which are able to provide funds are expected to meet at least part of the living expenses of the participants.
Deadlines: Candidates requesting financial support: June 1, 1999; candidates not requesting financial support: June 15, 1999. The organizing committee will make running evalutations and will communicate its decisions to all the candidates within as short a time as possible.

*12-14 **Feynman Integrals and Related Topics**, Yonsei University, Seoul, Korea.
Sponsors: Natural Science Research Inst. and Inst. for Mathematical Sciences; Yonsei Univ.; Korean Mathematical Society; Korea Science and Engineering Foundation.
Organizers: S. Albeverio (Ruhr-Univ.), K. S. Chang (Yonsei Univ.), T. Hida (Meijo Univ.), G. W. Johnson (Univ. of Nebraska), G. Kallianpur (Univ. of N. Carolina), M. L. Lapidus (Univ. of California, Riverside), Y. M. Park (Yonsei Univ.).
Invited Speakers: S. Albeverio (Ruhr-Univ.), Z. Brzezniak (Univ. of Hull), J. Van Casteren (Univ.of Antwerp), B. D. Choi (KAIST), D. M. Chung (Sogang Univ.), A. B. Cruzeiro (Univ. Lisbon), B. DeFacio (Univ. of Missouri), T. Hida (Meijo Univ.), T. Ichinose (Kanazawa Univ.), B. Jefferies (Univ. of New South Wales), G. W. Johnson (Univ. of Nebraska), G. Kallianpur (Univ. of N. Carolina), L. Kauffman (Univ. of Ill., Chicago), M. L. Lapidus (Univ. of California, Riverside), Y. J. Lee (Cheng Kung Univ.), N. Obata (Nagoya Univ.), Y. M. Park (Yonsei Univ.), A. N. Sengupta (Louisiana State Univ.), D. A. Storvick (Univ. of Minnesota), L. Streit (Bielefeld and Lisbon), V. K. Tuan (Kuwait Univ.), A. Truman (Univ. of Wales-Swansea), I. S. Wee (Korea Univ.), J. C. Zambrini (Univ. of Lisbon), T. Zastawniak (Univ. of Hull).
Call for Papers: We invite submissions for 20-minute presentations on any aspect of Feynman integral and related topics. A one-page abstract typed in $\mathcal{A}_{\mathcal{M}}\mathcal{S}$-TEX or LaTeX must be received by June 11, 1999, to be considered for inclusion in the program.
Proceedings: The proceedings of the conference will be submitted for publication in the *J. of Korean Math. Soc.* The deadline for submitting a paper for the proceedings is July 14, 1999.
Social Program: Welcome reception, two social dinners, and an excursion. A guided half-day tour will be organized. One-day (or half-day) optional tour (July 15) will be arranged.
Information: K. S. Chang, Dept. of Mathematics, Yonsei Univ., Seoul, 120-749, Korea; fax: 82-2-392-6634; e-mail: kunchang@bubble.yonsei.ac.kr.

*12-15 **On-Line Decision Making**, Rutgers University, Busch Student Center, Piscataway, New Jersey.

Organizers: Y. Freund, AT&T Labs-Research, R. Vohra, Northwestern Univ.
Local Arrangements: P. Pravato, DIMACS Center, pravato@dimacs.rutgers.edu, tel: 732-445-5929.
Focus: In recent years there has been increasing interest in the analysis of algorithms for making repeated decisions within an unknown environment. This work is going on in a variety of fields, including: information theory, game theory and mathematical economics, machine learning, statistics, computer science, and behavioral science. To facilitate such collaborations, we are organizing this workshop as an opportunity for people from various fields to educate themselves about the work going on in other fields.
Information: Y. Freund, AT&T Labs-Research, e-mail: yoav@research.att.com; WWW: http://dimacs.rutgers.edu/Workshops/index.html.

* 12-17 **Workshop on "Model Theory and Permutation Groups"**, University of Trento, Italy.
Aim: In recent years infinite permutation groups have been the subject of intensive investigation. An interesting aspect of this area is the interplay between algebra and model theory. Aim of the workshop is to provide an introduction to this subject and to address open problems and possible new developments.
Speakers: D. Evans (Univ. of East Anglia, Norwich, UK), D. Macpherson (Univ. of Leeds, UK), P. M. Neumann (Univ. of Oxford, UK).
Organizers: S. Baratella and O. Puglisi (Univ. of Trento).
Information: For information about travel and accomodation, please contact E. Nones, tel: +39-0461-881166; fax: +39-0461-881122; e-mail: enones@amm.unitn.it. Information about the scientific program can be obtained from the organizers, tel: +39-0461-881616; fax: +39-0461-881624; baratell@science.unitn.it, puglisi@science.unitn.it.

* 13-22 **International Conference on Biomathematics-Bioinformatics and Applications of Functional Differential Difference Equations**, Akdeniz University, Antalya, Turkey.
Focus: The aim of the conference is to stimulate collaboration between mathematicians and bioscientists and to act as a forum for the exchange of recent research results and new perspectives in those fields. In addition, the conference is devoted to a rapidly growing interdisciplinary domain of science where experimental biology and medicine, biochemistry, functional differential and difference equations, stochastic functional differential equations and stochastic processing, functional analysis, evolution equations, operator theory, computational mathematics, and various fields of technology all come together.
Topics: The conference will cover the theory of difference and differential equations with applications to related disciplines within biology and medicine, including immunology, epidemiology, evolution, population dynamics and ecology, molecular biology, cell signaling, tumor growth and treatment, metabolic modeling, neuromodeling, computational biology, cardiovascular modeling, and biomechanics. In addition, special sessions will be organized around focused topics that are particularly new or rapidly gaining importance. Titles of the planned parallel sessions: Theory of Differential Difference Equations; Discrete and Dynamical Modeling; Cell and Molecular Biology; Ecology and Evolutionary Dynamics; Neural Networks and Applications; Epidemiology and Theory of Epidemics.
Organizers: Z. Agur, O. Arino, J. Cushing, O. Diekmann, S. Elaydi, K. Gopalsamy, G. Ladas, E. Litsyn, M. C. Mackey, G. Webb, H. Yoshiyuki.
Local Organizing Committee: H. Akca, B. Attili, L. Berezansky, L. Byszewski, B. Ciplak, V. Covachev, K. Fiskin, E. Galperin, H. Parnas, Z. Taib.
Information: H. Akca, King Fahd University of Petroleum and Minerals, Mathematical Sciences Department, P. O. Box 1071, Dhahran 31261, Saudi Arabia; e-mail: akca@kfupm.edu.sa, or ciplak@pascal.sci.akdeniz.edu.tr, or fiskin@pascal.sci.akdeniz.edu.tr.

* 19-23 **Statistical Inference from Genetic Data on Pedigrees**, Houghton, Michigan.
Organizers: J. Dong (Michigan Technological Univ.), e-mail: jdong@mtu.edu, tel: 906-482-3177; A. Godbole (Michigan Tech.).
Topics: E. A. Thompson will deliver ten lectures in a most dynamic area of mathematical activity—one that lies at the confluence of the fields of statistics, probability, molecular biology, and genetics.
Funding: This is an NSF/CBMS Regional Conference in the Mathematical Sciences supported by NSF and Michigan Technological University. Travel and subsistence support will be available for about thirty participants.
Information: http://www.math.mtu.edu/~jdong/CBMS.html.

* 19-24 **CT99 - International Category Theory Meeting**, University of Coimbra, Coimbra, Portugal.
Invited Speakers: S. Awodey (Carnegie Mellon Univ.), M. Batanin (Macquarie Univ., Australia), C. Butz (McGill Univ., Canada), M. P. Carrasco (Univ. Granada, Spain), J. Funk (UBC, Canada), S. Mac Lane (Univ. Chicago), I. Moerdijk (Univ. Utrecht, Netherlands), J. Rosicky (Masaryk Univ., Czech Republic), S. Schanuel (SUNY at Buffalo), E. Vitale (Univ. Louvain-la-Neuve, Belgium).
Call for Papers: Contributed talks of 30 minutes in length in all areas of category theory and applications are invited.
Scientific Committee: J. Adàmek (Tech. Univ. Braunschweig, Germany), B. Banaschewski (McMaster Univ., Canada), P. T. Johnstone (Univ. of Cambridge, UK), A. Joyal (Univ. Québec, Montréal, Canada), F. W. Lawvere (SUNY at Buffalo), D. Scott (Carnegie Mellon Univ.), R. Street (Macquarie Univ., Australia), W. Tholen (York Univ., Canada).
Organizing Committee: M. M. Clementino, G. Gutierres, J. Picado, M. Sobral, L. Sousa.
Satellite Event: School on Category Theory and Applications, University of Coimbra, Portugal, July 13-17, 1999; http://www.mat.uc.pt/~scta/; e-mail: scta@mat.uc.pt.
Information: For detailed information visit the conference Web page http://www.mat.uc.pt/~ct99/, or send e-mail to ct99@mat.uc.pt.

* 19-30 **Symmetries and the Moment Mapping**, CIRM (Marseille-Luminy), France.
Aim: Summer school aimed at doctoral students and young researchers in mathematics or theoretical physics.
Program: Six minicourses plus a number of research talks.
Main Lecturers: M. Audin, P. Iglesias, L. Jeffrey, A. Kirillov, R. Palais, E. Prato.
Organizers: P. Iglesias (Université de Provence, France) and E. Prato (Université de Nice, France).
Information: http://math.unice.fr/~elisa/sam/sam.html; http://www.cmi.univ-mrs.fr/sam/sam.html.

August 1999

* 2-4 **Workshop on the Theory and Practice of Integer Programming in Honor of Ralph E. Gomory on the Occasion of His 70th Birthday**, IBM Watson Research Center, Yorktown Heights, New York.
Sponsors: DIMACS Center, IBM Watson Research Center.
Organizers: W. Cook (Rice Univ.), W. Pulleyblank (IBM Watson Research Center).
Focus: The focus of the workshop will be on integer linear programming. Integer programming underlies much of modern OR, including scheduling, logistics, resource allocation, and routing problems. It is also the subject of much theoretical and computational research, leading to software much more powerful than a few years ago but still unable to deal with real-world problems of the required size and complexity.
Information: W. Cook, Rice Univ., e-mail: bico@caam.rice.edu. Local arrangements: P. Pravato, DIMACS Center; e-mail: pravato@dimacs.rutgers.edu; tel: 732-445-5929; WWW: http://dimacs.rutgers.edu/Workshops/index.html.

* 19-25 **Topology and Dynamics: Rokhlin Memorial**, Euler International Mathematical Institute, St. Petersburg Mathematical Institute of Russian Academy of Science, St. Petersburg, Russia.
Focus: The conference is devoted to the memory of prominent mathematician V. A. Rokhlin (1919-1984).
Topics: The main subjects of the conference are: algebraic and differential topology; al-

gebraic, real algebraic, and Riemannian geometry; smooth and symplectic dynamics, ergodic theory; applications.

Organizers: St. Petersburg State Univ., St. Petersburg Mathematical Institute of Russian Academy of Science, St. Petersburg Mathematical Society, and Euler International Mathematical Institute.

Program Committee: A. D. Alexandrov (St. Petersburg), V. Arnol'd (Moscow, Paris), M. Gromov (Paris), F. Hirzebruch (Bonn), S. Novikov (Moscow, Maryland), Ya. Sinai (Moscow, Princeton), S. Smale (Berkeley), V. Turaev (Strasburg), A. Vershik (St. Petersburg, chairman), O. Viro (St. Petersburg, Uppsala).

Local Organizers: N. Netsvetaev, A. Vershik.

Proceedings: One-hour talks and short communications (25 minutes) are planned. The proceedings of the conference will be published. Deadline for submission of talks: April 1, 1999.

Support: Support from RFBR (Russia) and Intas (EC) is expected.

Information: M. Zvagel'skii, 191011 Steklov Inst. of Math. (POMI), nab. reki Fontanka, 27, St. Petersburg, Russia; e-mail: `rokhlin@euler.pdmi.ras.ru`; `http://www.pdmi.ras.ru/EIMI/1999/rokhlin/`.

* 27-29 **GAMM-Workshop on Computational Plasticity**, Christian-Albrechts-University of Kiel, Germany.

Organizers: M. Brokate (Kiel), C. Carstensen (Kiel), B. D. Reddy (Cape Town).

Aim: The aim of the workshop is to provide a forum to discuss and present aspects of the state of the art of the mathematical foundations of computational plasticity.

Topics: Topics range from the mathematical theory of continuum models in plasticity to the well-posedness of boundary and of initial-boundary value problems and their efficient discretization, including algorithmic aspects in solution procedures. Topics of interest include, but are not restricted to, the following: Mathematical analysis of (visco-)plasticity, well-posedness of (perfectly) plastic problems, numerical analysis of variational inequalities, computational (visco-)plasticity, numerical analysis of localization, a priori error analysis, a posteriori error analysis, adaptive algorithms for spatial and time-step discretization, coarsening and special adaptive strategies.

Participation: Everybody interested in the topics of the symposium is warmly invited to attend. Please let us know about your intention to participate a.s.a.p. A second announcement with further information, in particular, concerning hotel accommodations, will be distributed in March 1999.

Call for Papers: Participants wanting to give a talk (20 min.) should submit an abstract before June 15, 1999. Notification of acceptance will be given in July 1999.

Information: All correspondence in connection with the workshop, including registration and submission of abstracts, is to be made via e-mail to: `jva@numerik.uni-kiel.de`. Visit the home page at `http://www.numerik.uni-kiel.de/cc/work99.html`, where more information on hotel reservations and a registration form are available.

September 1999

* 1-3 **Symposium on Operations Research 1999 (SOR'99)**, Magdeburg, Germany.

Organizer: German Operations Research Society (GOR).

Focus: All areas of operations research will be covered at this conference.

Deadline: Submission of papers (by e-mail): March 15, 1999.

Information: G. Schwödiauer (general chair), Univ. of Magdeburg, Faculty of Economics and Management, P. O. Box 41 20, D-39016 Magdeburg, Germany; tel: ++49-391-6718739; fax: ++49-391-6711136; e-mail: `schwoediauer@wiwi.uni-magdeburg.de`; WWW: `http://www.uni-magdeburg.de/SOR99/`.

* 23-24 **IMA Tutorial: Low-Speed Combustion**, IMA, University of Minnesota, Minneapolis, Minnesota.

Organizers: J. D. Buckmaster (Univ. of Illinois, Urbana), M. Matalon (Northwestern Univ.).

Focus: This tutorial will serve as an introduction to the topics of the "Low-Speed Combustion" and "Fires" workshops.

Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/fall/t1.html`.

* 27-October 1 **IMA Workshop: Low-Speed Combustion**, IMA, University of Minnesota, Minneapolis, Minnesota.

Organizers: J. D. Buckmaster (Univ. of Illinois, Urbana), M. Matalon (Northwestern Univ.).

Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/fall/rf1.html`.

October 1999

* 4-8 **International Workshop on General Topological Algebras**, Tartu, Estonia.

Organizers: The Estonian Academy of Sciences, the Estonian Mathematical Society, and the University of Tartu.

Program Committee: M. Abel (Univ. of Tartu, Estonia), M. Akkar (Univ. of Bordeaux I, France), G. Allan (Univ. of Cambridge, UK), M. Fragoulopoulou (Univ. of Athens, Greece), A. Helemskii (Moscow State Univ., Russia), A. Mallios (Univ. of Athens, Greece), and W. Zelazko (Polish Academy of Sciences, Poland).

Topics: Locally convex and more general topological algebras, nonassociative topological algebras, topologization of algebras, application of results of topological algebras.

Information: For more detailed information please contact M. Abel, 46 Vanemuise St., Room 232, Institute of Pure Mathematics, University of Tartu, 51014 Tartu, Estonia; e-mail: `abel@math.ut.ee`; fax: 372-7-375-862.

* 11-13 **IMA Workshop: Fires**, IMA, University of Minnesota, Minneapolis, Minnesota.

Organizers: H. Baum (NIST), R. Rehm (NIST).

Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/fall/rf2.html`.

* 14-15 **IMA Minisymposium: Mathematical and Computational Strategies for Simplifying Complex Kinetics**, IMA, University of Minnesota, Minneapolis, Minnesota.

Organizers: J. D. Buckmaster (Univ. of Illinois, Urbana), another organizer to be determined.

Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/fall/ms1.html`.

* 22-24 **IMA "Hot Topics" Workshop: Scaling Phenomena in Communication Networks**, IMA, University of Minnesota, Minneapolis, Minnesota.

Sponsors: DIMACS Center; IMA, Univ. of Minnesota.

Organizers: A. Erramilli (Bellcore Research/Netmetrix Inc.), V. Paxson (Lawrence Berkeley National Laboratory), I. Saniee (Lucent Technologies), W. Willinger (AT&T-Labs Research).

Focus: This workshop will be structured around three fundamental aspects of the study of scaling phenomena in networks: description, analysis, and control. Participants are asked to contribute to this effort by giving a talk and/or actively engaging in the proceedings. This area shows great potential to apply the theory to analyze and control complex, large-scale networks such as the Internet. It is expected this workshop will advance the study of scaling phenomena in networks from a descriptive theory to a prescriptive reality. Presented under the auspices of the Special Year on Networks.

Information: Contact I. Saniee, Lucent Technologies, e-mail: `iis@research.bell-labs.com`; Web page: `http://dimacs.rutgers.edu/Workshops/index.html` or `http://www.ima.umn.edu/reactive/fall/networks.html`.

November 1999

* 5 **IMA Tutorial: High-Speed Combustion**, IMA, University of Minnesota, Minneapolis,

Minnesota.
Organizer: A. Kapila (Renssaelaer Polytechnic Institute).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/fall/t2.html`.

* 8-12 **IMA Workshop: High-Speed Combustion in Gaseous and Condensed-Phase Energetic Materials**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: A. Kapila (Rensselaer Polytechnic Institute), D. S. Stewart (Univ. of Illinois, Urbana).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/fall/rf4.html`.

January 2000

* 26-30 **IMA Workshop: Confinement and Remediation of Environmental Hazards**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: J. Chadam (Univ. of Pittsburgh), A. C. Cunningham (Montana State Univ.), R. Ewing (Texas A&M Univ.).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/winter/rf5.html`.

February 2000

* 9-13 **IMA Workshop: Resource Recovery**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: J. Chadam (Univ. of Pittsburgh), P. Ortoleva (Indiana Univ.), M. Wheeler (Univ. of Texas, Austin).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/winter/rf6.html`.

March 2000

* 15-19 **IMA Workshop: Air Quality Engineering**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: G. Carmichael (Univ. of Iowa), D. Chock (Ford Motor Company).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/winter/rf7.html`.

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 2000

* 16-19 **FRACTAL 2000: "Complexity and Fractals in the Sciences", 6th International Multidisciplinary Conference**, Singapore.
Information: `http://www.kingston.ac.uk/fractal/`.

May 2000

* 1-5 **IMA Workshop: Dispersive Corrections to Transport Equations**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: N. B. Abdallah (Univ. of Toulouse), A. Arnold (Berlin Technical Univ.), C. D. Levermore (Univ. of Arizona), K. T.-R. McLaughlin (Univ. of Arizona).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/spring/rf8.html`.

* 18-19 **IMA Tutorial: Simulation of Transport in Transition Regimes**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizer: I. Gamba (University of Texas, Austin).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/spring/t3.html`.

* 21-26 **Millennial Conference on Number Theory**, University of Illinois, Urbana, Illinois.
Focus: The Millennial Conference on Number Theory, held in conjunction with a Special Year in Number Theory at the Univ. of Illinois, is an international meeting on all areas of number theory. The conference will feature 19 one-hour plenary talks, invited talks of shorter length, and contributed talks.
Speakers: G. Andrews, J. Coates, H. Darmon, K. Ford, R. Graham, A. Granville, D. R. Heath-Brown, C. Hooley, W.-C. Li, K. Murty, M. Nathanson, K. Ono, C. Pomerance, W. Schmidt, C. Skinner, K. Soundararajan, R. Taylor, R. Tijdeman, R. C. Vaughan.
Organizing Committee: B. C. Berndt, N. Boston, H. G. Diamond, A. J. Hildebrand, W. Philipp.
Information: The conference Web page is `http://www.math.uiuc.edu/nt2000/millennial.html`. Additional information will be posted on this Web page as it becomes available.

* 22-26 **IMA Workshop: Simulation of Transport in Transition Regimes**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: P. Degond (Toulouse), I. Gamba (Univ. of Texas, Austin), R. Glassey (Indiana Univ.), P. Roe (Univ. of Michigan).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/spring/rf9.html`.

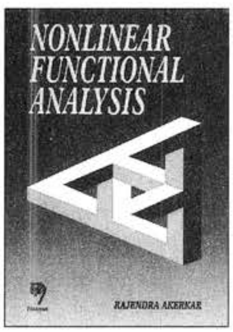
June 2000

* 5-9 **IMA Workshop: Multiscale Models for Surface Evolution and Reacting Flows**, IMA, University of Minnesota, Minneapolis, Minnesota.
Organizers: L. Borucki (Motorola), C. Ringhofer (Arizona State Univ.).
Information: Institute for Mathematics and its Applications, Univ. of Minnesota, 207 Church St. SE, 400 Lind Hall, Minneapolis, MN 55455; tel: 612-624-6066; e-mail: `staff@ima.umn.edu`; Web page: `http://www.ima.umn.edu/reactive/spring/rf10.html`.

New Publications Offered by the AMS

Analysis

Supplementary Reading



Nonlinear Functional Analysis

Rajendra Akerkar, *Chh. Shahu Central Institute of Business Education and Research, Kolhapur, India*

A publication of Narosa Publishing House.

This book presents background for the solution of nonlinear equations in Banach spaces. It contains basic techniques in nonlinear analysis and also touches upon today's research. The book deals with recent topics, such as measures on non-compactness, topological degree, and bifurcation theory. It can be used as a text and as a reference source for students and researchers.

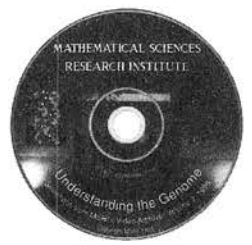
Distributed by the AMS exclusively in North America and Europe and non-exclusively elsewhere.

Contents: Contraction; Differential calculus in Banach spaces; Newton's method; The implicit function theorem; Fixed point theorems; Set contractions and Darbo's fixed point theorem; The topological degree; Bifurcation theory; Exercises and hints; References; Index.

Narosa Publishing House

January 1999, 157 pages, Softcover, ISBN 81-7319-230-8, 1991 *Mathematics Subject Classification*: 46-01, **All AMS members $22**, List $27, Order code NAR/4N

Applications



Understanding the Genome: Technological and Mathematical Challenges, May 21–23, 1998

Hugo Rossi and **David Hoffman**, *Mathematical Sciences Research Institute, Berkeley, CA*

A publication of MSRI.

This CD-ROM presents on video the workshop held at MSRI (Berkeley, CA) for mathematical scientists and scientists in the biotech/pharmaceutical industry. The purpose of the workshop was to acquaint the audience with the contributions made by mathematics, statistics and computation to the acquisition and interpretation of genomic data and related areas of functional genomics. Invited speakers gave surveys of the challenges ahead, descriptions of key new technological developments, applications of mathematics and computation to specific related problems in genomics, and analysis of biological systems at the cellular level. Organizing Committee: Peter Bickel, University of California (Berkeley); Richard Karp, University of Washington (Seattle); Jill Mesirov, Whitehead Institute (Cambridge, MA); Michael Waterman, University of Southern California (Los Angeles).

The CD requires Real™Video Player, which can be downloaded for free from the RealNetworks Internet home page. RealVideo Player is available for Windows95/Windows NT, Windows 3.1, MacOS, IRIX 6.2/6.3, Solaris 2.5 and Linux 2.0.

®RealVideo is a registered trademark and RealNetworks is a trademark of RealNetworks, Inc.

Distributed worldwide by the American Mathematical Society.

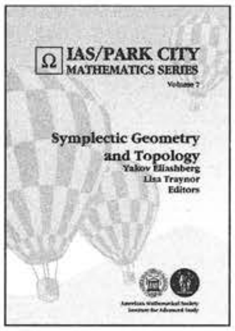
Contents: D. Botstein, Of genes and genomes; **E. Branscomb**, Comparative genomics: What, why, problems and challenges; **P. Green**, Genome sequence assembly; **D. Haussler**, Using hidden Markov models for biosequence analysis: Recent tests and new methods; **L. Hood**, Future mathematical challenges posed by the systems analysis of genomes and proteomes; **P. Pevzner**, Gene hunting without genomic sequencing: the twenty questions game with genes; **D. Siegmund**, Statistical aspects of gene mapping; **D. Slonim**, Mining gene expression data; **G. Stormo**, Uncovering regulatory networks using pattern recognition algorithms; **E. Wijsman**, Statistical and computational contributions to gene mapping: History and current developments.

Selections From MSRI's Video Archive

December 1998, CD-ROM, 1991 *Mathematics Subject Classification*: 92Dxx, List $15, Order code MSRICD/3N

Geometry and Topology

Supplementary Reading



Symplectic Geometry and Topology

Yakov Eliashberg, *Stanford University, CA*, and **Lisa Traynor**, *Bryn Mawr University, PA*, Editors

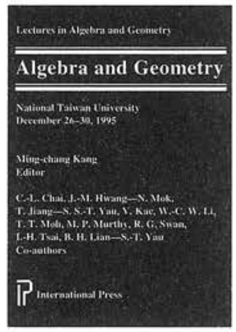
Symplectic geometry has its origins as a geometric language for classical mechanics. But it has recently exploded into an independent field interconnected with many other areas of mathematics and physics. The goal of the IAS/Park City Mathematics Institute Graduate Summer School on Symplectic Geometry and Topology was to give an intensive introduction to these exciting areas of current research. Included in this proceedings are lecture notes from the courses.

Members of the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM) receive a 20% discount from list price.

Contents: *D. McDuff, Introduction to Symplectic Topology:* Introduction; Basics; Moser's argument; The linear theory; The nonsqueezing theorem and capacities; Sketch proof of the nonsqueezing theorem; Bibliography; *H. Hofer, Holomorphic Curves and Dynamics in Dimension Three:* Problems, basic concepts and overview; Analytical tools; The Weinstein conjecture in the overtwisted case; The Weinstein conjecture in the tight case; Some outlook; Bibliography; *M. Hutchings and C. H. Taubes, An Introduction to the Seiberg-Witten Equations on Symplectic Manifolds:* Introduction; Background from differential geometry; Spin and the Seiberg-Witten equations; The Seiberg-Witten invariants; The symplectic case, part I; The symplectic case, part II; Bibliography; *D. Salamon, Lectures on Floer Homology:* Introduction; Symplectic fixed points and Morse theory; Fredholm theory; Floer homology; Gromov compactness and stable maps; Multi-valued perturbations; Bibliography; *A. Givental, A Tutorial on Quantum Cohomology:* Introduction; Moduli spaces of stable maps; Gromov-Witten invariants; $QH^*(G/B)$ and quantum Toda lattices; Singularity theory; Toda lattices and the mirror conjecture; Bibliography; *M. Grinberg and R. MacPherson, Euler Characteristics and Lagrangian Intersections:* Introduction; Lecture 1; Lecture 2; Lecture 3; Lecture 4; Lecture 5; Bibliography; *L. C. Jeffrey, Hamiltonian Group Actions and Symplectic Reduction:* Introduction to Hamiltonian group actions; The geometry of the moment map; Equivariant cohomology and the Cartan model; The Duistermaat-Heckman theorem and applications to the cohomology of symplectic quotients; Moduli spaces of vector bundles over Riemann surfaces; Exercises; Bibliography; *J. E. Marsden, Park City Lectures on Mechanics, Dynamics, and Symmetry:* Introduction; Reduction for mechanical systems with symmetry; Stability, underwater vehicle dynamics and phases; Systems with rolling constraints and locomotion; Optimal control and stabilization of balance systems; Variational integrators; Bibliography.

IAS/Park City Mathematics Series

May 1999, 431 pages, Hardcover, ISBN 0-8218-0838-9, LC 99-17909, 1991 *Mathematics Subject Classification*: 14-XX, 22-XX, 34-XX, 49-XX, 53-XX, 57-XX, 58-XX, 70-XX, **All AMS members $55**, List $69, Order code PCMS-ELIASHBERGN



Algebra and Geometry

Ming-chang Kang, *National Taiwan University, Taipei*, Editor

A publication of International Press.

This volume presents the proceedings from a conference held at the National Taiwan University. The conference brought together specialists in mathematical physics, algebraic geometry, differential geometry, algebra and number theory from five Pacific Rim countries. Included are articles by S.-T. Yau, V. Kac, M. P. Murthy, Shing-Tung Yau, and other leading specialists.

This item will also be of interest to those working in algebra and algebraic geometry and mathematical physics.

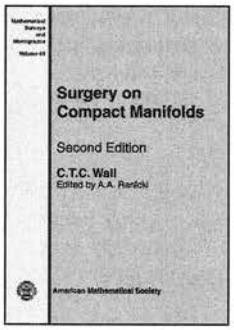
Distributed worldwide, except in Japan, by the American Mathematical Society.

Contents: C.-L. Chai, Linearity properties and Hecke orbits of Shimura varieties; **J.-M. Hwang** and **N. Mok**, Characterization and deformation-rigidity of compact irreducible Hermitian symmetric spaces of rank ≥ 2 among Fano manifolds; **T. Jiang** and **S. S.-T. Yau**, Explicit computation of cohomological algebra of complement of arrangement of hyperplanes in $\mathbb{C}^3$ and new geometric characterization of supersolvable arrangements; **V. Kac**, W-algebras and quantum hall effect; **W.-C. W. Li**, Geometry, graph theory and number theory; **T. T. Moh**, Jacobian conjecture; **M. P. Murthy**, Projective modules over affine algebras and efficient generation of modules; **R. G. Swan**, Néron-Popescu desingularization; **I.-H. Tsai**, Geometry of determinant line bundles associated with Riemann surfaces; **B. H. Lian** and **S.-T. Yau**, On mirror symmetry; **B. H. Lian** and **S.-T. Yau**, Integrality of certain exponential series.

International Press

August 1998, 227 pages, Hardcover, ISBN 1-57146-058-6, 1991 *Mathematics Subject Classification*: 00B25, **All AMS members $34**, List $42, Order code INPR/32N

A Classic



Surgery on Compact Manifolds

Second Edition

C. T. C. Wall, *University of Liverpool, England*, and **A. A. Ranicki (Editor)**, *University of Edinburgh, Scotland*

The publication of this book in 1970 marked the culmination of a particularly exciting period in the history of the topology of manifolds. The world of high-dimensional manifolds had been opened up to the classification methods of algebraic topology by Thom's work in 1952 on transversality and cobordism, the signature theorem of Hirzebruch in 1954, and by the discovery of exotic spheres by Milnor in 1956.

In the 1960s, there had been an explosive growth of interest in the surgery method of understanding the homotopy types of manifolds (initially in the differentiable category), including results such as the h-cobordism theory of Smale (1960), the classification of exotic spheres by Kervaire and Milnor (1962), Browder's converse to the Hirzebruch signature theorem for the existence of a manifold in a simply connected homotopy type (1962), the s-cobordism theorem of Barden, Mazur, and Stallings (1964), Novikov's proof of the topological invariance of the rational Pontrjagin classes of differentiable manifolds (1965), the fibering theorems of Browder and Levine (1966) and Farrell (1967), Sullivan's exact sequence for the set of manifold structures within a simply connected homotopy type (1966), Casson and Sullivan's disproof of the Hauptvermutung for piecewise linear manifolds (1967), Wall's classification of homotopy tori (1969), and Kirby and Siebenmann's classification theory of topological manifolds (1970).

The original edition of the book fulfilled five purposes by providing:

- a coherent framework for relating the homotopy theory of manifolds to the algebraic theory of quadratic forms, unifying many of the previous results;
- a surgery obstruction theory for manifolds with arbitrary fundamental group, including the exact sequence for the set of manifold structures within a homotopy type, and many computations;
- the extension of surgery theory from the differentiable and piecewise linear categories to the topological category;
- a survey of most of the activity in surgery up to 1970;
- a setting for the subsequent development and applications of the surgery classification of manifolds.

This new edition of this classic book is supplemented by notes on subsequent developments. References have been updated and numerous commentaries have been added. The volume remains the single most important book on surgery theory.

Contents: *Preliminaries:* Note on conventions; Basic homotopy notions; Surgery below the middle dimension; Appendix: Applications; Simple Poincaré complexes; *The main theorem:* Statement of results; An important special case; The even-dimensional case; The odd-dimensional case; The bounded odd-dimensional case; The bounded even-dimensional case; Completion of the proof; *Patterns of application:* Manifold structures on Poincaré complexes; Applications to submanifolds; Submanifolds: Other techniques; Separating submanifolds; Two-sided submanifolds; One-sided submanifolds; *Calculations and applications:* Calculations: Surgery obstruction groups; Calculations: The surgery obstructions; Applications: Free actions on spheres; General remarks; An extension of the Atiyah-Singer G-signature theorem; Free actions of S^1; Fake projective spaces (real); Fake lens spaces; Applications: Free uniform actions on euclidean space; Fake tori; Polycyclic groups; Applications to 4-manifolds; *Postscript:* Further ideas and suggestions: Recent work; Function space methods; Topological manifolds; Poincaré embeddings; Homotopy and simple homotopy; Further calculations; Sullivan's results; Reformulations of the algebra; Rational surgery; References; Index.

Mathematical Surveys and Monographs, Volume 69

April 1999, 302 pages, Hardcover, ISBN 0-8218-0942-3, LC 99-12274, 1991 *Mathematics Subject Classification*: 57-02, 57R57; 18F25, 19J25, 11E39, **All AMS members $47**, List $59, Order code SURV/69N

Previously Announced Publications

Higher Category Theory

Ezra Getzler and **Mikhail Kapranov**, *Northwestern University, Evanston, IL*, Editors

This volume presents the proceedings of the workshop on higher category theory and mathematical physics held at Northwestern University. Exciting new developments were presented with the aim of making them better known outside the community of experts. In particular, presentations in the style, "Higher Categories for the Working Mathematician", were encouraged. The volume is the first to bring together developments in higher category theory with applications. This collection is a valuable introduction to this topic—one that holds great promise for future developments in mathematics.

Contributors include: **J. C. Baez, J. Dolan; M. A. Batanin; L. Breen; J.-L. Brylinski; R. Street; D. N. Yetter.**

Contemporary Mathematics, Volume 230

January 1999, 134 pages, Softcover, ISBN 0-8218-1056-1, LC 98-32266, 1991 *Mathematics Subject Classification*: 18-06, 18D05, 18G50, **Individual member $20**, List $34, Institutional member $27, Order code CONM/230RT94

Trends in the Representation Theory of Finite Dimensional Algebras

Edward L. Green, *Virginia Polytechnic Institute and State University, Blacksburg*, and **Birge Huisgen-Zimmermann**, *University of California, Santa Barbara*, Editors

This refereed collection of research papers and survey articles reflects the interplay of finite-dimensional algebras with other areas (algebraic geometry, homological algebra, and the theory of quantum groups). Current trends are presented from the discussions at the AMS-IMS-SIAM Joint Summer Research Conference at the University of Washington (Seattle).

The volume features several excellent expository articles which will introduce the beginning researcher to cutting-edge topics in representation theory. The book will also provide inspiration to researchers in related areas, as it includes original papers spanning a broad spectrum of representation theory.

Features:

- Work outlining significant progress on long-standing open problems.
- Survey articles offering both overviews and introductions to various subfields of the topic.
- Expositions reflecting the interplay between the representation theory of algebras and other fields.

Contributors include: **I. Assem, F. U. Coelho, M. Barot, H. Lenzing, F. M. Bleher, S. Brenner, M. C. R. Butler, K. A. Brown, R.-O. Buchweitz, J. A. de la Peña, P. Dräxler; R. Farnsteiner; M. Gerstenhaber, A. Giaquinto D. Happel, I. Reiten, L. Unger; Y. Iwanaga, J. Miyachi; M. Kauer; O. Kerner; H. Krause, M. Saorín; R. Martínez-Villa; S. Montgomery; C. Riedtmann; C. M. Ringel; D. Simson; A. Skowroński, G. Zwara.**

Contemporary Mathematics, Volume 229

January 1999, 356 pages, Softcover, ISBN 0-8218-0928-8, LC 98-44526, 1991 *Mathematics Subject Classification*: 14D15, 14L30, 16D30, 16D60, 16E10, 16E30, 16E40, 16G10, 16G20, 16G30, 16G50, 16G60, 16G70, 16P10, 16P20, 16P40, 16S80, 16W30, 17B37, 81R50, **Individual member $45**, List $75, Institutional member $60, Order code CONM/229RT94

Symmetries and Conservation Laws for Differential Equations of Mathematical Physics

I. S. Krasil′shchik, *Moscow Institute for Municipal Economy, Russia*, and **A. M. Vinogradov**, *University of Salerno, Italy*, Editors

This book presents developments in the geometric approach to nonlinear partial differential equations (PDEs). The expositions discuss the main features of the approach, and the theory of symmetries and the conservation laws based on it. The book combines rigorous mathematics with concrete examples. Nontraditional topics, such as the theory of nonlocal symmetries and cohomological theory of conservation laws, are also included.

The volume is largely self-contained and includes detailed motivations, extensive examples and exercises, and careful proofs of all results. Readers interested in learning the basics of applications of symmetry methods to differential equations of mathematical physics will find the text useful. Experts will also find it useful as it gathers many results previously only available in journals.

Translations of Mathematical Monographs, Volume 182

February 1999, 333 pages, Hardcover, ISBN 0-8218-0958-X, LC 98-53018, 1991 *Mathematics Subject Classification*: 35A30, 58F07; 58F05, 58G05, **Individual member $77**, List $129, Institutional member $103, Order code MMONO/182RT94

Proceedings of the International Congress of Mathematicians, Berlin 1998

Gerd Fischer, *University of Dusseldorf, Germany*, and **Ulf Rehmann**, *University of Bielefeld, Germany*, Editors

A publication of DOCUMENTA MATHEMATICA.

Each International Congress brings together mathematicians from all over the world to discuss recent developments in all areas of mathematics. It is one of the most exciting gatherings of mathematicians. The 1998 Congress in Berlin was no exception.

The invited speakers at the ICM have been recognized by their colleagues as important leaders in their fields, with their work representing some of the most significant recent research in mathematics. The twenty-one plenary speakers are asked to address the whole congress on recent results and trends that are shaping mathematics today. All plenary and invited lectures are published in these proceedings.

The announcement of the Fields Medalists and the Nevanlinna Prize Winner is a particular highlight of each International Congress. Volume I of the proceedings includes a short description of their work and the text of the lectures presented by the Medalists and Prize Winner at the Congress. This year, the Fields Medal Committee also paid special tribute to Andrew Wiles for his proof of Fermat's Last Theorem.

The *Proceedings of an International Congress of Mathematicians* provides a snapshot of mathematics at a given time. The articles for ICM '98 are guideposts to the significant developments in mathematical research at the end of the millenium.

Members of the DMV (Deutschen Mathematiker-Vereinigung) may order at the AMS member price.

Contributors include: **J.-M. Bismut, C. Deninger, P. Diaconis, G. Gallavotti, W. Hackbusch, H. H. W. Hofer, E. Hrushovski, I. G. Macdonald, S. Mallat, D. McDuff, T. Miwa, J. Moser, G. Papanicolaou, G. Pisier, P. Sarnak, P. W. Shor, K. Sigmund, M. Talagrand, C. Vafa, M. Viana, V. Voevodsky, M. Safonov, A. J. Wilkie.**

December 1998, 2374 pages, Hardcover, 1991 *Mathematics Subject Classification*: 00, **Individual member $105**, List $140, Order code PICM/98RT94

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Dr. Vincent J. Ervin, Acting Chair
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*The annual dues for **reciprocity members** who reside outside the U.S. and Canada are $66. To be eligible for this classification, members must belong to one of those foreign societies with which the AMS has established a reciprocity agreement, and annual verification is required. Reciprocity members who reside in the U.S. or Canada must pay ordinary member dues ($99 or $132).*

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*Members can purchase a **multi-year membership** by prepaying their current dues rate for either two, three, four or five years. This option is not available to category-S, unemployed, or student members.*

1999 Dues Schedule (January through December)

Introductory ordinary member rate .... ☐ $50

Ordinary member .... ☐ $99 ☐ $132

CMS cooperative rate .... ☐ $84 ☐ $112

Joint family member (full rate) .... ☐ $99 ☐ $132

Joint family member (reduced rate) .... ☐ $79 ☐ $112

Contributing member (minimum $192) .... ☐

Student member (please verify)[1] .... ☐ $33

Unemployed member (please verify)[2] .... ☐ $33

Reciprocity member (please verify)[3] .... ☐ $66 ☐ $99 ☐ $132

Category-S member[4] .... ☐ $16

Multi-year membership .... $....... for .... years

[1] ***Student Verification*** (sign below)

I am a full-time student at ....

.... *currently working toward a degree.*

[2] ***Unemployed Verification*** (sign below) *I am currently unemployed and actively seeking employment.*

[3] ***Reciprocity Membership Verification*** (sign below) *I am currently a member of the society indicated on the right and am therefore eligible for reciprocity membership.*

....

Signature

[4] ☐ ***send*** **NOTICES** ☐ ***send*** **BULLETIN**

Reciprocating Societies

- ☐ Allahabad Mathematical Society
- ☐ Australian Mathematical Society
- ☐ Azerbaijan Mathematical Society
- ☐ Balkan Society of Geometers
- ☐ Berliner Mathematische Gessellschaft e.V.
- ☐ Calcutta Mathematical Society
- ☐ Croatian Mathematical Society
- ☐ Cyprus Mathematical Society
- ☐ Dansk Matematisk Forening
- ☐ Deutsche Mathematiker-Vereinigung e.V.
- ☐ Edinburgh Mathematical Society
- ☐ Egyptian Mathematical Society
- ☐ Gesellschaft für Angewandte Mathematik und Mechanik
- ☐ Glasgow Mathematical Association
- ☐ Hellenic Mathematical Society
- ☐ Icelandic Mathematical Society
- ☐ Indian Mathematical Society
- ☐ Iranian Mathematical Society
- ☐ Irish Mathematical Society
- ☐ Israel Mathematical Union
- ☐ János Bolyai Mathematical Society
- ☐ The Korean Mathematical Society
- ☐ London Mathematical Society
- ☐ Malaysian Mathematical Society
- ☐ Mathematical Society of Japan
- ☐ Mathematical Society of Serbia
- ☐ Mathematical Society of the Philippines
- ☐ Mathematical Society of the Republic of China
- ☐ Mongolian Mathematical Society
- ☐ Nepal Mathematical Society
- ☐ New Zealand Mathematical Society
- ☐ Nigerian Mathematical Society
- ☐ Norsk Matematisk Forening
- ☐ Österreichische Mathematische Gesellschaft
- ☐ Palestine Society for Mathematical Sciences
- ☐ Polskie Towarzystwo Matematyczne
- ☐ Punjab Mathematical Society
- ☐ Ramanujan Mathematical Society
- ☐ Real Sociedad Matemática Española
- ☐ Saudi Association for Mathematical Sciences
- ☐ Singapore Mathematical Society
- ☐ Sociedad Colombiana de Matemáticas
- ☐ Sociedad Española de Matemática Aplicada
- ☐ Sociedad de Matemática de Chile
- ☐ Sociedad Matemática de la Republica Dominicana
- ☐ Sociedad Matemática Mexicana
- ☐ Sociedad Uruguaya de Matemática y Estadística
- ☐ Sociedade Brasileira Matemática
- ☐ Sociedade Brasileira de Matemática Aplicada e Computacional
- ☐ Sociedade Paranaense de Matemática
- ☐ Sociedade Portuguesa de Matemática
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- ☐ Societatea de Ştiinţe Matematice din România
- ☐ Societatea Matematicienilor din Romania
- ☐ Société de Mathématiques Appliquées et Industrielles
- ☐ Société Mathématique de Belgique
- ☐ Société Mathématique de France
- ☐ Société Mathématique du Luxembourg
- ☐ Société Mathématique Suisse
- ☐ Society of Associations of Mathematicians & Computer Science of Macedonia
- ☐ Society of Mathematicians, Physicists, and Astronomers of Slovenia
- ☐ South African Mathematical Society
- ☐ Southeast Asian Mathematical Society
- ☐ Suomen Matemaattinen Yhdistys
- ☐ Svenska Matematikersamfundet
- ☐ Ukrainian Mathematical Society
- ☐ Union Mathemática Argentina
- ☐ Union of Bulgarian Mathematicians
- ☐ Union of Czech Mathematicians and Physicists
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- ☐ Unione Matematica Italiana
- ☐ Vijnana Parishad of India
- ☐ Wiskundig Genootschap

Change of Address

Members of the Society who move or change positions are urged to notify the Providence Office as soon as possible.

Journal mailing lists must be printed four to six weeks before the issue date. Therefore, in order to avoid disruption of service, members are requested to provide the required notice well in advance.

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.

If your address has changed or will change within the next two or three months, please fill out this form, supply any other information appropriate for the AMS records, and mail it to:

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Providence, RI 02940

or send the information on the form by e-mail to:

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Location of employer (city, state, zip code, country)

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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/`.

Gainesville, Florida

University of Florida

March 12–13, 1999

Meeting #940

Southeastern Section
Associate secretary: Robert J. Daverman
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: May 1999
Issue of *Abstracts*: Volume 20, Issue 2

Urbana, Illinois

University of Illinois, Urbana-Champaign

March 18–21, 1999

Meeting #941

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: January 1999
Program issue of *Notices*: May 1999
Issue of *Abstracts*: Volume 20, Issue 2

Invited Addresses

Alexander Beilinson, MIT, *Affine Grassmannians and the Bernstein center.*

Alexandra Bellow, Northwestern University, *Maximal functions revisited.*

Igor Krichever, Columbia University, *Discrete analogs of the Egoroff-Darboux metrics.*

Steven Rallis, Ohio State University, *Automorphic descent from GL(N) to classical groups.*

Trevor Wooley, University of Michigan, *Analytic methods count for diophantine problems.*

Special Sessions

Algebraic K-Theory (and the 5th Annual Great Lakes K-Theory Conference), **Daniel Grayson**, University of Illinois, Urbana.

Combinatorial Designs, **Ilene H. Morgan**, University of Missouri, Rolla, and **Walter D. Wallis**, Southern Illinois University, Carbondale.

Commutative Algebra, **Joseph Brennan**, North Dakota State University, and **Sankar Dutta**, **Robert Fossum**, and **Phillip Griffith**, University of Illinois, Urbana.

Diophantine Equations, Inequalities and Related Arithmetic Problems, **Michael Bennett**, University of Illinois, Urbana, and **Trevor Wooley**, University of Michigan.

Elementary and Analytic Number Theory, **Harold G. Diamond** and **A. J. Hildebrand**, University of Illinois, Urbana.

Galois Representations, **Nigel Boston**, University of Illinois, Urbana, and **Michael Larsen**, University of Missouri.

Graph Theory, **Douglas B. West**, University of Illinois, Urbana.

Holomorphic Vector Bundles and Complex Geometry, **Maarten Bergvelt**, **Steven Bradlow**, and **John P. D'Angelo**, University of Illinois, Urbana, and **Lawrence Ein**, University of Illinois, Chicago.

Integrable Equations, **Igor Krichever**, Columbia University, and **Kirill Vaninsky**, Kansas State University.

Low-Dimensional Topology, **Mark Brittenham**, University of North Texas, **Charles Delman**, Eastern Illinois University, and **Rachel Roberts**, Washington University.

Martingales and Analysis, **Joseph Max Rosenblatt**, **Renming Song**, and **Richard B. Sowers**, University of Illinois, Urbana.

Nonstandard Analysis, **C. Ward Henson** and **Peter Loeb**, University of Illinois, Urbana.

Operator Spaces and Their Applications, **Gilles Pisier**, Texas A&M University, and **Zhong-Jin Ruan**, University of Illinois, Urbana.

Optimization Problems in Geometry, **Robert Kusner**, University of Massachusetts, Amherst, and **John M. Sullivan**, University of Illinois, Urbana.

Recent Progress in Elementary Geometry, **John E. Wetzel**, University of Illinois, Urbana, and **Clark Kimberling**, University of Evansville.

Symplectic Geometry and Topology, **Eugene M. Lerman** and **Susan Tolman**, University of Illinois, Urbana.

Wavelet Analysis and Multiresolution Methods, **Tian-Xiao He**, Illinois Wesleyan University.

Las Vegas, Nevada

University of Nevada-Las Vegas

April 10-11, 1999

Meeting #942

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

Igor Frenkel, Yale University, *Representation theory and four-dimensional conformal field theory.*

Gregory J. Kuperberg, University of California, Davis, *Title to be announced.*

Lorenzo A. Sadun, University of Texas, Austin, *Title to be announced.*

John Steel, University of California, Berkeley, *Title to be announced.*

Special Sessions

Analysis and Geometry, **Peter Li** and **Song-Ying Li**, University of California, Irvine.

Combinatorial Theory, **Kequan Ding**, University of Illinois, Urbana, **Peter Shiue**, University of Nevada, Las Vegas, and **Yeong-Nan Yeh**, Academia Sinica.

Control and Dynamics of Partial Differential Equations, **Zhonghai Ding**, University of Nevada, Las Vegas.

Diophantine Problems, **Arthur Baragar**, University of Nevada, Las Vegas, and **Michael Bennett**, University of Illinois.

Geometric Group Theory, **Eric M. Freden**, Southern Utah University, and **Eric Lewis Swenson**, Brigham Young University.

Graph Theory, **Hung-Lin Fu**, National Chiao-Tung University-Taiwan, **Chris A. Rodger**, Auburn University, and **Michelle Schultz**, University of Nevada, Las Vegas.

Invariants, Distributions, Differential Operators and Harmonic Analysis, **Ronald L. Lipsman**, University of Maryland, College Park.

Nonlinear PDEs—Methods and Applications, **David Costa**, University of Nevada, Las Vegas.

Number Theory, **Gennady Bachman**, University of Nevada, Las Vegas, **Richard A. Mollin**, University of Calgary, and **Peter J. Shiue**, University of Nevada, Las Vegas.

Numerical Analysis and Computational Mathematics, **Jun Zhang**, University of Kentucky, and **Jennifer Zhao**, University of Michigan, Dearborn.

Set Theory, **Douglas Burke** and **Derrick DuBose**, University Nevada, Las Vegas.

Symmetries of Knots and Three-Manifolds, **Swatee Naik**, University of Nevada, Reno, and **Jozef H. Przytycki**, George Washington University.

Buffalo, New York

State University of New York at Buffalo

April 24-25, 1999

Meeting #943

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: Expired

Invited Addresses

Michele M. Audin, University of Louis Pasteur, *Integrable systems and spaces of curves.*

Russel Caflisch, University of California, Los Angeles, *Atomistic, continuum and bulk models for epitaxial growth.*

Jeffrey H. Smith, Purdue University, *Symmetric spectra.*

Alexander Voronov, Michigan State University, *Operad theory and some applications.*

Gregg J. Zuckerman, Yale University, *Harmonic algebra.*

Special Sessions

Combinatorics and Graph Theory, **Harris Kwong**, SUNY College at Fredonia.

Complex Geometry, **Terrence Napier**, Lehigh University, and **Mohan Ramachandran**, SUNY at Buffalo.

Integrable Systems, **Michéle Audin**, Université Louis Pasteur et NCRS, and **Lisa Claire Jeffrey**, University of Toronto.

Knot and 3-Manifolds, **Thang T.Q. Le**, SUNY at Buffalo, **William W. Menasco**, SUNY at Buffalo, and **Morwen B. Thistlethwaite**, University of Tennessee.

Mathematical Physics, **Jonathan Dimock**, SUNY at Buffalo.

Operads, Algebras, and Their Applications, **Alexander A. Voronov**, Michigan State University.

Representations of Lie Algebras, **Duncan J. Melville**, Saint Lawrence University.

Smooth Categories in Geometry and Mechanics, **F. William Lawvere**, SUNY at Buffalo.

Thin Films: Solid and Liquid, **E. Bruce Pitman**, SUNY at Buffalo, and **Brian Spencer**, SUNY at Buffalo.

Denton, Texas

University of North Texas

May 19–22, 1999

Meeting #944

Fourth International Joint Meeting of the AMS and the Sociedad Matemática Mexicana (SMM).
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: February 1999
Program issue of *Notices*: June/July 1999
Issue of *Abstracts*: Volume 20, Issue 3

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: Expired
For abstracts: March 24, 1999

Invited Addresses

Raymundo Bautista, UNAM, *Title to be announced.*

William Fulton, University of Michigan, Ann Arbor, *Title to be announced.*

Francisco Gonzalez Acuna, UNAM, *Title to be announced.*

Ronald L. Graham, AT&T Labs, *Title to be announced* (Erdős Memorial Lecture).

Jack K. Hale, Georgia Institute of Technology, *Title to be announced.*

Onesimo Hernandez-Lerma, CINVESTAV del IPN, *Title to be announced.*

Special Sessions

Algebraic Geometry and Commutative Algebra (Code: AMS SS F1), **Javier Elizondo**, UNAM, **Xavier Gomez-Mont**, CIMAT, **Alberto Corso**, Michigan State University, and **David A. Jorgensen**, University of Texas at Arlington.

Algebraic Topology (Code: AMS SS Q1), **Frederick R. Cohen** and **Samuel Gitler**, University of Rochester, and **Carlos Prieto**, UNAM.

Combinatorics and Combinatorial Geometry (Code: AMS SS N1), **Jorge Urrutia**, IMATE-UNAM and University of Ottawa, and **Wlodzimierz Kuperberg**, Auburn University.

Complex Analysis (Code: AMS SS R1), **E. Ramirez de Arellano**, CINVESTAV, and **John E. Fornaess**, University of Michigan, Ann Arbor.

Continuum Theory (Code: AMS SS D1), **Wayne Lewis**, Texas Tech University, and **Sergio Macias** and **Alejandro Illanes**, UNAM.

Differential Equations, Nonlinear Analysis, and Numerical Solutions to PDEs. (Code: AMS SS E1), **John W. Neuberger**, University of North Texas, and **Alfredo C. Nicolas**, UAM.

Differential Geometry and Geodesics (Code: AMS SS S1), **Phillip E. Parker**, Wichita State University, and **Lilia Del Riego**, Univ Auto de San Luis Potosi.

Functional Analysis and Its Applications (Code: AMS SS C1), **S. Perez-Esteva**, UNAM, and **Josefina Alvarez**, University of New Mexico.

Geometric and Symbolic Dynamical Systems (Code: AMS SS G1), **Luca Q. Zamboni**, University of North Texas, and **Edgardo Ugalde**, University of San Luis Potosi.

Low Dimensional Topology (Code: AMS SS H1), **Mark W. Brittenham**, University of North Texas, **Francisco Gonzalez Acuna**, IM-UNAM, and **Luis Valdez-Sanchez**, University of Texas at El Paso.

Noncommutative Geometry, Quantum Groups, and Applications (Code: AMS SS L1), **Micho Durdevich**, UNAM, and **Hanna Ewa Makaruk** and **Robert M. Owczarek**, Los Alamos National Laboratory.

Nonlinear Models in Biology and Celestial Mechanics (Code: AMS SS M1), **Ernesto Perez-Chavela** and **Jorge X. Velasco-Hernandez**, UAM, **Mary E. Parrott**, University of South Florida, and **Ernesto A. Lacomba**, UAM.

Representation Theory of Algebras (Code: AMS SS A1), **Jose A. de la Pena** and **Christof Geiss**, UNAM, and **Birge Zimmerman**, University of California, Berkeley.

Ring Theory (Code: AMS SS K1), **Carlos Signoret-Poillon**, UNAM-UAM, **Sergio Lopez-Permouth**, Ohio University, and **Ricardo Alfaro**, University of Michigan-Flint.

Smooth Dynamical Systems (Code: AMS SS P1), **David A. Delatte** and **Dan Mauldin**, University of North Texas, **Jose Seade**, UNAM, **Mariusz Urbanski**, University of North Texas, and **Alberto Verjovsky**, UNAM.

Stochastic Processes (Code: AMS SS J1), **Frederi G. Viens**, University of North Texas, **Jorge A. Leon**, CINVESTAV, and **Juan Ruiz de Chavez**, UAM.

Stochastic Systems and Control (Code: AMS SS B1), **Daniel Hernandez-Hernandez** and **Onesimo Hernandez-Lerma**, CINVESTAV, and **Guillermo Ferrayra**, Louisiana State University.

Melbourne, Australia

Melbourne, Australia

July 12-16, 1999

Meeting #945

First International Joint Meeting of the American Mathematical Society and the Australian Mathematical Society
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: April 1999
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: April 2, 1999

Invited Addresses

Jennifer Chayes, Microsoft, *Title to be announced.*

Michael Eastwood, University of Adelaide, *Title to be announced.*

Roger Grimshaw, Monash University, *Title to be announced.*

Gerhard Huisken, University of Tuebingen, *Title to be announced.*

Vaughan Jones, University of California, Berkeley, *Title to be announced.*

Hyam Rubinstein, Melbourne University, *Title to be announced.*

Richard M. Schoen, Stanford University, *Title to be announced.*

Neil Trudinger, Australian National University, *Title to be announced.*

Special Sessions

Algebraic Groups and Related Topics (Code: AMS SS M1), **Eric Friedlander**, Northwestern University, and **Gustav Lehrer**, University of Sydney.

Computability and Complexity (Code: AMS SS R1), **Rod Downey**, Victoria University.

Differential Geometry and Partial Differential Equations (Code: AMS SS N1), **Benjamin H. Andrews**, Australian National University, **Michael G. Eastwood**, University of Adelaide, **Klaus Ecker**, Monash University, and **Gerhard Huisken**, Princeton University and University of Tuebingen.

Fluid Dynamics (Code: AMS SS C1), **Susan Friedlander**, Northwestern University, and **Roger H. J. Grimshaw**, Monash University.

General Relativity (Code: AMS SS Q1), **Robert Bartnik**, University of Canberra, **Gregory Galloway**, University of Miami, and **Anthony Lun**, Monash University.

Geometric Group Theory (Code: AMS SS K1), **Swarup Gadde** and **Walter Neumann**, University of Melbourne.

Geometric Themes in Group Theory (Code: AMS SS A1), **Gustav I. Lehrer**, University of Sydney, **Cheryl E. Praeger**, University of Western Australia, and **Stephen D. Smith**, University of Illinois at Chicago.

Group Actions (Code: AMS SS H1), **Marston Conder**, **Gaven Martin**, and **Eamonn O'Brien**, University of Auckland.

Low Dimensional Topology (Code: AMS SS D1), **William H. Jaco**, Oklahoma State University, and **Hyam Rubinstein**, Melbourne University.

Mathematical Physics: Many Body Systems (Code: AMS SS B1), **Alan L. Carey**, University of Adelaide, **Paul A. Pearce**, University of Melbourne, and **Mary Beth Ruskai**, University of Massachusetts, Lowell.

Mathematics Learning Centers (Code: AMS SS G1), **Judith Baxter**, University of Illinois, Chicago, **Marian Kemp**, Murdoch University, **Jackie Nicholas**, University of Sidney, and **Jeanne Wald**, Michigan State University.

Moduli Spaces of Riemann Surfaces, Mapping Class Groups and Invariants of 3-Manifolds (Code: AMS SS F1), **Ezra Getzler**, Northwestern University, and **Richard Hain**, Duke University.

Nonlinear Dynamics and Optimization (Code: AMS SS L1), **A. F. Ivanov**, Pennsylvania State University and University of Ballarat, **A. Mees**, University of Western Australia, and **A. Rubinov**, University of Ballarat.

Operations Research Methods and Applications (Code: AMS SS S1), **Adi Ben-Israel**, Rutgers University, and **Moshe Sniedovich**, University of Melbourne.

Probability Theory and Its Applications (Code: AMS SS E1), **Timothy Brown**, University of Melbourne, **Phil Pollett**, University of Queensland, and **Ruth J. Williams**, University of California, San Diego.

Recent Trends in Operator Theory and Harmonic Analysis (Code: AMS SS J1), **Michael T. Lacey**, Georgia Institute of Technology, and **Alan G. R. McIntosh**, Macquarie University.

Solitons, Integrable Systems and Singular Limits (Code: AMS SS P1), **Jared Bronski**, University of Illinois, Urbana, **Nalini Joshi**, University of Adelaide, **Peter Miller**, Monash University, and **Colin Rogers**, University of New South Wales.

Accommodations

Accommodations will be available at Newman college at the university, as well as in selected hotels in the surrounding Carlton and Parkville area. More detailed information will be available soon and posted on the Web site maintained by the local organizers: `http://www.maths.monash.edu.au/~ams99/`.

Location

The conference will be held at the University of Melbourne's city campus, which is located in Parkville, walking distance from the city center. The area around the university is home to one of Australia's best restaurant districts, including the famous Lygon street. Melbourne is Australia's second largest city and the capital of the state of Victoria. It is famous for its cultural offerings, restaurants, parks, and gardens. Within a close range one can find spectacular ocean beaches, national parks, and vineyards. For local information please visit the Web site maintained by the local organizers: `http://www.maths.monash.edu.au/~ams99/`.

Transportation

Melbourne's international airport, Tullamarine, is approximately 20 kilometers (13 miles) from the city center. A taxi ride takes about one-half hour, and costs about $A25 each way. Overseas visitors should note that tipping is not common practice in Australia. An airport bus leaves every half hour during the daytime, and costs about $A10. You should, however, confirm these details.

Overseas visitors who would like to hire a car should remember that Australians drive on the left side of the road. City driving can also provide excitement for those not used to sharing roads with trams. The University of Melbourne campus is particularly well serviced by public transport, including buses, a nearby underground rail station, and Melbourne's famous trams.

Climate

Melbourne is in a temperate climate zone. According to the Bureau of Meteorology, a typical temperature range for July is a minimum low of 6°C, with an average high of 13°C.

Salt Lake City, Utah

University of Utah

September 25–26, 1999

Meeting #946

Western Section
Associate secretary: Bernard Russo
Announcement issue of *Notices*: June 1999
Program issue of *Notices*: November 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 8, 1999
For abstracts: August 3, 1999

Invited Addresses

Robert Burton, Oregon State University, *Title to be announced.*

Richard Wentworth, University of California, Irvine, *Title to be announced.*

Maciej Zworski, University of California, Berkeley, *Title to be announced.*

Special Sessions

Arithmetical Algebraic Geometry (Code: AMS SS B1), **Minhyong Kim**, University of Arizona, and **Wieslawa Niziol**, University of Utah.

Commutative Algebra (Code: AMS SS C1), **Paul Roberts**, University of Utah, and **Roger Wiegand**, University of Nebraska.

Complex Variables and Operator Theory (Code: AMS SS A1), **Siqi Fu**, **Farhad Jafari**, and **Peter Polyakov**, University of Wyoming.

Providence, Rhode Island

Providence College

October 2–3, 1999

Meeting #947

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: November 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 16, 1999
For abstracts: August 11, 1999

Invited Addresses

Dan M. Barbasch, Cornell University, *Title to be announced.*

Henri Berestycki, Université Paris VI and Ecole Normale Superieure, *Title to be announced.*

David Mumford, Brown University, *Title to be announced.*

Guoliang Yu, University of Colorado, *Title to be announced.*

Special Sessions

Algebraic and Geometric Combinatorics (Code: AMS SS A1), **Vesselin N. Gasharov**, Cornell University, and **Ira M. Gessel**, Brandeis University.

Difference Equations and Applications (Code: AMS SS E1), **Gerasimos Ladas**, University of Rhode Island, and **Jeffrey T. Hoag**, Providence College.

Geometry and Representation Theory of Algebraic Groups (Code: AMS SS C1), **James E. Humphreys** and **Ivan Mirkovic**, University of Massachusetts.

Operator K-Theory and its Applications to Geometry and Topology (Code: AMS SS D1), **Guoliang Yu**, **Carla E. Farsi**, and **Jeffrey S. Fox**, University of Colorado, Boulder.

Representation Theory of Reductive Groups (Code: AMS SS B1), **Dan M. Barbasch** and **Birgit Speh**, Cornell University.

Austin, Texas

University of Texas-Austin

October 8-10, 1999

Meeting #948

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 16, 1999
For abstracts: August 11, 1999

Invited Addresses

Mikhail Kapranov, Northwestern University, *Title to be announced.*

John Roe, Oxford and Pennsylvania State University, *Title to be announced.*

Catherine Sulem, University of Toronto, *Title to be announced.*

Tatiana Toro, University of Washington, *Title to be announced.*

Special Sessions

Aperiodic Tiling (Code: AMS SS D1), **Charles Radin** and **Lorenzo Sadun**, University of Texas, Austin.

Banach and Operator Spaces: Isomorphic and Geometric Structure (Code: AMS SS E1), **Edward Odell** and **Haskell P. Rosenthal**, University of Texas, Austin.

DNA Topology (Code: AMS SS J1), **Isabel K. Darcy**, University of Texas, Austin, and **Makkuni Jayaram**, University of Texas, Austin.

Dehn Surgery and Kleinian Groups (Code: AMS SS L1), **John Luecke** and **Alan Reid**, University of Texas, Austin.

Free Surface Interfaces and PDEs (Code: AMS SS K1), **Kirk Lancaster**, Wichita State University, and **Thomas Vogel**, Texas A&M University.

Harmonic Analysis and PDEs (Code: AMS SS C1), **William Beckner** and **Luis A. Caffarelli**, University of Texas at Austin, **Toti Daskalopoulos**, University of California, Irvine, and **Tatiana Toro**, University of Washington.

Interconnections Among Diophantine Geometry, Algebraic Geometry, and Value Distribution Theory (Code: AMS SS Q1), **William Cherry**, University of North Texas, **Min Ru**, University of Houston, and **Felipe Voloch**, University of Texas, Austin.

Mathematical Problems in Transport Phenomena (Code: AMS SS M1), **Jose Antonio Carrillo** and **Irene M. Gamba**, University of Texas, Austin.

Mathematical and Computational Finance (Code: AMS SS H1), **Stathis Tompaidis**, University of Texas, Austin.

Nonlinear Waves (Code: AMS SS G1), **Catherine Sulem**, University of Toronto.

Recent Developments in Index Theory (Code: AMS SS F1), **Daniel S. Freed**, University of Texas, Austin, and **John Roe**, Pennsylvania State University.

The Development of Topology in the Americas (Code: AMS SS A1), **Cameron Gordon**, University of Texas, Austin, and **Ioan Mackenzie James**, University of Oxford.

The Diverse Mathematical Legacy of Jean Leray (Code: AMS SS N1), **Eric M. Friedlander**, Northwestern University, and **Susan J. Friedlander**, University of Illinois, Chicago.

Theoretical, Computational and Experimental Aspects of Mechanics (Code: AMS SS P1), **Jerry Bona**, **Steven Levandosky**, and **Jiahong Wu**, University of Texas, Austin.

Wavelets and Approximation Theory (Code: AMS SS B1), **Don Hong**, Eastern Tennessee State University, and **Michael Prophet**, Murray State University.

Charlotte, North Carolina

University of North Carolina, Charlotte

October 15-17, 1999

Meeting #949

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: August 1999
Program issue of *Notices*: December 1999
Issue of *Abstracts*: Volume 20, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 23, 1999
For abstracts: August 18, 1999

Invited Addresses

Valery Alexeev, University of Georgia, *Title to be announced.*

Béla Bollobás, University of Memphis and Cambridge University, *Title to be announced.*

Konstantin M. Mischaikow, Georgia Institute of Technology, *Title to be announced.*

Yakov Sinai, Princeton University, *Title to be announced.*

Special Sessions

Algebraic Geometry (Code: AMS SS K1), **Valery Aleexev**, **William Graham**, **Roy C. Smith**, and **Robert Varley**, University of Georgia.

Commutative Algebra (Code: AMS SS B1), **Sarah Glaz**, University of Connecticut, and **Evan G. Houston** and **Thomas G. Lucas**, University of North Carolina at Charlotte.

Contemporary Methods in Dynamics and Differential Equations (Code: AMS SS J1), **Robert W. Ghrist** and **Konstantin M. Mischaikow**, Georgia Institute of Technology.

Geometric Function Theory (Code: AMS SS H1), **David A. Herron**, University of Cincinnati, and **Shanshuang Yang**, Emory University.

Knot Theory and Its Applications (Code: AMS SS A1), **Yuanan Diao**, University of North Carolina at Charlotte.

Operator Theory, including Applications in Operator Algebras and Wavelets (Code: AMS SS F1), **Alan L. Lambert** and **Xingde Dai**, University of North Carolina at Charlotte.

Optimal Control and Computational Optimization (Code: AMS SS D1), **Mohammed A. Kazemi**, University of North Carolina at Charlotte, and **Gamal N. Elnagar**, University of South Carolina at Spartanburg.

Set-Theoretic Topology (Code: AMS SS G1), **Ronald F. Levy**, George Mason University.

Spectral Theory of Differential Operators and Applications (Code: AMS SS C1), **Boris R. Vainberg** and **Stanislav Molchanov**, University of North Carolina at Charlotte.

Stochastic PDEs and Turbulence (Code: AMS SS E1), **Weinan E**, Courant Institute, New York University.

Washington, District of Columbia

Marriott Wardman Park Hotel and Omni Shoreham Hotel

January 19–22, 2000

Note: This is a World Math Year 2000 (WMY2000) event.

Meeting #950

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: Bernard Russo
Announcement issue of *Notices*: October 1999
Program issue of *Notices*: January 2000
Issue of *Abstracts*: Volume 21, Issue 1

Deadlines

For organizers: April 20, 1999
For consideration of contributed papers in Special Sessions: August 10, 1999
For abstracts: October 5, 1999
For summaries of papers to MAA organizers: To be announced

AMS Invited Addresses

Arthur M. Jaffe, Harvard University, *Title to be announced* (AMS Retiring Presidential Address).

Roger Penrose, Oxford University, *Title to be announced* (AMS Josiah Willard Gibbs Lecture).

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

Invited Addresses

Walter Craig, Brown University, *Title to be announced.*

Erwin Lutwak, Polytechnic University, *Title to be announced.*

Alexander Nabutovsky, Courant Institute of Mathematical Sciences, NYU, *Title to be announced.*

Mary Beth Ruskai, University of Massachusetts, Lowell, *Title to be announced.*

Special Sessions

Invariance in Convex Geometry (Code: AMS SS A1), **Daniel A. Klain**, Georgia Institute of Technology, and **Elisabeth Werner**, Case Western Reserve University.

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

Lafayette, Louisiana

University of Southwestern Louisiana

April 14–16, 2000

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: July 14, 1999
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Odense, Denmark

Odense University

June 12–15, 2000

First AMS-Scandinaivan International Mathematics Meeting. Sponsored by the AMS, Dansk Matematisk Forening, Suomen matemaattinen yhdistys, Icelandic Mathematical Society, Norsk Matematisk Forening, and Svenska matematikersamfundet.
Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Los Angeles, California

University of California-Los Angeles

August 7–12, 2000

Note: This is a World Math Year 2000 (WMY2000) event.

Associate secretary: Robert M. Fossum
Announcement issue of *Notices*: To be announced
Program issue of *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Toronto, Ontario Canada

University of Toronto

September 22–24, 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: To be announced
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New York, New York

Columbia University

November 3–5, 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: February 3, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Paula Cohen, Université des Sciences et Technologies de Lille, France, *Title 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 Asso-

ciation 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: John L. Bryant
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

Lawrence, Kansas

University of Kansas

March 30–31, 2001

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 28, 2000
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Hoboken, New Jersey

Stevens Institute of Technology

April 28–29, 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: July 28, 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

Joint Mathematics Meetings, including the 108th Annual Meeting of the AMS and 85th Meeting of the Mathematical Association of America (MAA).
Associate secretary: John L. Bryant
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: Bernard Russo, Department of Mathematics, University of California, Irvine, CA 92697; e-mail: brusso@math.uci.edu; telephone: 949-824-5505.

Central Section: Susan J. Friedlander, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan (M/C 249), Chicago, IL 60607-7045; e-mail: susan@math.nwu.edu; telephone: 312-996-3041.

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: John L. Bryant, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; e-mail: bryant@math.fsu.edu; telephone: 850-644-5805.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information 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 106 in the January 1999 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX or AMS-LaTeX may submit abstracts with such coding. To see descriptions of the forms available, visit `http://www.ams.org/abstracts/instructions.html` or send mail to `abs-submit@ams.org`, typing `help` as the subject line, 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.)

1999:

June 13-July 1: Joint Summer Research Conferences in the Mathematical Sciences, Boulder, CO. See pp. 1435-1441 (1998) for details.

July 26-August 13: Summer Research Institute on Smooth Ergodic Theory and Applications, Seattle, WA. See pp. 1442-1443 (1998) for details.

August 16-27: 1999 Von Neumann Conference, Symposium on Arithmetic Fundamental Groups and Noncommutative Algebra, Berkeley, CA. See pp. 405-406 (March 1999) for details.

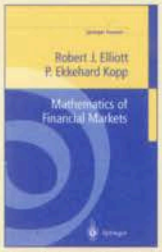
Cosponsored Conference:

July 18-28, 1999: Foundations of Computational Mathematics (FoCM), University of Oxford, England. See `http://www-sccm.stanford.edu/FoCM/` for details.

SPRINGER FOR MATHEMATICS

ROBERT J. ELLIOTT, University of Alberta, Canada and **EKKEHARD KOPP,** The University of Hull, United Kingdom

Mathematics of Financial Markets



This book presents the mathematics which underpins pricing models for derivative securities, such as options, futures and swaps, in modern financial markets. The treatment is careful and detailed rather than comprehensive, aiming in particular to provide a clear understanding of pricing and hedging for call and put options. From here the reader can progress to the use of similar methods for more exotic instruments and further research.

1998/304 PP., 6 ILLUS./HARDCOVER/$64.95
ISBN 0-387-98553-0
SPRINGER FINANCE

ANDREW I. DALE, University of Natal, South Africa

History of Inverse Probability

From Thomas Bayes to Karl Pearson
Second Edition

This a history of the use of Bayes's theorem over 150 years, from its discovery by Thomas Bayes to the rise of the statistical competitors in the first third of the twentieth century. In the new edition, the Author's concern is the foundations of statistics, in particular, the examination of the development of one of the fundamental aspects of Bayesian statistics. The reader will find new sections on contributors to the theory omitted from the first edition, which will shed light on the use of inverse probability by nineteenth century authors. In addition, there is amplified discussion of relevant work from the first edition. This text will be a valuable reference source in the wider field of the history of statistics and probability.

1999/APP. 704 PP., 14 ILLUS./HARDCOVER
$89.95 (TENT.)/ISBN 0-387-98807-6
SOURCES AND STUDIES IN THE HISTORY OF MATHEMATICS AND PHYSICAL SCIENCES

MICHAEL W. FRAZIER, Michigan State University

An Introduction to Wavelets Through Linear Algebra

This text was originally written for a "Capstone" course (a course intended for undergraduate mathematics majors as one of the final courses taken in their undergraduate curriculum) at Michigan State University. Its purpose is to bring together different topics covered in the undergraduate curriculum and introduce students to current developments in mathematics and their applications. Basic wavelet theory seems to be a perfect topic for such a course. As a subject, it dates back only to 1985. Since then there has been an explosion of wavelet research, both pure and applied. The only prerequisites assumed are a basic linear algebra background and a bit of analysis background.

1999/APP. 536 PP., 162 ILLUS./HARDCOVER/$49.95
ISBN 0-387-98639-1
UNDERGRADUATE TEXTS IN MATHEMATICS

FUZHEN ZHANG, Nova Southeastern University, Fort Lauderdale, FL

Matrix Theory

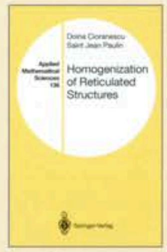
Basic Results and Techniques

The aim of this book is to concisely present fundamental ideas, results, and techniques in linear algebra and mainly matrix theory. The book contains eight chapters covering various topics ranging from similarity and special types of matrices to Schur complements and matrix normality. Each chapter focuses on the results, techniques, and methods that are beautiful, interesting, and representative, followed by carefully selected problems. For many theorems several different proofs are given. The book can be used as a text or a supplement for a linear algebra and matrix theory class or seminar for senior or graduate students. The only prerequisites are a decent background in elementary linear algebra and calculus. The book can also serve as a reference for instructors and researchers in the fields of algebra, matrix analysis, operator theory, statistics, computer science, engineering, operations research, economics, and other fields.

1999/APP. 278 PP./HARDCOVER/$49.95
ISBN 0-387-98696-0
UNIVERSITEXT

DOINA CIORANESCU, Université Pierre et Marie Curie, France and **SAINT JEAN PAULIN,** Université de Metz, France

Homogenization of Reticulated Structures



This book provides a comprehensive and unified treatment of the homogenization of porous and lattice type structures. Its aim is to give continuous simple models for thin reticulated structures (which may have a very complex pattern). For this reason, the authors treat partial differential equations depending on several small parameters, and give the asymptotic behavior with respect to these parameters. Throughout the book attention has been paid to mathematical rigor, convergence results and error estimates. This book will be very useful to researchers and graduate students in the fields of mathematics, materials science, and engineering.

1999/APP. 360 PP., 114 ILLUS./HARDCOVER/$74.95
ISBN 0-387-98634-0
APPLIED MATHEMATICAL SCIENCES, VOLUME 136

RAINER KRESS, Universität Göttingen, Germany

Linear Integral Equations

Second Edition

This book resulted from the author's fascination with the mathematical beauty of integral equations. It is an attempt to combine theory, applications, and numerical methods, and cover each of these fields with the same weight. In order to make the book accessible to mathematicians, physicists, and engineers, the author has made the work as self-contained as possible by requiring only a solid foundation in differential and integral calculus. The functional analysis which is necessary for an adequate treatment of the theory and the numerical solution of integral equations is developed within the book. Problems are included at the end of each chapter. The second edition features many new topics along with corrections and adjustments throughout the text.

1999/APP. 384 PP./HARDCOVER/$59.95
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APPLIED MATHEMATICAL SCIENCES, VOLUME 82

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