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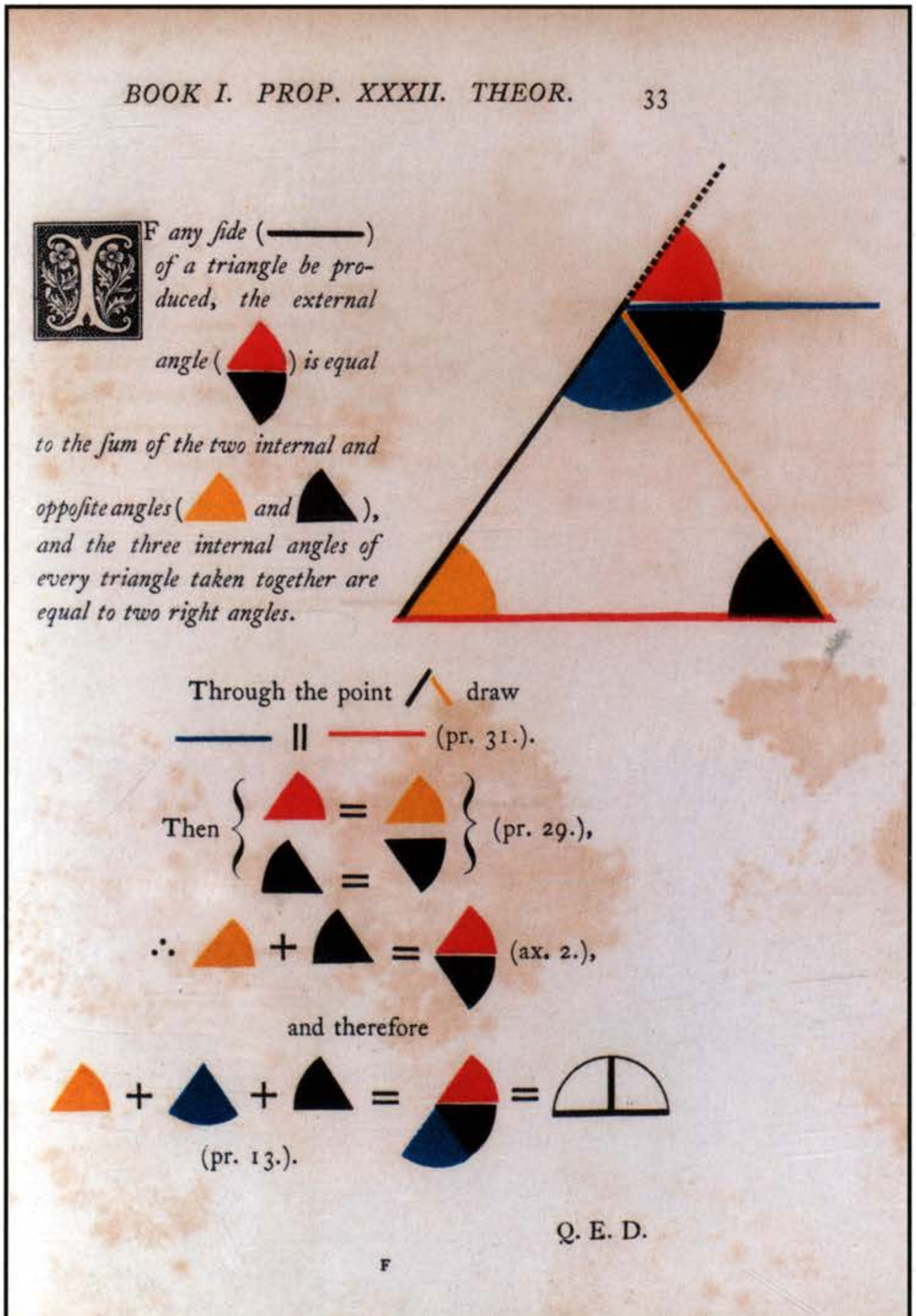
BOOK I. PROP. XXXII. THEOR. 33

IF any ſide ( ) of a triangle be produced, the external angle ( ) is equal to the ſum of the two internal and oppoſite angles (and), and the three internal angles of every triangle taken together are equal to two right angles.

Through the point draw

|| (pr. 31.).

Then (pr. 29.),

∴ + = (ax. 2.),

and therefore

+ + = = (pr. 13.).

Q. E. D.

F

A ninteenth-century window on Euclid (see page 565)

American Mathematical Society

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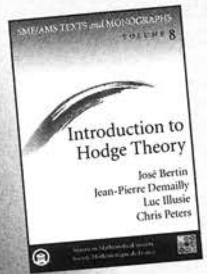

Introduction to Hodge Theory

José Bertin, *University of Grenoble I, St. Martin D'Heres, France*, **Jean-Pierre Demailly**, *University of Grenoble I, St. Martin d'Heres, France*, **Luc Illusie**, *University of Paris-Sud, Orsay, France*, and **Chris Peters**, *University of Grenoble I, St. Martin d'Heres, France*

From reviews of the French Edition:

The present book … may be regarded as a masterly introduction to Hodge theory in its classical and very recent, analytic and algebraic aspects … it is by far much more than only an introduction to the subject. The material leads the reader to the forefront of research in many areas related to Hodge theory, and that in a detailed highly self-contained manner … this text is also a valuable source for active researchers and teachers in the field …

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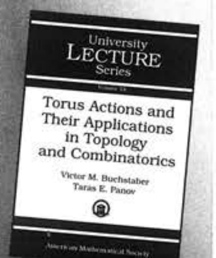

Torus Actions and Their Applications in Topology and Combinatorics

Victor M. Buchstaber and **Taras E. Panov**, *Moscow State University, Russia*

This exposition centers around the theory of moment-angle complexes, providing an effective way to study invariants of triangulations by methods of equivariant topology. The book includes many new and well-known open problems and would be suitable as a textbook. It will be useful for specialists both in topology and in combinatorics and will help to establish even tighter connections between the subjects involved.

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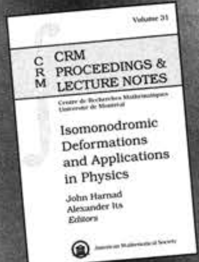

Isomonodromic Deformations and Applications in Physics

John Harnad, *University of Montreal, PQ, Canada*, and **Alexander Its**, *Indiana University–Purdue University, Indianapolis*, Editors

The contributions in this volume are based on lectures given by leading experts at the CRM workshop (Montreal, Canada). Included are both survey articles and more detailed expositions relating to the theory of isomonodromic deformations, the Riemann-Hilbert problem, and modern applications.

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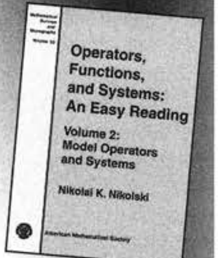

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Nikolai K. Nikolski, *University of Bordeaux I, Talence, France*

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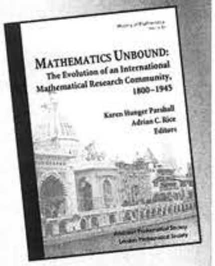

Mathematics Unbound: The Evolution of an International Mathematical Research Community, 1800–1945

Karen Hunger Parshall, *University of Virginia, Charlottesville*, and **Adrian C. Rice**, *Randolph-Macon College, Ashland, VA*, Editors

Although today's mathematical research community takes its international character very much for granted, this "global nature" is relatively recent, having evolved over a period of roughly 150 years—from the beginning of the nineteenth century to the middle of the twentieth century. Until now, this evolution has been largely overlooked by historians and mathematicians alike. This book addresses the issue by bringing together essays by twenty experts in the history of mathematics who have investigated the genesis of today's international mathematical community. This includes not only developments within component national mathematical communities, such as the growth of societies and journals, but also more wide-ranging political, philosophical, linguistic, and pedagogical issues.

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History of Mathematics, Volume 23; 2002; 408 pages; Hardcover; ISBN 0-8218-2124-5; List $85; All AMS members $68; Order code HMATH/23NT205

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of the American Mathematical Society

May 2002

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Communications

Commentary

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Departments

From the AMS Secretary

Mathematical Articles and Bottled Water

The system for publishing mathematical articles should be reformed, and the new system should resemble, on the economic side, the bottled water industry. My main theses are: (i) the results of mathematical research should be available to the public just like tap water, (ii) the role of the commercial (and noncommercial) publishers should be to sell an upgraded version of the product ("bottled water"), and (iii) only a coordinated action of big and powerful institutions (i.e., universities and the government) can bring about the change to the system.

The advent of electronic databases and the Internet changed the economics of mathematics publishing. In the past, a mathematical paper used to be sold only once, on paper. Recently commercial (and not only commercial) journal publishers started collecting journal articles in their private databases. Then they started selling access to their databases—an article can now be sold an unlimited number of times over an indefinite period. Electronic databases have a huge technical advantage over paper versions of journals—they offer search facilities unparalleled by anything one can possibly do with paper copies.

Distinct mathematical results do not compete with each other the way various models of automobiles do—a mathematician must have access to all known results in the field to be efficient and competitive. Hence, universities cannot choose between various publishers—they have to subscribe to all major journals and databases. This gives the publisher of a journal monopoly power, even if the company owns only a small proportion of the scientific literature in the field. As a result, some journal prices are outrageous. The emergence of commercial electronic databases only aggravated the situation.

Mathematical articles should be made available to the public in the same way water is. Public money is used to provide safe and cheap drinking water to most people. Companies selling bottled water exploit the fact that many people are willing to pay a premium price for bottled water for various reasons—taste, portability, etc. People have a choice—to drink tap water, provided free or almost free at many locations, or pay an extra fee for extra value.

The public and private universities and the government should create databases for mathematical papers in their least refined form. The Mathematics ArXiv is an example of such a database. The articles deposited there are not refereed. They are available in several electronic formats but the typesetting is only as good as the author chooses it to be. This is equivalent to tap water. The universities and the government should make it mandatory for mathematicians supported in any way by salaries or grants to deposit their articles in one of such databases.

Journal publishers should be in the business of selling "bottled water", i.e., the enhanced version of research articles. The enhancements would include elegant typesetting and linking to other articles, for example. If the new system is implemented, one might expect that journal prices would go down. The price of bottled water cannot be too high, as long as everyone has access to tap water.

The new proposed system would work only if the universities had a choice to opt out and cancel subscriptions to commercial publisher databases. But this will be a realistic possibility only when the free, university and government supported databases of articles in their raw form are complete. One cannot expect that voluntary submissions of some articles by some researchers would make a difference. An appeal to the universities to create free databases and an appeal to the mathematicians to deposit their manuscripts in them will have little effect if even a small but nonnegligible proportion of researchers ignore it. The universities and the government agencies such as the National Science Foundation have a legitimate claim to ownership of the mathematical results as they are the organizations who pay for the research. They should make it mandatory for mathematicians to submit their preprints to free public databases in the final (revised) form before transmitting them to the publishers for typesetting.

My proposal is far from a new camouflaged form of taxation in which the government takes away from mathematicians the fruits of their labor. It is much closer to the government imposed and enforced traffic laws—even extreme libertarians might approve traffic lights. I believe that all mathematicians would be happy to distribute their theorems for free to all other mathematicians and to the general public. Many mathematicians send their recent results to their colleagues as paper preprints or electronic files, post their articles on their personal web pages, or deposit them in public archives. The current system is chaotic with the result that for most articles, the access is free only to a limited number of people and only for a limited amount of time. Only government action could introduce order in the system and assure permanent free access to all of the mathematical literature for everyone.

—Krzysztof Burdzy
University of Washington

Letters to the Editor

AP Calculus Grading

I would like to report to the community on my experience grading the 2001 AP Calculus exams and the conclusions I have drawn from that.

The AP Calculus scoring system is one which is fundamentally unfair to the students who take the exam. The scoring rubrics in many ways fail to reflect the knowledge of calculus displayed by the students taking the exam, and in some instances egregiously so. Furthermore, the reading system is deliberately designed to restrict the exercise of the readers' judgment. Throughout the entire process, I was frustrated by being unable to apply my judgment in scoring books and infuriated by being forced to score books in ways that I felt were simply wrong. All in all, the AP Calculus reading was one of the worst professional experiences I have ever had. Unless and until there are major changes, I would never participate in it again, and I strongly advise colleagues not to do so either.

My desire here is that the necessary changes be made, and the reader may ask why I am writing a letter to the *Notices* rather than communicating about these issues directly with those responsible for the exam reading. The answer is that I have. I wrote a seven-page letter to the Chief Reader. His reply consisted of a one-paragraph brush-off. Thus I think that the only way to effect change is to bring the problem into the open.

I have already used some AP terminology, which I must define. We are not graders, but readers, and we do not grade exams, but rather read books. The standards for reading each of the problems in the books are called scoring rubrics, and readers are given these rubrics, which we must follow to the letter, at briefings. The Chief Reader is in charge of the whole process, with a hierarchy reaching down to the ordinary readers.

Let me propose the following two grading axioms:

Axiom 1. An answer which is mathematically correct, correctly expressed, and supported by correct reasoning, shall be given full credit.

Axiom 2. An answer, correct or incorrect, the reasoning for which is totally specious, shall be given no credit.

The readers of the *Notices* will undoubtedly question my sanity when I claim that these axioms are violated in the AP reading process, but they are.

I regard Axioms 1 and 2 as self-evident. I propose a third axiom, perhaps not self-evident, but still, I think, pretty clear.

Axiom 3. Readers who, using their best professional judgment, are convinced beyond a reasonable doubt of the correctness of a student's solution may overlook harmless omissions and inconsequential errors and assign full credit for the solution.

This axiom is also violated. Furthermore, there are many other instances where the scoring rubrics reflect extremely poor judgment, resulting in scoring books in ways that are unreasonable and unfair.

The readers of this letter will naturally want proof of these claims. Unfortunately, the space available for letters in the *Notices* precludes giving it here. Instead, I have posted a slightly modified version of my letter to the Chief Reader on my website, at `http://www.lehigh.edu/~shw2/ap2001.html`, where extensive detailed evidence may be found.

In summary, the AP calculus scoring system is badly broken. It urgently needs to be fixed—not tinkered with, but fixed. I regard adoption of my axioms as necessary elements of any repair, but in any event what is necessary is a complete reexamination of the scoring system from the ground up. Nothing less will do.

—*Steven H. Weintraub*
Lehigh University

(Received December 4, 2001)

Response to Weintraub

We regret that Steven Weintraub felt frustrated by his experience at the 2001 AP Calculus Reading. For a different perspective on the positive experiences of participating in the Reading, we invite everyone to read the letter by Roger Howe of Yale University that appeared in the November 1995 *Notices* (`http://www.ams.org/notices/199511/letters.pdf`).

Readers are asked to exercise their judgment in evaluating student solutions (not just answers) within the context of the philosophy and guidelines established by the scoring rubrics and in agreement with the instructions given in each problem and for the exam as a whole. We recognize that not every Reader will agree with every scoring decision, but we firmly believe that the final AP grade accurately, consistently, and fairly reflects student achievement. Weintraub has raised some important concerns, and we do take them seriously, as we do all comments from Readers.

The statistical evidence does not support the contention that the scoring system is fundamentally unfair to students. Analyses have shown that the AP Calculus exam grades of 1 to 5 correlate well with other measures of student achievement, including college grades in subsequent mathematics courses. Student scores on the free-response problems, the ones graded at the Reading, have a high correlation with the scores on the multiple-choice section of the exam. AP Calculus traditionally has one of the highest reliability coefficients among all AP exams (reliability of the AP grade is a statistical measure that shows to what extent the grade would have been the same if the student had taken a different form of the exam and if the responses had been scored by different faculty consultants).

Over 600 college and high school faculty participate in the Reading, grading over one million calculus problems. It is impossible to involve every Reader in the development of the rubrics, but they are set by professional mathematicians using their professional judgment. The Chief Reader develops preliminary rubrics in consultation with the AP Calculus Development Committee as the problems are written. Before the Reading starts, the Chief Reader meets with the exam and question leaders to discuss, argue, agree, and sometimes disagree about how to allocate partial credit among the nine possible points on each of the six problems. A final consensus on the rubrics emerges after examinations of hundreds of actual student responses and lengthy discussions with the eighty table leaders, all of whom have many years of experience with the AP Program and with the difficulty of fairly grading thousands of exams (almost 185,000 in 2001). After the Reading is completed, the composite scores based upon 108 points from the multiple-choice and free-response sections are converted to an AP grade of 1 to 5 by the Chief Reader in consultation with statisticians from Educational Testing Service. Decisions on cut scores are based on such factors as statistical information based on common multiple-choice items in the current exam and one or more past exams, studies comparing college student and AP student scores on both multiple-choice items and free-response problems, AP grade distributions from past years, and observations from the Reading.

The issues raised in Weintraub's "axioms" have been considered repeatedly and thoroughly over the years by the mathematics faculty who have participated in many Readings. Situations that arise in grading individual solutions revive these discussions. The positions taken at the 2001 Reading reflected established practices that these repeated considerations have eventually supported.

One of the primary goals throughout the process is that a student should receive the same score for a problem regardless of which Reader grades that problem. Axiom 1 is a guiding principle in every scoring rubric, but still allows interpretation about the depth that is needed to be "correct." One problem with Axioms 2 and 3 is interpreting "totally specious" and deciding what are "harmless omissions and inconsequential errors." Even if everyone agreed with these axioms, there is subjective evaluation about levels of "correctness," especially when "completeness" is part of the correctness. If Axioms 2 and 3 were to be adopted in full, consistency and fairness would certainly suffer, and students would be much more at the mercy of individual Reader attitudes. What would not be fair is to have the student's score depend to a large degree on who graded the paper.

We invite college faculty to participate in the AP Reading as the program continues to strive to improve even more the grading of the AP Calculus exam.

—Larry Riddle
Chief Reader, 2000–2003
Agnes Scott College

—Bernard Madison
Chief Reader, 1996–1999
University of Arkansas

—Ray Cannon
Chief Reader, 1992–1995
Baylor University

—George Rosenstein
Chief Reader, 1988–1991
Franklin and Marshall College

(Received February 5, 2002)

Contribution of John Nash to General Topology and Real Analysis

With the release of the movie *A Beautiful Mind* and the publication of several books, it is now widely known that John F. Nash Jr. did research in the theory of games which revolutionized economics. In other areas of mathematics his work is rated even more highly by mathematicians.

One of his lesser-known mathematical contributions is a problem he posed in 1956 that stimulated extensive research in general topology and real analysis. In "Research Problem 1: Generalized Brouwer Theorem" [*Bull. Amer. Math. Soc.* **62** (1956), 76], Nash defined a "connectivity map" from a space A into a space B to be one such that the induced map $A \to A \times B$ preserves the connectedness of any connected set in A. He asked if every connectivity map of a cell into itself must have a fixed point.

Motivation for this problem stems from the fact that to prove the Brouwer fixed point theorem for dimension 1, we need the function to have merely a connected graph, which is a consequence of continuity. So it is natural to ask if the result is true for higher dimensional cells for a *connectivity function.*

O. H. Hamilton showed that the problem has an affirmative solution ["Fixed points for certain noncontinuous transformations", *Proc. Amer. Math. Soc.* **8** (1957), 750–756], but his proof contained a gap. This gap was filled by J. Stallings ["Fixed point theorems for connectivity maps", *Fund. Math.* **47** (1959), 249–263], and the importance of connectivity functions was established. Moreover, Hamilton introduced *peripherally continuous functions* and Stallings introduced *almost continuous functions*, both of which are closely related to connectivity functions. These together with the previously known *connected* or *Darboux* functions and their generalizations began to be studied widely.

The following beautiful characterization of connectivity functions was discovered by S. K. Hildebrand and D. E. Sanderson ["Connectivity functions and retracts", *Fund. Math.* **57** (1965), 237–245].

Theorem. *Let $f:(X,T)\to(Y,T')$ be a function and consider the topology τ generated by $T \cup f^{-1}(T')$ on X. Then f is a connectivity function if and only if T and τ induce the same family of connected sets in X.*

Further references may be found by consulting MathSciNet and issues of the journals *Real Analysis Exchange* and *Fundamenta Mathematica.*

—Som Naimpally
Lakehead University

(Received January 17, 2002)

Software Patents

When asked about software patents, Donald Knuth [*Notices*, March 2002] conjectured that it might be possible to patent a 300-digit integer. The readers might be interested to know that I have already patented a 309-digit integer as claim 37 of U.S. Patent 5,373,560, issued in 1994. It relates to cryptography, and it is not as interesting as what Knuth had in mind. At the time, some people thought that patenting a number was a new extreme in silly software patents, but now we have business method patents that are even sillier.

—Roger Schlafly

(Received February 13, 2002)

Mathematical Challenges from Genomics and Molecular Biology

Richard M. Karp

A fundamental goal of biology is to understand how living cells function. This understanding is the foundation for all higher levels of explanation, including physiology, anatomy, behavior, ecology, and the study of populations. The field of molecular biology analyzes the functioning of cells and the processes of inheritance principally in terms of interactions among three crucially important classes of macromolecules: DNA, RNA, and proteins. Proteins are the molecules that enable and execute most of the processes within a cell. DNA is the carrier of hereditary information in the form of genes and directs the production of proteins. RNA is a key intermediary between DNA and proteins.

Molecular biology and genetics are undergoing revolutionary changes. These changes are guided by a view of a cell as a collection of interrelated subsystems, each involving the interaction among many genes and proteins. Emphasis has shifted from the study of individual genes and proteins to the exploration of the entire genome of an organism and the study of networks of genes and proteins. As the level of aspiration rises and the amount of available data grows by orders of magnitude, the field becomes increasingly dependent on mathematical modeling, mathematical analysis, and computation. In the sections that follow we give an introduction to the mathematical and computational challenges that arise in this field, with an emphasis on discrete algorithms and the role of combinatorics, optimization, probability, statistics, pattern recognition, and machine learning.

We begin by presenting the minimal information about genes, genomes, and proteins required to understand some of the key problems in genomics. Next we describe some of the fundamental goals of the molecular life sciences and the role of genomics in attaining these goals. We then give a series of brief vignettes illustrating algorithmic and mathematical questions arising in a number of specific areas: sequence comparison, sequence assembly, gene finding, phylogeny construction, genome rearrangement, associations between polymorphisms and disease, classification and clustering of gene expression data, and the logic of transcriptional control. An annotated bibliography provides pointers to more detailed information.

Richard M. Karp is a member of the International Computer Science Institute (ICSI), Berkeley, and a University Professor at the University of California, Berkeley. His e-mail address is `karp@icsi.berkeley.edu`.

This article grew out of a lecture presented by Karp at the meeting "Mathematical Challenges of the 21st Century", sponsored by the AMS and held at the University of California, Los Angeles, in August 2000. The article will also appear in a planned proceedings volume for the meeting.

Genes, Genomes, and Proteins

The Double Helix

The field of genetics began with Gregor Mendel (1865), who postulated the existence of discrete units of information (which later came to be called genes) that govern the inheritance of individual characteristics in an organism. In the first half of the twentieth century it was determined that the genes are physically embodied within complex DNA macromolecules that lie within structures called chromosomes which occur in every living cell. This set the stage for the epochal discovery of the structure of DNA by Watson and Crick in 1953. They showed that a DNA molecule is a double helix consisting of two strands. Each helix is a chain of *bases*, chemical units of four types: A, C, T, and G. Each base on one strand is joined by a hydrogen bond to a complementary base on the other strand, where A is complementary to T, and C is complementary to G. Thus the two strands contain the same information. Certain segments within these chromosomal DNA molecules contain genes, which are the carriers of the genetic information and, in a sense to be explained later, spell the names of the proteins. Thus the genetic information is encoded digitally, as strings over the four-letter alphabet $\{A, C, T, G\}$, much as information is encoded digitally in computers as strings of zeros and ones.

In humans there are forty-six chromosomes. All but two of these (the sex chromosomes) occur in pairs of "homologous" chromosomes. Two homologous chromosomes contain the same genes, but a gene may have several alternate forms called alleles, and the alleles of a gene on the two chromosomes may be different.

The total content of the DNA molecules within the chromosomes is called the *genome* of an organism. Within an organism, each cell contains a complete copy of the genome. The human genome contains about three billion base pairs and about 35,000 genes.

Proteins

Proteins are the workhorses of cells. They act as structural elements, catalyze chemical reactions, regulate cellular activities, and are responsible for communication between cells. A protein is a linear chain of chemical units called amino acids, of which there are twenty common types. The function of a protein is determined by the three-dimensional structure into which it folds. One of the premier problems in science is the *protein folding problem* of predicting the three-dimensional structure of a protein from its linear sequence of amino acids. This problem is far from being solved, although progress has been made by a variety of methods. These range from numerical simulation of the physical forces exerted by the amino acids on one another to pattern recognition techniques which correlate motifs within the linear amino acid sequence with structural features of a protein.

From Genes to Proteins

The fundamental dogma of molecular biology is that DNA codes for RNA and RNA codes for protein. Thus the production of a protein is a two-stage process, with RNA playing a key role in both stages. An RNA molecule is a single-stranded chain of chemical bases of four types: A, U, C, and G. In the first stage, called transcription, a gene within the chromosomal DNA is copied base-by-base into RNA according to the correspondence $A \to U$, $C \to G$, $T \to A$, $G \to C$. The resulting RNA transcript of the gene is then transported within the cell to a molecular machine called a ribosome which has the function of translating the RNA into protein. Translation takes place according to the genetic code, which maps successive triplets of RNA bases to amino acids. With minor exceptions, this many-to-one function from the sixty-four triplets of bases to the twenty amino acids is the same in all organisms on Earth.

Regulation of Gene Expression

All the cells within a living organism (with the exception of the sperm and egg cells) contain nearly identical copies of the entire genome of the organism. Thus every cell has the information needed to produce any protein that the organism can produce. Nevertheless, cells differ radically in the proteins that they actually produce. For example, there are more than 200 different human cell types, and most proteins are produced in only a subset of these cell types. Moreover, any given cell produces different proteins at different stages within its cycle of operation, and its protein production is influenced by its internal environment and by the signals impinging upon it from other cells.

It is clear, then, that the expression of a gene within a cell (as measured by the abundance and level of activity of the proteins it produces) is regulated by the environment of the cell. Transcription of a gene is typically regulated by proteins called transcription factors that bind to the DNA near the gene and enhance or inhibit the copying of the gene into RNA. Similarly, translation can be regulated by proteins that bind to the ribosome. Certain post-translational processes, such as the chemical modification of the protein or the transport of protein to a particular compartment in the cell can also be regulated so as to affect the activity of the protein. Thus gene expression can be viewed as a complex network of interactions involving genes, proteins, and RNA, as well as other factors such as temperature and the presence or absence of nutrients and drugs within the cell.

The Goals of Genomics

In this section we enumerate some of the goals of genomics.

1. Sequence and compare the genomes of different species. To sequence a genome means to determine its sequence of bases. This sequence will, of course, vary from individual to individual, and those individual differences are of paramount importance in determining each individual's genetic makeup, but there is enough agreement to justify the creation of a composite reference genome for a species. For example, any two humans will have the same complement of genes (but different alleles) and will agree in about 999 bases out of 1,000.

   The sequencing of the human genome has been a central goal of the world genomics community since 1990. Draft sequences were completed in February 2001, and the quest continues for a much more accurate sequence.

This achievement was preceded by the sequencing of many bacterial genomes, yeast, the nematode, and, in June 1999, the fruit fly *Drosophila melanogaster*. The sequencing of a new organism is often of value for medical, agricultural, or environmental studies. In addition, it may be useful for comparative studies with related organisms.

2. Identify the genes and determine the functions of the proteins they encode. This process is essential, since without it a sequenced genome is merely a meaningless jumble of A's, C's, T's, and G's. Genes can be identified by methods confined to a single genome or by comparative methods that use information about one organism to understand another related one.
3. Understand gene expression. How do genes and proteins act in concert to control cellular processes? Why do different cell types express different genes and do so at different times?
4. Trace the evolutionary relationships among existing species and their evolutionary ancestors.
5. Solve the protein folding problem: From the linear sequence of amino acids in a protein, determine the three-dimensional structure into which it folds.
6. Discover associations between gene mutations and disease. Some diseases, such as cystic fibrosis and Huntington's disease, are caused by a single mutation. Others, such as heart disease, cancer, and diabetes, are influenced by both genetic and environmental factors, and the genetic component involves a combination of influences from many genes. By studying the relation between genetic endowment and disease states in a population of individuals, it may be possible to sort out the genetic influences on such complex diseases.

Having completed our brief survey of the general goals of genomics, we now turn to a number of examples of specific problems in genomics. These typically involve the creation of a mathematical model, the development of an algorithm, and a mathematical analysis of the algorithm's performance.

Sequence Comparison

The similarity of a newly discovered gene or protein to known genes or proteins is often an indication of its importance and a clue to its function. Thus, whenever a biologist sequences a gene or protein, the next step is to search the sequence databases for similar sequences. The BLAST (Basic Local Alignment Search Tool) program and its successive refinements serve this purpose and are the most important single software tool for biologists.

In preparation for giving a measure of the similarity between two sequences of residues (i.e., bases or amino acids), we need a definition: An *alignment* of a pair of sequences x and y is a new pair of sequences x' and y' of equal length such that x' is obtained from x and y' is obtained from y by inserting occurrences of the special space symbol $(-)$. Thus, if $x = acbcdb$ and $y = abbdcdc$, then one alignment of x and y is as follows:

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x' = a - c b c - d b,
y' = a b - b d c d c.
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Given an alignment of two sequences x and y, it is natural to assess its quality (i.e., the extent to which it displays the similarity between the two sequences) as a score, which is the sum of scores associated with the individual columns of the alignment. The score of a column is given by a symmetric scoring function σ that maps pairs of symbols from the alphabet $\Sigma \cup \{-\}$ to the real numbers, where Σ is the set of residues. Normally we will choose $\sigma(a, a) > 0$ for all symbols $a \in \Sigma$, so that matched symbols increase the score of the alignment, and $\sigma(a, -) < 0$ for all $a \in \Sigma$, so that misalignments are penalized. In the case of the alphabet of amino acids, $\sigma(a, b)$ reflects the frequency with which amino acid a replaces amino acid b in evolutionarily related sequences.

The global alignment problem is to find the optimal alignment of two strings x and y with respect to a given scoring function σ. A dynamic programming algorithm called the Needleman-Wunsch algorithm solves this problem in a number of steps proportional to the product of the lengths of the two sequences. A straightforward implementation of this algorithm requires space proportional to the product of the lengths of the two sequences, but there is a refinement which, at the cost of doubling the execution time, reduces the space requirement to $m + \log n$, where m and n are the lengths of the shorter and the longer of the two sequences.

A related problem is that of local alignment, in which we seek the highest score of an alignment between consecutive subsequences of x and y, where these subsequences may be chosen as desired. Such an alignment is intended to reveal the extent of local similarity between sequences that may not be globally similar. This problem can be solved within the same time and space bounds as the global alignment problem, using a dynamic programming algorithm due to Smith and Waterman.

A *gap* is a sequence of consecutive columns in an alignment in which each symbol of one of the sequences (x' or y') is the space symbol $(-)$. Gaps typically correspond to insertions or deletions of residue sequences over the course of evolution. Because mutations causing such insertions and deletions may be considered a single evolutionary event (and may be nearly as likely as the insertion or deletion of a single residue), we may wish to assign a (negative) score to a gap which is greater than the sum of the (negative) scores of its columns. The above dynamic programming algorithms can be adapted for this purpose.

One of the most commonly occurring tasks in computational genomics is to search a database for sequences similar to a given sequence. BLAST is a set of programs designed for this purpose. Ideally, it would be desirable to scan through the entire database for high-scoring local alignments, but this would require a prohibitive amount of computation. Instead, a filtering program is used to find regions of the database likely to have a high-scoring local alignment with the given sequences; the full local alignment algorithm is then used within these regions. One principle underlying the filtering program is that two sequences are likely to have a high-scoring local alignment only if there is a reasonably long exact match between them.

Multiple Alignment

The concept of an alignment can be extended to alignments of several sequences. A *multiple alignment* of the sequences $x_1, x_2, \ldots, x_n$ is an n-tuple $(x'_1, x'_2, \ldots, x'_n)$ of sequences of equal length where, for $i = 1, 2, \ldots, n$, the sequence x'_i is obtained from x_i by inserting occurrences of the space symbol.

Just as in the case of a pairwise alignment, the scoring of a multiple alignment is based on a symmetric score function σ from $(\Sigma \cup \{-\})^2$ into the real numbers; usually we take $\sigma(-,-)$ to be zero. The score of a multiple alignment is then computed column by column. The *sum-of-pairs scoring method*, in which the score of a multiple alignment is the sum of $\sigma(a,b)$ over all aligned pairs of symbol occurrences, is a natural choice, with the convenient property that the score of an alignment is the sum of the scores of its induced pairwise alignments.

For the commonly used scoring methods, the problem of finding a maximum-score multiple alignment of a set of sequences is NP-hard, and various heuristics are used in practice.

Hidden Markov Models

Multiple alignments are an important tool for exhibiting the similarities among a set of sequences. Hidden Markov models (HMMs) provide a more flexible probabilistic method of exhibiting such similarities. An HMM is a Markov chain that stochastically emits an output symbol in each state. It is specified by a finite set of states, a finite set of output symbols, an initial state, transition probabilities $p(q,q')$, and emission probabilities $e(q,b)$. Here $p(q,q')$ is the probability that the next state is q' given that the present state is q, and $e(q,b)$ is the probability of emitting output symbol b in state q. In typical biological applications the output symbols are residues (nucleotides or amino acids), and an HMM is used to represent the statistical features of a family of sequences, such as the family of globin proteins. A subsequent section describes the construction of an HMM representing the statistical features of human genes.

An HMM for a family of sequences should have the property that sequences in the family tend to be generated with higher probability than other sequences of the same length. In view of this property, one can judge whether any given sequence lies in the family by computing the probability that the HMM generates it, a task that can be performed efficiently by a simple dynamic programming algorithm.

In order to construct a hidden Markov model of a family of sequences, one needs a *training set* consisting of representative sequences from the family. The first step in constructing the HMM is to choose the set of states and the initial state and to specify which transition probabilities and which emission probabilities can be nonzero. These choices are guided by the modeler's knowledge of the family. Given these choices, one can use the *EM-algorithm* to choose the numerical values of the nonzero transition probabilities and emission probabilities in order to maximize the product of the emission probabilities of the sequences in the training set.

Sequence Assembly

The genomes of different organisms vary greatly in size. There are about 3 billion base pairs in the human genome, 120 million in the genome of the fruit fly *Drosophila melanogaster*, and 4.7 million in the genome of the bacterium *E. coli*. There is no magic microscope than can simply scan across a genome and read off the bases. Instead, genomes are sequenced by extracting many fragments called *reads* from the genome, sequencing each of these reads, and then computationally assembling the genome from these reads. The typical length of a read is about 500 bases, and the total length of all the reads is typically five to eight times the length of the genome. The reads come from initially unknown locations distributed more or less randomly across the genome. The process of sequencing a read is subject to error, but the error rate is usually low.

Shotgun sequencing is conceptually the simplest way to assemble a genome from a set of reads. In this method the reads are compared in pairs to identify those pairs that appear to have a significant overlap. Then the reads are aligned in a manner consistent with as many of these overlaps as possible. Finally, the most likely genomic sequence is derived from the alignment.

During the 1990s The Institute for Genomic Research (TIGR) used the shotgun method to sequence the genomes of many microorganisms, of size up to about five megabases. However, the method was not believed to be applicable to organisms, such as *Homo sapiens*, having much larger genomes containing many *repeat families*. Repeat families are sequences that are repeated with very little variation throughout a genome. For example, the ALU repeat family consists of nearly exact repetitions of a sequence of about 280 bases covering about 10 percent of the human genome. Repeat families in a genome complicate the sequence assembly process, since matching sequences within two reads may come from distinct occurrences of a repeat sequence and therefore need not indicate that the reads overlap.

The Human Genome Project, an international effort coordinated by the U.S. Department of Energy and the National Institutes of Health, favors a divide and conquer approach over the shotgun sequencing approach. The basic idea is to reduce the sequencing of the entire genome to the sequencing of many fragments called *clones* of length about 130,000 bases whose approximate locations on the genome have been determined by a process called *physical mapping.*

In 1998 the biologist Craig Venter established Celera Genomics as a rival to the Human Genome Project and set out to sequence the human genome using the shotgun sequencing approach. Venter was joined by the computer scientist Gene Myers, who had conducted mathematical analyses and simulation studies indicating that the shotgun sequencing approach would work provided that most of the reads were obtained in pairs extracted from the ends of short clones. The advantage of using paired reads is that the approximate distance between the two reads is known. This added information reduces the danger of falsely inferring overlaps between reads that are incident with different members of the same repeat family. Celera demonstrated the feasibility of its approach by completing the sequencing of *Drosophila melanogaster* (the fruit fly) in March 2000.

In February 2001 Celera and the Human Genome Project independently reported on their efforts to sequence the human genome. Each group had obtained a rough draft sequence covering upwards of 90 percent of the genome but containing numerous gaps and inaccuracies. Both groups are continuing to refine their sequences. The relative merits of their contrasting approaches remain a topic of debate, but there is no doubt about the significance of their achievement.

Gene Finding

Although the sequencing of the human genome is a landmark achievement, it is not an end in itself. A string of three billion A's, C's, T's, and G's is of little value until the meaning hidden within it has been extracted. This requires finding the genes, determining how their expression is regulated, and determining the functions of the proteins they encode. These are among the goals of the field of *functional genomics.* In this section we discuss the first of these tasks, gene finding.

Living organisms divide into two main classes: prokaryotes, such as bacteria and blue-green algae, in which the cell does not have a distinct nucleus, and eukaryotes, in which the cells contain visibly evident nuclei and organelles. Gene finding within prokaryotes is relatively easy because each gene consists of a single contiguous sequence of bases. In higher eukaryotes, however, a gene typically consists of two or more segments called *exons* that code for parts of a protein, separated by noncoding intervening segments called *introns.* In the process of transcription the entire sequence of exons and introns is transcribed into a *pre-mRNA transcript.* Then the introns are removed and the exons are spliced together to form the mRNA transcript that goes to a ribosome to be translated into protein. Thus the task of gene identification involves parsing the genomic region of a gene into exons and introns. Often this parsing is not unique, so that the same gene can code for several different proteins. This phenomenon is called *alternative splicing.*

The identification of a gene and its parsing into exons and introns is based on signals in the genomic sequence that help to identify the beginning of the first exon of a gene, the end of the last exon, and the exon-intron boundaries in between. Some of these signals derive from the nature of the genetic code. Define a *codon* as a triplet of DNA bases. Sixty-one of the sixty-four codons code for specific amino acids. One of these (ATG) is also a start codon determining the start of translation. The other three codons (TAA, TAG, and TGA) are stop codons which terminate translation. It follows that the concatenation of all the exons starts with ATG (with occasional exceptions) and ends with one of the three stop codons. In addition, each intron must start with GT and end with AG. There are also important statistical tendencies concerning the distribution of codons within exons and introns and the distribution of bases in certain positions near the exon-intron boundaries. These deterministic signals and statistical tendencies can be incorporated into a hidden Markov model for generating genomic sequence. Given a genomic sequence, one can use a dynamic programming algorithm called the Viterbi algorithm to calculate the most likely sequence of states that would occur during the emission of the given sequence by the model. Each symbol is then identified as belonging to an exon, intron, regulatory region, etc., according to the state that the HMM resided in when the symbol was emitted.

Another approach to gene finding is based on the principle that functioning genes tend to be preserved in evolution. Two genes in different species are said to be *orthologous* if they are derived from the same gene in a common ancestral species. In a pair of species that diverged from one another late in evolution, such as man and mouse, one can expect to find many orthologous pairs of genes which exhibit a high level of sequence similarity; hence the fact that a sequence from the human genome has a highly similar counterpart in the mouse increases the likelihood that both sequences are genes. Thus one can enhance gene finding in both man and mouse by aligning the two genomes to exhibit possible orthologous pairs of genes.

Phylogeny Construction

The evolutionary history of a genetically related group of organisms can be represented by a *phylogenetic tree.* The leaves of the tree represent extant species. Each internal node represents a postulated *speciation event* in which a species divides into two populations that follow separate evolutionary paths and become distinct species.

The construction of a phylogenetic tree for a group of species is typically based on observed properties of the species. Before the era of genomics these properties were usually morphological characteristics such as the presence or absence of hair, fur, or scales or the number and type of teeth. With the advent of genomics the trees are often constructed by computer programs based on comparison of related DNA sequences or protein sequences in the different species.

An instance of the phylogeny construction problem typically involves n species and m *characters.* For each species and each character a *character state* is given. If, for example, the data consists of protein sequences of a common length aligned without gap symbols, then there will be a character for each column of the alignment, and the character state will be the residue in that position. The output will be a rooted binary tree whose leaves are in one-to-one correspondence with the n species.

The informal principle underlying phylogenetic tree construction is that species with similar character states should be close together in the tree. Different interpretations of this principle yield different formulations of the tree construction problem as an optimization problem, leading to several classes of tree construction methods. In all cases, the resulting optimization problem is NP-hard. We shall discuss *parsimony methods, distance-based methods,* and *maximum-likelihood methods.*

Parsimony Methods

The internal nodes of a phylogenetic tree are intended to represent ancestral species whose character states cannot be observed. In *parsimony methods* of tree construction the task is to construct a tree T and an assignment A of character states to the internal nodes to minimize the sum, over all edges of the tree, of the number of changes in character state along the edge.

Distance-Based Methods

Distance-based methods are based on the concept of an *additive metric.* Define a *weighted phylogenetic tree* T as a phylogenetic tree in which a nonnegative *length* $\lambda(e)$ is associated with each edge e. Define the distance between two species as the sum of the lengths of the edges on the path between the two species in the tree. The resulting distance function is called the *additive metric* realized by T.

Distance-based methods for phylogeny construction are based on the following assumptions:

1. There is a well-defined evolutionary distance between each pair of species, and this distance function is an additive metric.
2. The "correct" phylogenetic tree, together with appropriately chosen edge distances, realizes this additive metric.
3. The evolutionary distances between the extant species can be estimated from the character state data for those species.

This suggests the following *additive metric reconstruction problem*: Given a distance function D defined on pairs of species, construct a tree and a set of edge distances such that the resulting additive metric approximates D as closely as possible (for a suitable measure of closeness of approximation).

The following is an example of a simple stochastic model of molecular evolution which implies that the distances between species form an additive metric. The models used in practice are similar, but more complex.

The model is specified by a weighted phylogenetic tree T with edge lengths $\lambda(e)$. The following assumptions are made:

1. All differences between the character states of species are due to random mutations.
2. Each edge e represents the transition from an ancestral species to a new species. Independently for each character, the number of mutations during this transition has a Poisson distribution with mean $\lambda(e)$.
3. Whenever a mutation occurs, the new character state is drawn uniformly from the set of all character states (not excluding the character state that existed before the mutation).

The *neighbor-joining algorithm* is a widely used linear-time algorithm for the additive metric reconstruction problem. Whenever the given distance function D is an additive metric, the neighbor-joining algorithm produces a weighted tree whose metric is D. The neighbor-joining algorithm also enjoys the property of *asymptotic consistency.* This means that, if the data is generated according to the stochastic model described above (or to certain generalizations of that model) then, as the number of characters tends to infinity, the tree and edge weights produced by the neighbor-joining algorithm will converge to the correct tree and edge weights with probability one.

Maximum Likelihood Methods

Maximum likelihood methods for phylogeny construction are based on a stochastic model such as the one described above. Let A_X be the observed assignment of states for character x to the extant species. For any model $M = (T, \lambda)$ specifying the tree structure and the edge lengths, let $L_X(M)$ be the probability of observing the assignment A_X, given the model M. Define $L(M)$, the likelihood of model M, as the product of $L_X(M)$ over all characters x. The goal is to maximize $L(M)$ over the set of all models. This problem is NP-hard, but near-optimal solutions can be found using a combination of the following three algorithms:

1. an efficient algorithm based on dynamic programming for computing the likelihood of a model $M = (T, \lambda)$;
2. an iterative numerical algorithm for optimizing the edge lengths for a given tree; i.e., computing $F(T) = \max_\lambda L(T, \lambda)$;
3. a heuristic algorithm for searching in the space of trees to determine $\max_T F(T)$.

Genome Rearrangement

In comparing closely related species such as cabbage and turnip or man and mouse, one often finds that individual genes are almost perfectly conserved, but their locations within the genome are radically different. These differences seem to arise from global rearrangements involving the duplication, reversal, or translocation of large regions within a genome. This suggests that the distance between genomes should be measured not only by counting mutations, but also by determining the number of large-scale rearrangements needed to transform one genome to another.

To study these problems mathematically we view a genome as a sequence of occurrences of genes, define a set of primitive rearrangement operations, and define the distance between two genomes as the number of such operations needed to pass from one genome to the other. As an example, consider the case of two genomes that contain the same n genes but in different orders, and in which the only primitive operation is the reversal of a sequence of consecutive genes. Each genome can be modeled as a permutation of $\{1, 2, \ldots, n\}$ (i.e., a sequence of length n containing each element of $\{1, 2, \ldots, n\}$ exactly once), and we are interested in the *reversal distance* between the two permutations, defined as the minimum number of reversal operations required to pass from one permutation to the other. To make the problem more realistic we can take into account that genes are oriented objects and that the reversal of a segment not only reverses the order of the genes within it, but also reverses the orientation of each gene within the segment. In this case each genome can be modeled as a *signed permutation*, i.e., a permutation with a sign ($+$ or $-$) attached to each of the n elements, and the reversal operation reverses the order of a sequence of consecutive elements and the sign of each of these elements. It turns out that the problem of computing the reversal distance between two (unsigned) permutations is NP-hard, but there is an elegant quadratic-time algorithm for computing the reversal distance between two signed permutations.

DNA Microarrays

In this section we describe a key technology for measuring the abundances of specific DNA or RNA molecules within a complex mixture, and we describe applications of this technology to the study of associations between polymorphisms and disease, to the classification and clustering of genes and biological samples, and to the analysis of genetic regulatory networks.

Two oriented DNA molecules x and y are called *complementary* if y can be obtained by reversing x and replacing each base by its complementary base, where the pairs (A,T) and (C,G) are complementary. There is a similar notion of complementarity between RNA and DNA. *Hybridization* is the tendency of complementary, or nearly complementary, molecules to bind together.

Specific molecules within a complex sample of DNA or RNA can be identified by detecting their hybridization to complementary *DNA probes*. A DNA microarray is a regular array of DNA probes deposited at discrete addressable spots on a solid surface; each probe is designed to measure the abundance of a specific DNA or RNA molecule such as the mRNA transcript of a gene. It is possible to manufacture DNA microarrays with tens of thousands of spots on a surface the size of a postage stamp.

Here we concentrate on the applications of DNA microarrays, omitting all technological details about the manufacture of the arrays, the application of DNA or RNA samples to the arrays, and the measurement of hybridization. It is important to note, however, that at the present state of the art the measurements are subject to large experimental error. Methods of experimental design and statistical analysis are being developed to extract meaningful results from the noisy measurements, but currently one can obtain only a rough estimate of the abundance of particular molecules in the sample.

Associations between Polymorphisms and Disease

The genomes of any two humans differ considerably. Each of us carries different alleles (commonly occurring variant forms) of genes and *polymorphisms* (local variations in the sequence, typically due to mutations). Of particular interest are *Single-Nucleotide Polymorphisms* (SNPs) caused by mutations at a single position. Several million commonly occurring SNPs within the human genome have been identified. It is of great interest to find statistical associations between a genotype (the variations within an individual's genome) and phenotype (observable characteristics such as eye color or the presence of disease). Some genetic diseases result from a single polymorphism, but more commonly there are many genetic variations that influence susceptibility to a disease; this is the case for atherosclerosis, diabetes, and the many types of cancer. Microarrays are a fundamental tool for association studies because they enable an experimenter to apply DNA probes for thousands of different polymorphisms in a single experiment. The statistical problems of finding subtle associations between polymorphisms and complex diseases are currently being investigated intensively.

Classification and Clustering Based on Microarray Data

Microarrays can be used to identify the genetic changes associated with diseases, drug treatments, or stages in cellular processes such as apoptosis (programmed cell death) or the cycle of cell growth and division. In such applications a number of array experiments are performed, each of which produces noisy measurements of the abundances of many gene transcripts (mRNAs) under a given experimental condition. The process is repeated for many conditions, resulting in a *gene expression matrix* in which the rows represent experiments, the columns represent genes, and the entries represent the mRNA levels of the different gene products in the different experiments. A fundamental computational problem is to find significant structure within this data. The simplest kind of structure would be a partition of the experiments, or of the genes, into subclasses having distinct patterns of expression.

In the case of *supervised learning* one is given independent information assigning a *class label* to each experiment. For example, each experiment might measure the mRNA levels in a leukemia specimen, and a physician might label each specimen as either an acute lymphoblastic leukemia (ALL) or an acute myeloid leukemia (AML). The computational task is to construct a decision rule that correctly predicts the class labels and can be expected to generalize to unknown specimens. In the case of *unsupervised learning* the class labels are not available, and the computational task is to partition the experiments into homogeneous clusters on the basis of their expression data.

Typically the number of genes measured in microarray experiments is in the thousands, but the classes into which the experiments should be partitioned can be distinguished by the expression levels of a few dozens of critical genes, with the other genes being irrelevant, redundant, or of lesser significance. Thus there arises the *feature selection problem* of identifying the handful of genes that best distinguish the classes inherent in the data. Sometimes a gene expression matrix contains local patterns, in which a subset of the genes exhibit consistent expression patterns within a subset of experiments. These local patterns cannot be discerned through a global partitioning of the experiments or of the genes but require identification of the relevant subsets of genes and of experiments. Research on the feature selection problem and on the problem of identifying local patterns is in its infancy.

Supervised Learning

Machine learning theory casts the problem of supervised learning in the following terms. Given a set of *training examples* $\{x_1, x_2, \ldots, x_n\}$ drawn from a probability distribution over R^d, together with an assignment of a class label to each training example, find a rule for partitioning all of R^d into classes that is consistent with the class labels for the training examples and is likely to generalize correctly, i.e., to give correct class labels for other points in R^d.

There is a general principle of machine learning theory which, informally stated, says that, under some smoothness conditions on the probability distribution from which the training examples are drawn, a rule is likely to generalize correctly if

1. each training example lies within the region assigned to its class and is far from the boundary of that region;
2. the rule is drawn from a "simple" parametrized set of candidate rules. The notion of simplicity involves a concept called the Vapnik-Chervonenkis dimension, which we omit from this discussion.

One reasonably effective decision rule is the *nearest neighbor rule*, which assigns to each point the same class label as the training example at minimum Euclidean distance from it.

In the case of two classes (*positive examples* and *negative examples*) the *support vector machine* method is often used. It consists of the following two stages:

Mapping into feature space: Map each training example x to a point $\phi(x) = (\phi_1(x), \phi_2(x), \ldots)$, where the ϕ_i are called *features*. The point $\phi(x)$ is called the *image* of training example x.

Maximum-margin separation: Find a hyperplane that separates the images of the positive training examples from the images of the negative training examples and, among such separating hyperplanes, maximizes the smallest distance from the image of a training example to the hyperplane.

The problem of computing a maximum-margin separation is a quadratic programming problem. It turns out that the only information needed about the training examples is the set of inner products $\phi(x)^T\phi(y)$ between pairs (x, y) of training examples. It is possible for the images of the training examples to be points in an infinite-dimensional Hilbert space, as long as these inner products can be computed. *Mercer's Theorem* characterizes those functions $K(x, y)$ which can be expressed as inner products in finite- or infinite-dimensional feature spaces. These functions are called *kernels*, and the freedom to use infinite-dimensional feature spaces defined through their kernels is a major advantage of the support vector machine approach to supervised learning.

Clustering

Clustering is the process of partitioning a set of objects into subsets based on some measure of similarity (or dissimilarity) between pairs of objects. Ideally, objects in the same cluster should be similar, and objects in different clusters should be dissimilar.

Given a matrix of gene expression data, it is of interest to cluster the genes and to cluster the experiments. A cluster of genes could suggest either that the genes have a similar function in the cell or that they are regulated by the same transcription factors. A cluster of experiments might arise from tissues in the same disease state or experimental samples from the same stage of a cellular process. Such hypotheses about the biological origin of a cluster would, of course, have to be verified by further biochemical experiments.

Each gene or experiment can be viewed as an n-dimensional vector, with each coordinate derived from a measured expression level. The similarity between points can be defined as the inner product, after scaling each vector to Euclidean length 1. When experiments are being clustered the vectors are of very high dimension, and a preliminary feature selection step is required to exclude all but the most salient genes.

In the K-means algorithm the number of clusters is specified in advance, and the goal is to minimize the sum of the distances of points from the centers of gravity of their clusters. Locally optimal solutions can be obtained by an iterative computation which repeats the following step: Given a set of K clusters, compute the center of gravity of each cluster; then reassign each point to the cluster whose center of gravity is closest to the point.

Maximum likelihood methods assume a given number of clusters and also assume that the points in each cluster have a multidimensional Gaussian distribution. The object is to choose the parameters of the Gaussian distributions so as to maximize the likelihood of the observed data. In these methods a point is not definitely assigned to a cluster, but is assigned a probability of lying in each cluster.

Merging methods start with each object in a cluster by itself and repeatedly combine the two clusters that are closest together as measured, for example, by the distance between their centers of gravity. Most merging and splitting methods that have been proposed are heuristic in nature, since they do not aim to optimize a clearly defined objective function.

The Logic of Transcriptional Control

Cellular processes such as cell division, programmed cell death, and responses to drugs, nutrients, and hormones are regulated by complex interactions among large numbers of genes, proteins, and other molecules. A fundamental problem of molecular life science is to understand the nature of this regulation. This is a very formidable problem whose complete solution seems to entail detailed mathematical modeling of the abundances and spatial distributions within a cell of thousands of chemical species and of the interactions among them. It is unlikely that this problem will be solved within this century.

One aspect of the problem that seems amenable to mathematical methods is the logic of transcriptional control. As Eric Davidson has stated, "A large part of the answer lies in the gene control circuitry encoded in the DNA, its structure and its functional organization. The regulatory interactions mandated in the circuitry determine whether each gene is expressed in every cell, throughout developmental space and time, and if so, at what amplitude. In physical terms the control circuitry encoded in the DNA is comprised of *cis*-regulatory elements, i.e., the regions in the vicinity of each gene which contain the specific sequence motifs at which those regulatory proteins which affect its expression bind; plus the set of genes which encode these specific regulatory proteins (i.e., transcription factors)."

It appears that the transcriptional control of a gene can be described by a discrete-valued function of several discrete-valued variables. The value of the function represents the level of transcription of the gene, and each input variable represents the extent to which a transcription factor has attached to binding sites in the vicinity of the gene. The genes that code for transcription factors are themselves subject to transcriptional control and also need to be characterized by discrete-valued functions. A regulatory network, consisting of many interacting genes and transcription factors, can be described as a collection of interrelated discrete functions and depicted by a "wiring diagram" similar to the diagram of a digital logic circuit.

The analysis of this control circuitry involves biochemical analysis and genomic sequence analysis to identify the transcription factors and the sequence motifs characteristic of the sites at which they bind, together with microarray experiments which measure the transcriptional response of many genes to selected perturbations of the cell. These perturbations may involve changes in environmental factors such as temperature or the presence of a nutrient or drug, or interventions that either disable selected genes or enhance their transcription rates. The major mathematical challenges in this area are the design of informative perturbations and the inference of the transcriptional logic from information about transcription factors, their binding sites, and the results of microarray experiments under perturbed conditions.

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[8] B. EVERITT, S. LANDAU, and M. LEESE, *Cluster Analysis*, Edward Arnold, fourth edition, 2001.

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Euclid's Windows and Our Mirrors

A Review of Euclid's Window: The Story of Geometry from Parallel Lines to Hyperspace

Reviewed by Robert P. Langlands

Euclid's Window: The Story of Geometry from Parallel Lines to Hyperspace
Leonard Mlodinow
Simon & Schuster, 2001
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This is a shallow book on deep matters, about which the author knows next to nothing. The concept of the book is appealing: a popular review of geometrical notions from Euclid to Einstein as background to contemporary string theory with comments on the related intellectual history and portraits of some principal figures: Descartes, Gauss, Riemann and Einstein. Unfortunately the author is indifferent to mathematics, has only approximate notions of European history, and no curiosity about individuals. Famous names serve only as tags for the cardboard figures that he paints. Disoriented by ideas and by individuals whose feelings and behavior are not those of late twentieth-century America, he attempts to hide his confusion by an incessant, sometimes tasteless, facetiousness, almost a nervous tick with him, by railing at or mocking his pretended dolts or villains, Kant, Gauss's father or Kronecker, or by maudlin attempts to turn his heros into victims. There would be little point in reviewing the book, were it not that the germ of an excellent monograph is there that, in competent and sensitive hands, could have been read with pleasure and profit by students, mature mathematicians, and curious laymen. As a member of the second group who knows scarcely more than the author about the material, I certainly found it an occasion to reflect on what I would have liked to learn from the book and, indeed, an occasion to discover more about the topics discussed, not from the book itself, but from more reliable sources.

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String theory itself or, better and more broadly, the conceptual apparatus of much of modern theoretical physics, above all of relativity theory, statistical physics and quantum field theory, whether in its original form as quantum electrodynamics, or as the basis of the standard theory of weak and strong interactions, or as string theory, is mathematics, or seems to be, although often not mathematics of a kind with which those with a traditional training are very comfortable. Nonetheless many of us would like to acquire some genuine understanding of it and, for students especially, it is a legitimate object of curiosity or of more ambitious intellectual aspirations.

Mlodinow was trained as a physicist, and, at the level at which he is working, there is no reason, except perhaps his rather facile condemnation of Heisenberg, to fault his chapter on string theory, the culmination of the book. It is a brief rehearsal, larded with low humor, of the standard litany: the uncertainty principle; the difficulty of reconciling it with the differential geometry of relativity; particles and fields; Kaluza-Klein and the introduction of additional dimensions; the function of "strings" as carriers of multiple fields and particles; supersymmetry; and, finally, M-branes that permit the passage from one form of the theory to another.

In his introduction and in an epilogue Mlodinow expresses vividly and passionately his conviction that geometry is the legacy of Euclid and string theorists his heirs. Mathematicians, to whom this review is addressed, will recall that there is more in Euclid than geometry: Eudoxus's theory of proportion; the irrational; and primes. Since the last two are central to the modern theory of diophantine equations, there are other claims on the heritage, but they need no defense here. We are concerned with the geometry; with it alone we have our hands full.

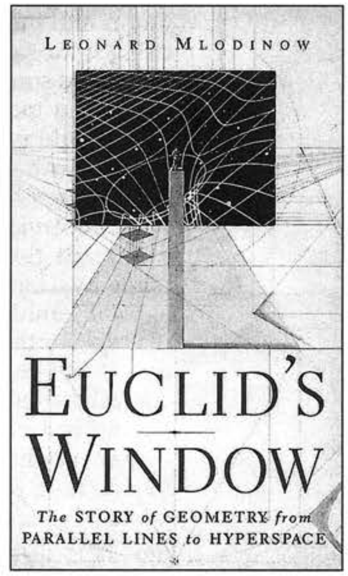
A reservation that is more in need of expression is that, with their emphasis on string theory or, better, the geometrical consequences of quantum field theory, mathematicians are in danger of shortchanging themselves. These consequences, especially the dynamical methods—dynamical in the sense of dynamical systems—used to deduce them, methods discovered, I believe, largely by Witten, are of great appeal and undoubtedly very deep. They are certainly worthy of the careful attention of mathematicians; but, as a community, we should well be trying to address in a coherent way all dynamical questions, both analytic and geometric, raised by or related to renormalization in statistical mechanics and in field theory.

Although these questions as a whole lie athwart Mlodinow's concept, it is difficult when reading the last chapter of his book not to reflect on them and on the current relation between mathematics and physics. So after finishing with other aspects of the book, about which there is a good deal to be said, I shall return to these matters.

History and Biography

Euclid. The background metric, thus the general theory of relativity, is a feature of string theory that is not present in most other field theories. There are several evident milestones on the way from ancient mathematics to Einstein's theory: Euclid's account of plane geometry; Descartes's advocacy of coordinates to solve specific geometrical problems; the introduction of curvature by Gauss and the discovery of noneuclidean geometries; Riemann's conceptions of higher-dimensional geometries and his criterion for flatness; Einstein's equations for general relativity. To isolate these five developments, each a major moment in intellectual history, as the themes of a single essay on mathematics was brilliant; to realize the concept an enormous challenge, beyond me, beyond most readers of the *Notices*, and certainly far beyond the author, locked in the present, upon which for him all windows open, and dazzled by his own flippancy.

Euclid's *Elements* are, above all, a window on themselves and on Greek mathematics. Difficult to appreciate without commentary, they could never have been, in spite of tradition, suitable as independent reading for schoolboys. In Mlodinow's first chapter, the one on Euclid, the mathematics is given very short shrift; the author prefers trivial puzzles to real mathematics. He presents Euclid's five postulates, including the fifth, or parallel, postulate in Euclid's form (two lines falling on a given line in such a way that the sum of the interior angles on the same side is less than two right angles necessarily meet) and, in addition, in the form known as Playfair's axiom (a unique parallel to a given line can be drawn through any point), probably because Playfair's axiom is more familiar to him from highschool. If our concern is with Euclid as Einstein's predecessor, then it is Euclid's form that is pertinent, for it expresses the flatness. What the student or the layman needs from this chapter is an explanation of the fifth postulate's relation to flatness: to the basic property of a triangle that the sum of its interior angles is π and especially to the existence of similar figures, thus to what one might call a little pretentiously, imitating the current jargon, the conformal invariance of Euclidean geometry. Even the mature mathematician may enjoy recalling these deep, important, and yet elementary, logical relations, for not all of us have taken the time to think through the manifold concrete implications of noneuclidean geometry. It appears, however, that the author has not even read Heath's comments and does not appreciate how flatness manifests itself in the simple geometric facts that we know almost instinctively, so that, with all the impudence of the ignorant, he can, later in the book, mock Proclus, who attempted, as other important mathematicians, like Legendre, were still doing centuries later, to prove the postulate, or Kant, whose philosophical imagination was unfortunately inadequate to the mathematical reality.



Otherwise the space in the first chapter is largely devoted to tales suitable for children, or sometimes not so suitable for children, as the author has a penchant for the lewd that he might better have held in check. He trots out the old war-horses Thales and Pythagoras and a new feminist favorite, Hypatia. Cajori, in his *A History of Mathematics*, observes that the most reliable information about Thales and Pythagoras is to be found in Proclus, who used as his source a no longer extant history by Eudemus, a pupil of Aristotle. Thales and Pythagoras belong to the sixth century BC, Eudemus to the fourth, and Proclus to the fifth century AD. Common sense suggests that there is considerable room for distortion, intentional or unintentional, in information that has been transmitted over a thousand years. This did not stop

Cajori and many other historians of science from using it. Nor does it stop the present author, who even adds some gratuitous speculation of his own: could the merchant Thales have traded in the leather dildos for which Mlodinow claims Miletus was known?

Although Neugebauer writes in *The Exact Sciences in Antiquity*, "It seems to me evident, however, that the traditional stories of discoveries made by Thales or Pythagoras must be regarded as totally unhistorical", there may be a place in popular accounts for the myths attached to them, but not at the cost of completely neglecting the responsibility of introducing the reader, especially the young reader, to some serious notions of the history of science, or simply of history. I have not looked for a rigorous account of Thales, but there is a highly regarded account of Pythagoras, *Weisheit und Wissenschaft*, by the distinguished historian Walter Burkert in which the reality is separated from the myth, leaving little, if anything, of Pythagoras as a mathematician. One's first observation on reading this book is that it is almost as much of a challenge to discover something about the Greeks in the sixth century as to discover something about physics at the Planck length (10^{-33} cm., the characteristic length for string theory). A second is that most of us are much better off learning more about the accessible philosophers, as a start, Plato and Aristotle, or about Hellenistic mathematics, that the earlier mythical figures are well left to the specialists. The third is that one should not ask about the scientific or mathematical achievements of Pythagoras but of the Pythagoreans, whose relation to him is not immediately evident. Burkert's arguments are complex and difficult, but a key factor is, briefly and imprecisely, that for various reasons Plato and the Platonists ascribed ideas that were properly Platonic to Pythagoras, who in fact was a religious rather than a scientific figure.

Whether as mathematician, shaman, or purveyor to Ionian and Egyptian sex-shops, neither Thales nor Pythagoras belongs in this essay; nor does Hypatia. Since Hypatia is a figure from the late fourth century AD, it is easier to separate the myth from the reality, and there is an instructive monograph *Hypatia of Alexandria* by Maria Dzielska that does just this. Mlodinow refers to the book but there is no sign that he has read it. If he has, he ignored it!

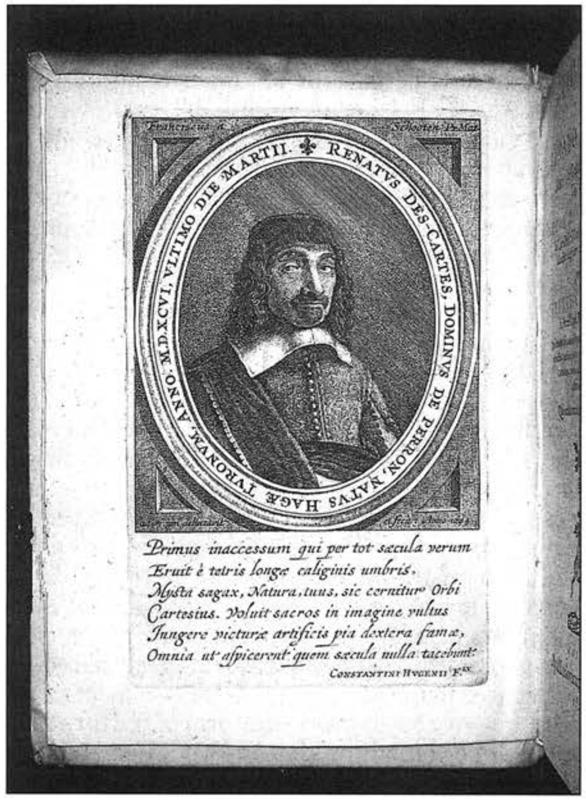
Mlodinow's book is short, and the space is largely taken up with material that is irrelevant or false, and often both. Much of the reliable information about Hypatia comes from the letters of Synesius of Cyrene, bishop of Ptolemais. An Alexandrian philosopher, a late Platonist, and mathematician of some repute, the daughter of the mathematician Theon, Hypatia was renowned for her wisdom, erudition and virtue. Of some political influence in the city, an ally of the prefect Orestes, she was brutally murdered in 415 at, according to Dzielska, the age of sixty (this estimate is not yet reflected in standard references) by supporters of his rival, the bishop Cyril. Although now a feminist heroine, which brings with it its own distortions, Hypatia first achieved mythical status in the early eighteenth century in an essay of John Toland, for whom she was a club with which to beat the Catholic church. His lurid tale was elaborated by Gibbon, no friend of Christianity, in his unique style: "...her learned comments have elucidated the geometry of Apollonius ...she taught ...at Athens and Alexandria, the philosophy of Plato and Aristotle ...In the bloom of beauty, and in the maturity of wisdom, the modest maid refused her lovers ...Cyril beheld with a jealous eye the gorgeous train of horses and slaves who crowded the door of her academy ...On a fatal day ...Hypatia was torn from her chariot, stripped naked, ...her flesh was scraped from her bones with sharp oyster-shells ...the murder ...an indelible stain on the character and religion of Cyril." This version, in which Hypatia is not an old maid but a young virgin, so that it is a tale not only of brutality but also of lust, is the version preferred by Mlodinow.

There is yet another component of the myth: Hypatia's death and the victory of Cyril mark the end of Greek civilization and the triumph of Christianity. Such dramatic simplification is right up Mlodinow's alley, who from this springboard leaps, as a transition from Euclid to Descartes, into a breezy tourist's account of Europe's descent into the Dark Ages and its resurrection from them, in which, in a characteristic display of ambiguity, the author wants to make Charlemagne out both a dunce and a statesman.

Descartes. Mlodinow would have done well to pass directly from Euclid to Descartes. Both Descartes and Gauss had a great deal of epistolary energy; so a genuine acquaintance with them as individuals is possible. The letters of Gauss especially are often quite candid. A good deal of their mathematics, perhaps all that of Descartes, is also readily accessible without any very exigent prerequisites. Yet Mlodinow relies on secondary, even tertiary, sources, so that his account, having already passed through several hands, is stale and insipid. Moreover, he exhibits a complete lack of historical imagination and sympathy, of any notion that men and women in other times and places might respond to surroundings familiar to them from birth differently than a late twentieth-century sight-seer from New York or Los Angeles. What is even more exasperating is that almost every sentence is infected by the itch to be jocose, to mock, or to create drama, so that a mendacious film covers everything. Without a much deeper and more detailed knowledge of various kinds of history than I possess, there is no question of recognizing each time exactly how veracity is sacrificed to effect. In some egregious instances, with which I was more than usually outraged, I have attempted to analyze his insinuations. It will be apparent that I am neither geometer nor physicist, and not a philosopher or a historian; I make no further apology for this.

Descartes was primarily a philosopher or natural scientist, and only incidentally a mathematician. So far as I can see, almost all the mathematics that we owe to him is in one appendix, *La géométrie*, to *Discours de la méthode*. Anyone who turns to this appendix will discover, perhaps to his surprise, that contrary to what Mlodinow states, Descartes does not employ the method we learned in school and "begin his analysis by turning the plane into a kind of graph". Not at all, Descartes is a much more exciting author, full, like Grothendieck and Galois, of philosophical enthusiasm for his methods. He begins by discussing the relation between the geometrical solution with ruler and compass of simple geometrical problems and the algebraic solution, goes on to a brilliant analysis of the curve determined by a generalized form of the problem of Pappus, an analysis that exploits oblique coordinates, not for all points but for a single one, and chosen not once and for all but adapted to the data of the problem. The analysis is incisive and elegant, well worth studying, and is followed by a discussion of curves in general, especially algebraic curves, and their classification, which is applied to his solution of the problem of Pappus. Descartes does not stop there, but the point should be clear: this is analytic geometry at a high conceptual but accessible mathematical level that could be communicated to a broad public by anyone with some enthusiasm for mathematics. He would of course have first to read Descartes, but there is no sign that Mlodinow regarded that as appropriate preparation.

Although adverse to controversy, even timid, Descartes, a pivotal figure in the transition from the theologically or confessionally organized society to the philosophically and scientifically open societies of the Enlightenment, made every effort to ensure that his philosophy became a part of the curriculum both in the United Provinces where he made his home and in his native, Catholic France. In spite of the author's suggestion, his person was never in danger: with independence from Spain, the Inquisition had ceased in Holland and by the seventeenth century it had long been allowed to lapse in France. Atheism was nonetheless a serious charge. Raised by his opponent, the Calvinist theologian Voetius, it could, if given credence, have led to a proscription of his teachings in the Dutch universities and the Jesuit schools of France and the Spanish Netherlands, but not to the stake. The



This portrait of Descartes is the frontispiece of the 1659 edition of the Latin translation of *La Géométrie*. The engraver, Frans van Schooten the younger, was also the translator and editor of the book, from which many mathematicians of the late seventeenth century learned analytic geometry.

From the Rosenwald Collection of the Institute for Advanced Study.

author knows this—as did no doubt Descartes—but leaves, once again for dramatic effect and at the cost of missing the real point, the reader with the contrary impression.

Gauss. It appears that, in contrast to many other mathematical achievements, the formal concept of noneuclidean geometry appeared only some time after a basic mathematical understanding of its properties. This is suggested by the descriptions of the work of Gauss and of earlier and later authors, Lambert in particular, that are found in Reichardt's *Gauß und die nicht-euklidische Geometrie* and by the documents included there. It was known what the properties must be, but their possibility, whether logical or in reference to the natural world, was not accepted. Modern mathematicians often learn about hyperbolic geometry quickly, almost in passing, in terms of the Poincaré model in the unit disk or the upper half-plane. Most of us have never learned how to argue in elementary geometry without Euclid's fifth postulate. What would we do if, without previous experience, we discovered that when the sum of the interior angles of just one triangle is less than π, as is possible when the parallel postulate is not admitted, then there is necessarily an upper bound for the area of all triangles, even a universal length? Would we conclude that such a geometry was totally irrelevant to the real world, indeed impossible? If we were not jaded by our education, we might better understand how even very perceptive philosophers could be misled by the evidence.

An intelligent, curious author would seize the occasion of presenting these notions to an audience to which they would reveal a new world and new insights, but not Mlodinow. What do we have as mathematics from him? Not the thoughts of Legendre, not the contributions of Lambert, not even the arguments of Gauss, taken from his reviews, from his letters, from his notes, nothing that suggests that the heart of the matter, expressed of course in terms of the difference between π and the sum of the interior angles of triangles, is whether the plane is curved. No, he does not even mention curvature in connection with noneuclidean geometry! There is a discussion, cluttered by references to the geography of Manhattan, of an attempt by Proclus to prove one form of the fifth postulate, but something that incorporated the perceptions of the late eighteenth or early nineteenth century would have been more useful. There is also a brief description of the Poincaré model, muddled by references to zebras, but any appreciation of an essential element of Gauss's thought, noneuclidean geometry as a genuine possibility for the space we see around us, is absent. The weakness of the Poincaré model as an expository device is that it puts us outside the noneuclidean space; the early mathematicians and philosophers were inside it.

Gauss's paper on the intrinsic curvature of surfaces, *Disquisitiones generales circa superficies curvas*, seems to have been inspired much less by his intermittent reflections on the fifth postulate than by the geodetic survey of Hannover. The paper is not only a classic of the mathematical canon but also elementary, not so elementary as noneuclidean geometry, but as the sequence Gauss, Riemann, Einstein begins with this paper, a serious essay would deal with it in a serious way and for a broad class of readers.

Having learned, as he claims, from Feynman that philosophy was "b.s.", Mlodinow feels free to amuse his readers by abusing Kant. He seems to have come away, perhaps because of the impoverished vocabulary, with a far too simple version of Feynman's dictum. It was not, I hope, encouraging us to scorn what we do not understand, and it was surely not to apply universally, especially not to the Enlightenment, in which Kant is an honored figure. As a corrective to the author's obscurantism and pretended contempt—since his views are plastic, shaped more by changing dramatic needs than by conviction, he has to concede some insight to Kant in his chapter on Einstein—I include some comments of Gauss, in which we see his views changing over the years, as he grows more certain of the existence of a noneuclidean geometry, and some mature comments of Einstein.

In a sharply critical 1816 review of an essay by J. C. Schwab on the theory of parallels of which, apparently, a large part is concerned with refuting Kant's notion that geometry is founded on intuition, Gauss writes,[1] "dass von diesen logischen Hilfsmitteln …Gebrauch gemacht wird, hat wohl Kant nicht läugnen wollen, aber dass dieselben für sich nichts zu leisten vermögen, und nur taube Blüthen treiben, wenn nicht die befruchtende lebendige Anschaung des Gegenstandes überall waltet, kann wohl niemand verkennen, der mit dem Wesen der Geometrie vertraut ist." So, for whatever it is worth, Gauss seems here to be in complete agreement with Kant. In the 1832 letter to Wolfgang von Bolyai, he comments on the contrary,[2] "in der Unmöglichkeit (to decide *a priori* between euclidean and noneuclidean geometry) liegt der klarste Beweis, dass Kant Unrecht hatte…" So he has not come easily to the conclusion that, in this point, Kant was wrong. He also refers Bolyai to his brief 1831 essay in the Göttingsche Gelehrte Anzeigen on biquadratic residues and complex numbers, in which he remarks,[3] "Beide Bemerkungen (on spatial reflections and intuition) hat schon Kant gemacht, aber man begreift nicht, wie dieser scharfsinniger Philosoph in der ersteren einen Beweis für seine Meinung, daß der Raum nur Form unserer äußern Anschaung sei, zu finden glauben konnte,…"

Einstein's remarks appear in his *Reply to criticisms* at the end of the Schilpp volume *Albert Einstein, Philosopher-Scientist.* Excerpts will suffice: "you have not at all done justice to the really significant philosophical achievements of Kant"; "He, however, was misled by the erroneous opinion—

Language is bound to time and place; translation, even by a skilled hand, entails choices and changes not merely its intonations but sometimes its sense. Since so much space has had to be devoted in this review to the issue of misrepresentation, I thought it best to let Gauss and Riemann speak for themselves. As a help to those unfamiliar with German, I add rough translations.

[1] *"Kant hardly wanted to deny that use is made of these logical methods, but no-one familiar with the nature of geometry can fail to recognize that these alone can achieve nothing and produce nothing but barren blossoms if the living, fructifying perception of the object itself does not prevail."*

[2] *"the clearest proof that Kant was wrong lies in this impossibility…"*

[3] *"Kant had already made both observations, but one does not understand how this perceptive philosopher was able to believe that he had found in the first a proof for his view that space is only a form of our external intuition,…"*

difficult to avoid in his time—that Euclidean geometry is necessary to thinking..."; "I did not grow up in the Kantian tradition, but came to understand the truly valuable which is to be found in his doctrine, alongside of errors which today are quite obvious, only quite late."

There is a grab-bag of doubtful tales about Gauss's family and childhood; Mlodinow, of course, retails a large number of them. He seems to be particularly incensed at Gauss's father, of whom he states, "Gauss was openly scornful...calling him 'domineering, uncouth, and unrefined'," and to be persuaded that Gauss's father was determined at all costs to make a navvy of him. Having dug a good many ditches in my own youth, I can assure the author, who seems to regard the occupation as the male equivalent of white slavery, that it was, when hand-shovels were still a common tool, a healthful outdoor activity that, practiced regularly in early life, does much to prevent later back problems. In any case, the one extant description of his father by Gauss in a letter to Minna Waldeck, later his second wife, suggests that the author has created the danger out of whole cloth:[4] "Mein Vater hat vielerlei Beschäftigungen getrieben..., da er nach und nach zu einer Art Wohlhabenheit gelangte...Mein Vater war ein vollkommen rechtschaffener, in mancher Rücksicht achtungswerter und wirklich geachteter Mann; aber in seinem Haus war er sehr herrisch, rauh und unfein ...obwohl nie ein eigentliches Mißverhältnis entstanden ist, da ich früh von ihm ganz unabhängig wurde." As usual, Mlodinow takes only that part of the story that suits him and invents the rest. The reader who insists nonetheless on the "herrisch, rauh und unfein" and not on the virtues that Gauss ascribes to him should reflect on possible difficulties of the father's rise and on the nature of the social gap that separated him, two hundred years ago, from Gauss at the age of thirty-three and, above all, from Gauss's future wife, the daughter of a professor.

Reimann and Einstein. In two booklets published very early, the first in 1917, the second in 1922, *Über die spezielle und die allgemeine Relativitätstheorie*, and *Grundzüge der Relativitätstheorie*, the second better known in its English translation, *The meaning of relativity*, Einstein himself gave an account of the Gauss-Riemann-Einstein connection. If Mlodinow had not got off on the wrong foot with Euclid, Descartes, and Gauss, he might have made the transition from Gauss to Riemann by, first of all, briefly describing the progress of coordinate geometry from Descartes to Gauss. Then, the Bolyai-Lobatchevsky noneuclidean geometry already at hand as an example, he could have continued with Gauss's theory of the intrinsic geometry of surfaces and their curvature, presenting at least some of the mathematics, especially the *theorema egregium* that the curvature is an isometric invariant and the formula that relates the difference between π and the sum of the interior angles of a triangle to the curvature. (Why he thinks the failure of the pythagorean theorem is the more significant feature of curved surfaces is not clear to me.) For the rest of the connection, he could have done worse than to crib from Einstein, who explains briefly and cogently not only the physics but also the function of the mathematics. On his own, Mlodinow does not really get to the point.

In the first of the two booklets, Einstein explains only the basic physical principles and the consequences that can be deduced from them with simple arguments and simple mathematics: the special theory of relativity with its two postulates that all inertial frames have equal status and that the velocity of light is the same whether emitted by a body at rest or a body in uniform motion; the general theory of relativity, especially the equivalence principle (physical indistinguishability of a gravitational field and an accelerating reference frame) as well as the interpretation of space-time as a space with a Minkowski metric form in which all Gaussian coordinate systems are allowed. These principles lead, without any serious mathematics but also without precise numerical predictions, to the consequence that light will be bent in a gravitational field.

In the second, he presents the field equations, thus the differential equations for the metric form, which is now the field to be determined by the mass distribution or simultaneously with it. More sophisticated arguments from electromagnetism and the special theory allow the introduction of the energy-momentum tensor $T_{\mu\nu}$, which appears in the field equation in part as an expression of the distribution of mass; the Ricci tensor $R_{\mu\nu}$, a contraction of the Riemann tensor associated to the metric form $g_{\mu\nu}$, is an expression of the gravitational field. The field equations are a simple relation between the two,

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = -\kappa T_{\mu\nu}, \qquad R = g^{\alpha\beta}R_{\alpha\beta}$$

where κ is in essence Newton's constant.

With this equation the mathematics becomes markedly less elementary, but, with some explanation, accessible to a large number of people and inevitable if Riemann's contribution is to be appreciated. Although it would certainly be desirable

[4] *"My father had various occupations...since he became over the course of time fairly well-off...my father was a completely upright, in many respects admirable and, indeed, admired man; but in his own home he was overbearing, rude, and coarse...although no real disagreement ever arose because I very soon became independent of him."*

to explain, as Einstein does, how Newton's customary law of gravitation follows from this equation and to describe how Einstein arrived at it, the cardinal point, where the mathematics anticipates the needs of physics, is the introduction of the Riemann tensor. It does not appear explicitly in Riemann's lecture, published as *Über die Hypothesen welche der Geometrie zu Grunde liegen* and intended for a broad audience, so that the mathematical detail is suppressed; at best it is possible to extract from the lecture the assertion that, to use our terminology, a Riemannian manifold is euclidean if and only if it is flat. The mathematics that was developed by his successors and that Einstein was able to exploit is implicit in this assertion but appears only in a paper on heat conduction published posthumously in Riemann's collected works. Because it was submitted in response to a prize theme proposed by the Academy in Paris, the paper is often referred to as the *Pariserarbeit*. Once again, Mlodinow misses the point. Coming up to the plate against several of the great geometers of history, he strikes out each time. I could hardly believe my eyes, but it seems he is persuaded that the introduction of elliptic geometry was the principal achievement of the lecture.

It appears from the biography prepared by Dedekind and included in his collected works that Riemann, born in 1826, was very moved as a child by the stories that he heard from his father, a lieutenant during the Napoleonic wars and later pastor, of the[5] "unglückliche Schicksal Polens", partitioned at the Congress of Vienna and then oppressed by the first Tsar Nicolas. Entering university, Riemann chose at first to study theology, partly at the urging of his father, who was devoted to his vocation, but partly to secure his future so that he could contribute to the support of his family. Mlodinow, unmoved by parental sentiments or filial piety or by the plight of a hapless nation but always ready with a wisecrack, suggests that his choice was so that "he could pray for the downtrodden Poles".

It is well known that of the three possible topics proposed by Riemann for his qualifying lecture on the occasion of his Habilitation, Gauss chose, sometime in December, 1853, the third, on the foundations of geometry, the only one that Riemann did not have in a drawer fully prepared. There are two accounts of Riemann's reactions to Gauss's unexpected choice, one by Mlodinow, one by Riemann.

Mlodinow: "Riemann's next step was understandable—he spent several weeks having some kind of breakdown, staring at the walls, paralyzed by the pressure. Finally, when spring came, he pulled himself together and in seven weeks hammered out a lecture."

Riemann in a letter to his brother:[6] "...dass ich...mich wieder mit meiner Untersuchung über den Zusammenhang der physikalischen Grundgesetze beschäftigte und mich so darin vertiefte, dass ich, als mir das Thema zur Probevorlesung beim Colloquium gestellt war, nicht gleich wieder loskommen konnte. Ich ward nun bald darauf krank, theils wohl in folge zu vielen Grübelns, theils in Folge des vielen Stubensitzens bei dem schlechten Wetter; es stellte sich mein altes Uebel wieder mit grosser Hartnäckigkeit ein und ich kam dabei mit meinen Arbeiten nicht vom Fleck. Erst nach mehreren Wochen, als das Wetter besser wurde und ich wieder mehr Umgang suchte, ging es mit meiner Gesundheit besser. Für den Sommer habe ich nun eine Gartenwohnung gemiethet und habe seitdem gottlob über meine Gesundheit nicht zu klagen gehabt. Nachdem ich etwa vierzehn Tage nach Ostern mit einer andern Arbeit, die ich nicht gut vermeiden konnte, fertig geworden war, ging ich nun eifrig an die Ausarbeitung meiner Probevorlesung und wurde um Pfingsten damit fertig."

Recalling that Pentecost falls seven weeks after Easter and subtracting fourteen days, we find that the preparations took only five weeks, but this discrepancy is of little importance. The others make for two accounts with quite different implications.

According to Pais, in his scientific biography *Subtle is the Lord*, Einstein, at the age of sixteen, troubled by the separation from his family, which had moved to Italy, and anxious at the prospect of military service, obtained, with the help of his family doctor, a medical certificate that released him from the Luitpold Gymnasium and allowed him to join his parents in Pavia. It was apparently not rare to leave the gymnasium before the Abitur. Thomas Mann, the novelist, left with two years to go, perhaps for similar reasons, as his recently widowed mother had moved from Lübeck to Munich. Einstein left early to avoid military service; Mann stayed only to the end of the Obersekunda, the stage required

[5] *"unhappy fate of Poland"*

[6] *"I was so deeply occupied with my investigation of the connection of the basic physical laws that I could not abandon it immediately when the topic of the qualifying lecture for the colloquium was proposed to me. Shortly thereafter I became ill, partly because of too much brooding, partly because I had kept too much to my room in the bad weather; my old ailment appeared again with great tenacity, so that my work stood stock-still. Only after several weeks, as the weather improved and I began to get about again, did my health improve. I rented a country place for the summer and since then, thank goodness, have had no complaints about my health. After I finished another paper that I could hardly avoid, I started, about fourteen days after Easter, to work zealously on the preparation of my qualifying lecture and was finished by Whitsuntide."*

for a reduction of compulsory military service to one year. The account in Victor Klemperer's autobiography, *Curriculum vitae*, suggests that for many students it was even normal to stay only to this point and then to find a commercial position of some sort.

Einstein, who was, Pais stresses, an excellent student, had, however, no such intention. He resumed his studies elsewhere almost immediately. Nonetheless, this turn in his career gives Mlodinow a foot in the door: Einstein becomes, in a late twentieth-century word with inevitable modern connotations, a dropout. This is a pernicious notion.

As André Weil pointed out many years ago in an observation at the beginning of his essay, *The mathematics curriculum*, "The American student...suffers under some severe handicaps,... Apart from his lack of earlier training in mathematics..., he suffers chiefly from his lack of training in the fundamental skills—reading, writing, and speaking...". Unfortunately this is not less valid today than when written; indeed it may now be true of students in Europe as well. It has certainly always applied to North Americans. Although we sometimes do better than Weil foresaw (*L'avenir des mathématiques*), we are, almost without exception, handicapped all our lives because we could not begin serious thinking when our minds were fresh and free.

What is striking about the education of Gauss and Einstein is the conjunction of talent and timely opportunity. They were both encouraged very early: Gauss by his first teachers, Büttner and Bartels; Einstein by his uncle and by a family friend, Max Talmud. Both had excellent educational opportunities: Einstein because of his milieu; Gauss by chance. An Einstein from a home without books, without music, without intellectual conversation would almost certainly have been much less confident, less intellectually certain, and much more dependent; a Gauss without early freedom, without early, extensive knowledge of the eighteenth-century mathematical literature would not have discovered the implications of cyclotomy or proved the law of quadratic reciprocity so soon, if at all.

To forget this, to exaggerate his difficulties and to represent Einstein as an academically narrow, misunderstood or mistreated high-school dropout is a cruel disservice to any young reader or to any educator who swallows such falsehoods.

Mlodinow adds the occasional literary touch, not always carried off with the desired aplomb. The first lines of Blake's *Auguries of Innocence*,

> To see a World in a Grain of Sand
> And a Heaven in a Wild Flower,
> Hold Infinity in the palm of your hand
> And Eternity in an hour.

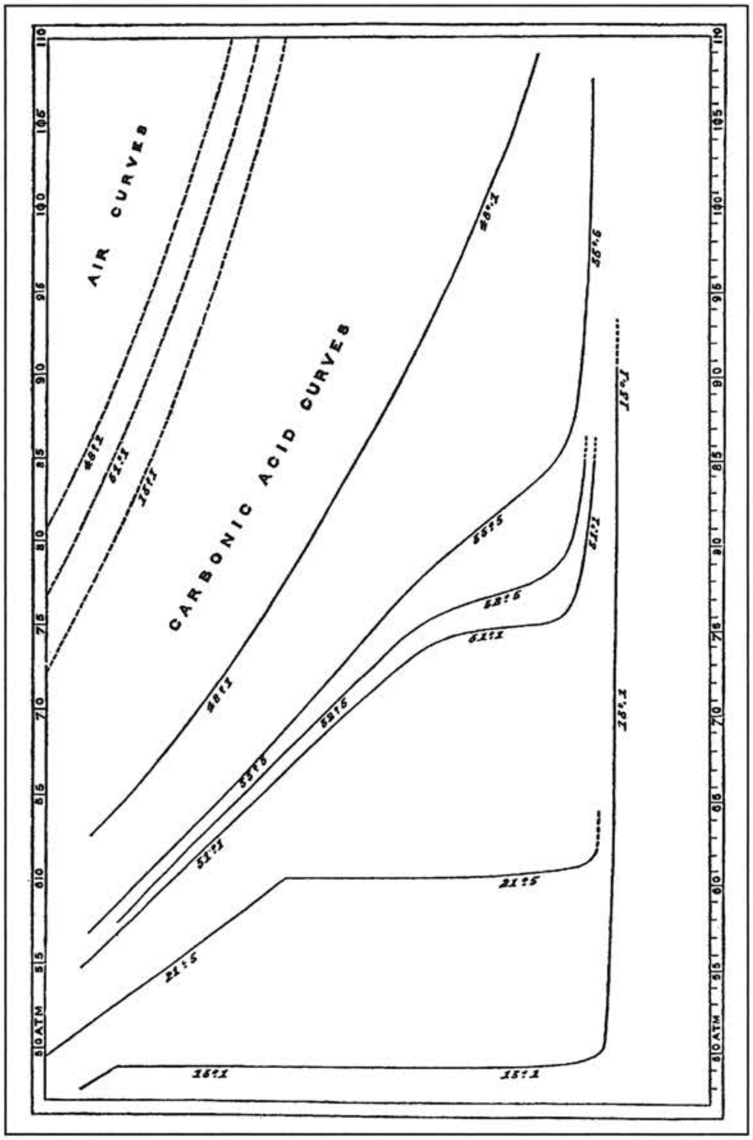
are fused, compressed to *the universe in a grain of sand*, and attributed to Keats. This is a fair measure of his scholarly care and, I suppose, of his literary culture. His own style is smooth enough; he adheres by and large to the usual conventions of contemporary American grammar, although there is a smattering of dangling participles and the occasional blooper. Confronted with an unexpected "like", he panics; the resulting "like you and I" might in earlier, happier times have been caught by his copy-editor.

The book is wretched; there is no group of readers, young or old, lay or professional, to whom I would care to recommend it. Nonetheless, there are several encomiums on the dust-jacket: from Edward Witten, the dean of string theorists, and from a number of authors of what appear to be popularizations of mathematics. They are all of the contrary opinion; they find that it is "written with grace and charm", "readable and entertaining", and so on. Perhaps the book is a hoax, written to expose the vanity of physicists, the fatuity of vulgarizers, the illiteracy of publishers, and the pedantry of at least one priggish mathematician. Would that this were so, for it is certainly thoroughly dishonest, but not to any purpose, rather simply because the author shrinks from nothing in his desperation to be "readable and entertaining".

The lesson to draw for those who have a genuine desire to learn something about mathematics and its history is that the most effective and the most entertaining strategy is to go directly to the sources, equipped with a competent, straightforward guide, say Kline's *Mathematical thought from ancient to modern times* or, for more specific topics, Buhler's *Gauss* and similar studies and, of course, whatever linguistic skills they can muster. To learn about current goals the sources are of little help, and it is up to mathematicians to acquire sufficient understanding of their own field to provide clear and honest introductions. Whether the subject is old mathematics or new, intellectual junk-food just undermines the constitution and corrupts the taste.

Mathematics and Physics

Although this heading is brief, it is far too sweeping. More established areas aside, the dynamics of renormalization by no means exhausts even those domains of mathematical physics in which fundamentally novel conceptual structures are called for. Nevertheless, if what is wanted is encouragement to a broader view of the relation between mathematics and physics than is suggested by *Euclid's Window* and similar books then it is a good place to begin. So, at the risk of seriously overstepping my limits, for the subject is large and my knowledge fragmentary and uncertain, I recall the



From an article of Thomas Andrews, *Proceedings of the Royal Society of London*, vol. 18, no. 114 (1869), pp. 42-45. Shows P-V curves for air and carbonic acid, with the carbonic acid curves near the critical point.

dynamical questions that arise in statistical physics and in quantum field theories.

Thermodynamics and Statistical Mechanics. An historical approach, beginning with the statistical mechanics and even the thermodynamics, is the simplest and perhaps the most persuasive. Fortunately there is a very good book to draw on, Cyril Domb's *The Critical Point*, written by a specialist with wide knowledge and great experience. It would be a superb book, were it not for the high density of misprints, especially in the formulas, which are often a challenge to decipher. Even with this flaw, it can be highly recommended.

Few mathematicians are familiar with the notion of the critical point, although all are aware of the phase transition from the liquid to the gaseous state of a substance. It occurs for pairs of values $(T, P(T))$ of the temperature and pressure where the two states can coexist. It was Thomas Andrews, a calorimetrist in Belfast, who in 1869 first understood the nature of the thermodynamic phenomena at that pair of values for the temperature and pressure at which for ordinary substances, such as water, or in his case carbon dioxide, there ceases to be any difference between the liquid and the gaseous state. More precisely, for a fixed temperature below the critical temperature, as the pressure is increased there comes a point, $P = P(T)$, where a gas, rather than simply being compressed, starts to condense. This is the point at which there is a transition from gas to liquid. When the pressure is large enough, the gas is completely condensed and the substance entirely in the liquid phase, which upon further increase of the pressure continues to be slowly compressed. When, however, T reaches the critical temperature T_c, different for different substances, there ceases to be any sudden change at $P = P_c$, which can therefore only be defined as a limiting value. The liquid at pressures above P_c is not distinguishable from the gas at pressures below. For $T > T_c$, $P(T)$ is no longer even defined. So the curve of values $(T, P(T))$ ends at the critical point. What happens at the curve's other end is not pertinent here as the solid state is not considered.

There is a fascinating phenomenon, critical opalescence, associated with the critical point that the mathematical physicists among the reader's colleagues may or may not be able to describe. If not, I recommend the description in Michael Fisher's contribution to Lecture Notes in Physics, v. 186. Critical opalescence is a manifestation of a statistical mechanical feature of the critical point: the correlation length becomes infinite there. This shows itself in a less flamboyant way as singular behavior at the critical point of various thermodynamic parameters, compressibility or specific heats, although the disturbing influence of gravity renders the experiments difficult. The critical point also appears for magnets, investigated later by Pierre Curie, for which other thermodynamic parameters, susceptibility or spontaneous magnetization, are pertinent. What was understood only much later was the nature of the singularities. They are the focus of the mathematical interest.

The first theory of the critical point, now referred to as a mean-field theory, was proposed within a very few years by van der Waals in his thesis and was warmly greeted by Maxwell, for whom it seems it was an occasion to learn Dutch or Low German, as it was then called, just as earlier, Lobatchevsky seems to have been an occasion for Gauss to begin the study of Russian. The mean-field theories, for gases and for magnets, were in general highly regarded, so highly regarded indeed that almost no-one paid any attention to their experimental confirmation. The critical indices describing the singular behavior are not those predicted by van der Waals, but almost no-one noticed, at least not until the forties, when Onsager, exploiting the spinor covering of orthogonal groups, succeeded in calculating explicitly some critical indices for a planar model of magnetization, the Ising model, and discovered values different than those of mean-field theory.

Suddenly there was great interest in measuring and calculating critical indices, calculating them above all for planar models. A striking discovery was made, *universality*: the indices, although not those predicted by the mean-field theory, are equal—or appear to be for they are difficult to measure—for broad classes of materials or models. Then came the first glimpses, by L. P. Kadanoff, of a dynamical explanation. At the critical point, the material or the model becomes in a statistical sense self-similar, and the behavior of the critical indices is an expression of the dynamics of the action of dilation on the system.

The probabilistic content of statistical mechanics is determined by the Boltzmann statistical weight of each state, an exponential with a negative exponent directly proportional to its energy and inversely proportional to the temperature. The energy will usually be an extensive property that depends on the interactions defined by a finite number of parameters and by a finite number of local properties such as the magnetization. The basic idea of the dynamical transformation is that, because it is only the statistics that matter, small-scale fluctuations can be averaged and substantial chunks of the system, blocks, can be reinterpreted, after a change of scale, as small uniform pieces with well-defined local properties.

It appears to have been K. G. Wilson who turned this idea into an effective computational tool, the renormalization group, and it is probably his papers that it is most important that analysts read, for the success of the renormalization-group method is a result of a basic property of the associated (infinite-dimensional) dynamical system: at certain fixed points, the pertinent ones, there are only a finite number, usually one, two or three, of unstable directions (or, more precisely, a finite number, perhaps larger, of nonstable directions). All other directions are contracting and indeed most of them strongly so. A model, depending on parameters, temperature, pressure, or magnetic field, appears as a point in the space of the dynamical transformation. A critical point appears as the parameters are varied and the corresponding point traverses a stable manifold. Because the manifold is stable and because it is the transformation that determines the properties of the system, all questions can be referred to the fixed point in it. This is the explanation of universality.

To establish such a theory for even the simplest of planar models, percolation for example, is a daunting mathematical challenge—in my view central. For other planar models, it is not even clearly understood what the dynamical system might be; indeed on reflection it is clear that the very definition of the dynamical transformation relies on the property to be proved. So if there is a theory to be created, its construction will entail a delicate architecture of difficult theorems and subtle definitions. My guess is that there may be a lot to be learned from Wilson, who after all must have been able at least to isolate the expanding directions sufficiently to permit effective calculations, but this guess is not yet based on much knowledge of his papers.

Quantun Field Theories. In quantum field theory exactly the same dynamical structure of a finite-dimensional unstable manifold and a stable manifold of finite codimension plays a central role in the construction, by renormalization, of theories like quantum electrodynamics. Indeed it is sometimes possible to pass, by an analytic continuation in an appropriate parameter, from statistical mechanics to quantum field theories, but a direct approach to them is often more intuitively appealing.

The field theory is a much more complex object in which the algebra takes precedence over the analysis, most analytic problems being, apparently, so difficult that they are best left unacknowledged. In statistical mechanics there is an underlying probability space, say (X, μ). A related space—there is a conditioning by time—appears in field theories. It is enormous. In addition to functions on X, whose expectations are the pertinent objects in statistical mechanics and which act on $L^2(\mu)$, there are in a field theory many other operators as well, to monitor the symmetries or to implement creation and annihilation of particles. So temporal evolution in a field theory is more easily grasped directly than as an analytic continuation of some stochastic process. Seen most simply, it arises from a constant creation and annihilation of particles, anti-particles and fields, most created only to last for a very short time and then to be destroyed again.

The difficulties of the theory lie in these processes and its appeal to mathematicians in the constructs necessary to surmount the difficulties. The theory is usually prescribed by a Lagrangian, $\mathcal{L}$, which can perhaps be thought of as a prescription for the probabilities with which the elementary processes of creation or annihilation occur, when, for example, an electron and a photon collide to produce an electron of different energy and momentum or an electron and a positron collide, annihilate each other, and produce a photon. The distinction between an elementary process and a compound process is to a large extent arbitrary. We do not observe the processes occurring, only their outcome, so that what for one theory is purely compound may for another, equivalent theory be partly compound, partly elementary; for example, two electrons exchanging a photon, and then emerging from this intimate encounter with changed momenta could be elementary or it could be the composition of two electron-photon interactions, or an electron could briefly separate into an electron and a photon, that then fused into a single electron. Infinities arise because the elementary processes that enter into a compound process, being unobserved, can occur at all energies and momenta; the usual relation between energy, mass and momentum is violated.

One way to attempt to surmount this difficulty is to allow only elementary processes with momenta and energy that are no larger than some prescribed constant Λ. This provides numbers $\mathcal{G}_\Lambda(\mathcal{L})$ that are finite, although perhaps inordinately large, for every conceivable process, thus, otherwise interpreted, for every conceivable scattering of an arbitrary number of incoming particles, with whatever momenta and energy they are allowed, as a collection of outgoing particles, although the distinction between ingoing and outgoing is to some extent arbitrary. In the numbers $\mathcal{G}_\Lambda(\mathcal{L})$, referred to as the amplitudes, the distinction between an elementary and a compound process is lost, except of course for $\mathcal{G}_0(\mathcal{L})$ which are just the amplitudes prescribed by the Lagrangian itself. To obtain a true theory, it is necessary to take Λ to infinity, but if the numbers $\mathcal{G}_\Lambda(\mathcal{L})$ are to have finite limits, it may be necessary to adjust simultaneously the parameters in the original Lagrangian, thus in the initial prescription, so that they go to infinity. Since the initial prescription was made on the basis of an arbitrary distinction between elementary and compound process, this is not so paradoxical as it at first appears.

The source of the success of this method is ultimately the same dynamic property as in statistical mechanics. For large Λ the transformation $\mathcal{L} \to \mathcal{L}'$ defined by requiring for all processes the equality of the amplitudes $\mathcal{G}_\Lambda(\mathcal{L}) = \mathcal{G}_0(\mathcal{L}')$ operates in essence only on an unstable subspace of very small dimension, other directions being strongly contracted. Moreover, a finite set of amplitudes $\mathcal{G}^i(\mathcal{L})$, $1 \le i \le n$, can be chosen as coordinates on this space. Thus for large Λ, we can choose $\mathcal{L}_\Lambda$ in a fixed space of dimension n so that $\mathcal{G}^i_\Lambda(\mathcal{L}_\Lambda)$ has any desired values for $i = 1, \dots, n$. In the end, as $\Lambda \to \infty$, the Lagrangian $\mathcal{L}_\Lambda$ sails off backwards in the stable directions, but the amplitudes $\lim \mathcal{G}^i_\Lambda(\mathcal{L}_\Lambda)$ and, more generally, because of the stability, all $\lim \mathcal{G}_\Lambda(\mathcal{L}_\Lambda)$ remain finite and define the theory. This is a crude geometric or dynamical description of what is in reality a very elaborate process: renormalization as it appears, for instance, in quantum electrodynamics. Nevertheless the dynamics is paramount.

The dynamics looks even more doubtful than in statistical mechanics because there is now a whole family of transformations, one for each Λ. That can be remedied. If μ is smaller than Λ, then it is relatively easy to find $\mathcal{L}_\mu$ such that $\mathcal{G}_\mu(\mathcal{L}_\mu) = \mathcal{G}_\Lambda(\mathcal{L}_\Lambda)$. The pertinent map is

$$R_\nu : \quad (\mathcal{L}, \Lambda) \to (\mathcal{L}_\mu, \mu), \qquad \nu = \frac{\mu}{\Lambda}.$$

These maps form a semigroup in ν, which is always less than 1. The presence of the second parameter is disagreeable but seems to be tolerable. There is now much more to be moved by the maps: the Hilbert space and all the attendant operators. It is not yet clear to me how this is done, but it is a process with which physicists appear to be at their ease. In addition, in the standard model of particle physics as well as in many of the geometric applications that appeal to mathematicians (see the lectures of Witten in the collection of surveys *Quantum fields and strings: a course for mathematicians*, two volumes that are indispensable when first trying to understand quantum field theory as a mathematical subject) it is gauge theories that occur and the renormalization and the dynamics have to respect the gauge invariance.

It appears—I have not understood the matter—that just as the heat equation can be used to establish various index theorems or fixed-point theorems by comparing traces near $t = 0$ and near $t = \infty$ where they have quite different analytic expressions, so does, by a comparison of calculations at low and high energies, the dynamics of quantum field theory, which moves from one to the other, allow the comparison of quite different topological invariants: the Donaldson invariants and the Seiberg-Witten invariants. My impression, but it is only an impression, is that a number of the applications to topology or to algebraic geometry involve similar devices. If so, that is perhaps one reason, but not the sole reason, for attempting to establish analytic foundations for the procedure.

String Theory. In string theory, there are even more ingredients to the dynamics. Grossly oversimplifying, one can say that the particles are replaced by the states of a field theory on an interval, thus by the modes of vibration of a string in a space M of dimension D, at first arbitrary. This is only the beginning! There is even at this stage a good deal of implicit structure that reveals the special role of $D = 10$ and $D = 26$: conformal field theory and supersymmetry above all. Moreover, the Feynman diagram is thickened; rather than a graph with vertices and edges, it becomes a surface with marked points. Finally the Lagrangian, which could be thought of as simply a finite collection of numbers, one attached to each of the different types of vertex, is now described by a minkowskian metric of signature $(1, D-1)$ on the space M, so that there appears to be an infinite number of free parameters. It has, however, been pointed out to me that the apparently free parameters are rather dynamical variables. As in the general theory of relativity, this background metric tensor is to be treated as a collection of fields, thus as a collection of dynamical variables, and, as a consequence, it is subject to a quantization. So there are no arbitrary parameters in the theory!

When discussing statistical mechanics, we emphasized the critical point, but the dynamical transformation bears on other matters as well. It will reflect, in particular, the abrupt change from a gas to a liquid at temperatures below the critical temperature or the possibility of spontaneous magnetization: very small changes in the imposed magnetic field entail very large differences in the induced magnetization, not merely in size but also in direction. The dynamics is moving points apart as $\nu \to 0$. Analogues in field theory are multiple vacua or, in string theory, the great variety of low-energy (small ν) limits. So the arbitrary parameters appear to resurface!

Certainly, in string theory the analytic problems that it is fair to regard as central mathematical, although perhaps not physical, issues in statistical mechanics recede—for the moment at least—into the background. They are not entirely unrelated to the problem of choosing among the vacua and thus of constructing a single distinguished physical theory rather than a family of theories, a problem that also seems to be in abeyance at the moment. Such matters are far over my head. The issues of most current appeal in mathematics, and to a lesser extent in physics, are algebraic or geometric, perhaps above all geometric: the transitions from one family of low-energy theories to another; or the possibility—another low-energy phenomenon—that different spaces M and different background metrics on them lead to the same theory (mirror symmetry and other dualities).

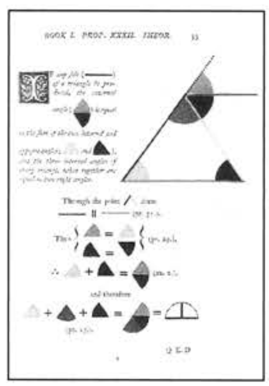
About the Cover

This month's cover accompanies Robert Langlands' review of the book "Euclid's Windows". It is taken from the version of the first six books of Euclid's *Elements* produced in 1847 by the amateur (and, some say, crank) mathematician Oliver Byrne. This remarkable book was published by the firm of William Pickering and printed at the Chiswick Press; these two companies were well known at that time for working together to produce fine books. The illustration shows in entirety Byrne's graphical proof of Proposition 32 of Book I, which asserts that the angles in a triangle add up to two right angles. Byrne's Euclid is well known to bibliophiles for its extraordinary wood-engraved color illustrations, but perhaps not so well known as it might be among mathematicians. It is not always successful in its aims of improving traditional exposition, but the excerpt displayed here seems lucid as well as attractive.

Little seems to be known about the exact conditions under which the book was produced, but the amount of effort and expense involved, presumably by both Byrne and the publishers, suggests that in the nineteenth century there was expected to be an audience for Euclidean geometry quite different from what we would now expect in our own culture. Unfortunately, the book was not in fact a financial success, although the reasons for this are not clear.

Our thanks to Richard Landon, director of the Thomas L. Fisher Rare Book Library at the University of Toronto, for providing the image.

—*Bill Casselman* (`covers@ams.org`)



NSF Fiscal Year 2003 Budget Request

This article is the 30th in a series of annual reports outlining the president's request to Congress for the budget of the National Science Foundation. Last year's report appeared in the August 2001 issue of the *Notices*, pages 705–708.

Last fall, Congress passed the appropriations bill providing money for the National Science Foundation (NSF) for fiscal year 2002, which runs from October 2001 through September 2002. Buried in the conference report for the bill, amid discussions of funding for high-profile projects like telescopes and particle colliders, is this statement: "The conferees have also placed a high priority on mathematics research within the amounts provided for this activity." This small statement is having a big impact on the mathematical sciences, for it has translated into a $30 million increase in NSF spending in this area.

Each year, on the first Monday in February, the federal budget cycle begins when the president sends his budget request to Congress for the next fiscal year, which starts the following October. The fiscal year 2002 request was delayed from February to April 2001, due to the change in administration. That request was not kind to science. The NSF stood to gain only a miserly 1 percent, although even in that lean budget the NSF's Division of Mathematical Sciences (DMS) was singled out for a substantial rise. As criticism came from many quarters about the paltry increases for science throughout the budget request, and as the events of September 11 underscored the need for scientific research to bolster the nation's defenses, Congress decided to put more money into science. As a result, the fiscal year 2002 federal budget, when it was finally enacted by Congress last fall, included an 8.4 percent increase for the NSF, and science budgets rose across the federal government. And the budget for the DMS surged past its requested level, climbing to $151.5 million, an increase of 24.7 percent.

The increases for the DMS have resulted from a mathematical sciences initiative (now being called a "priority area"), which was approved in October 2000 by the National Science Board, the NSF's policymaking body. The influence of this initiative can also be seen in the fiscal year 2003 budget request, which was sent to Congress on February 4, 2002. Although the requested increase for the NSF overall is only 5 percent, the DMS would receive a $30 million hike, amounting to a 20 percent rise for the division and bringing its total budget to $181 million for fiscal 2003. There has been "a recognition and an identification of the mathematical sciences as a priority area, with implications that 2003 is one increase in several to follow," said Philippe Tondeur, director of the DMS. "This may change the landscape of mathematical sciences funding by the NSF."

How did the mathematical sciences initiative come about? According to Samuel M. Rankin III, director of the AMS Washington Office, some of the groundwork was laid by Donald J. Lewis of the University of Michigan, when he was director of the DMS from 1995 to 1999. Lewis launched some innovative programs, such as VIGRE (Vertical Integration of Research and Education), that had a large impact in the mathematical sciences community and high visibility within the NSF. In addition, Rankin noted, then-AMS president Arthur Jaffe of Harvard University worked hard to convey the importance of the mathematical sciences to the upper echelons of the NSF. In September 1998, biologist Rita Colwell was named director of the NSF, and she has become an enthusiastic champion for the mathematical sciences. Jaffe invited her to speak at the May 1999 inauguration of the Clay Mathematics Institute, a philanthropic organization he heads. "From that time on, she really started talking a lot about mathematics," Rankin recalled. Then Tondeur came to the NSF in the summer of 1999 and aggressively began making the case for strong NSF support of the mathematical sciences. "On a daily basis, Tondeur is pushing mathematics, and he has done an excellent job working the system," Rankin said.

DMS Plans for Fiscal 2002

One way the DMS plans to use its fiscal year 2002 increase is in making three new awards for mathematical sciences institutes, bringing to six the total number of institutes funded by the DMS (the existing three are the Mathematical Sciences Research Institute in Berkeley, the Institute for Mathematics and its Applications at the University of Minnesota, and the Institute for Pure and Applied Mathematics at the University of California, Los Angeles). At the time of this writing, the awards were still in the process of negotiation and the locations and natures of the new institutes had not been announced. During fiscal year 2002, the new institutes will receive start-up funding and will come to full funding only in fiscal 2003. The current plan for fiscal year 2002 calls for the DMS to spend $12.8 million on institutes; the fiscal year 2003 request raises this amount to $14.0 million. The DMS is also contributing to a mathematical sciences institute established last year in Canada, the Banff International Research Station (BIRS). However, the DMS contribution to BIRS is much less than for the U.S. institutes: $1.3 million over four years. Primary funding for BIRS comes from the Canadian government and the province of Alberta.

In arguing for increases for mathematics, Tondeur has emphasized three themes—interdisciplinary research, fundamental research, and education—and these can be seen in the DMS plans for spending its $30 million increase for fiscal year 2002. Under the banner of interdisciplinary research, the DMS has issued calls for proposals for "partnership" programs in three areas. The first is designed to stimulate work at the interface of mathematics and biology and is jointly funded by the DMS (which is contributing $2 million) and the National Institute of General Medical Sciences (which is contributing $4 million). The second partnership focuses on mathematics and the geosciences, with an initial emphasis on analyzing and modeling geosystems that contain a broad range of interacting scales. For this partnership, the DMS and the NSF's Geosciences directorate will each contribute $2 million. The third partnership is called CARGO (Computational and Algorithmic Representation of Geometric Objects) and has three sponsors: the DMS ($1.5 million), the NSF's Computer and Information Science and Engineering directorate ($1.5 million), and the Defense Advanced Research Projects Agency ($1 million).

Under the theme of fundamental research, the Focused Research Groups (FRGs) program will go from $9 million in fiscal 2001 to $12 million in fiscal 2002. The DMS has always funded group grants, but often the researchers on such grants have only loose collaborative ties. To be funded under the FRG program, a proposal must justify how the group can together achieve things that would not be possible with the individual researchers working alone. Tondeur pointed to the earlier effort to classify all finite simple groups as an example of a project that required intensive group work. In fiscal year 2001, the DMS funded ten FRGs, and Tondeur said the number will increase in fiscal year 2002. Some FRGs involve researchers from other disciplines and are jointly funded with other NSF divisions.

The heart of the DMS portfolio in fundamental research remains its disciplinary programs, which emphasize individual research grants: Algebra, Number Theory, and Combinatorics; Analysis; Applied Mathematics; Computational Mathematics; Statistics and Probability; and Geometric Analysis, Topology, and Foundations. Tondeur said that in fiscal year 2002, increases for the disciplinary programs "will be bigger than ever before," with all the programs receiving increases in the 9 to 16 percent range. Further increases are also projected for fiscal year 2003. These increases, he indicated, have come as a result of the diversification of the DMS portfolio. "The programs get better increases in a diversified strategy than in any other way," he said. And, "the fact that we have diversified our portfolio has made us more attractive for increased investments." He pointed out that opportunities for research support will also increase through the FRGs and the partnership grants, which fund researchers in much the same way as individual grants do. According to an NSF "fact sheet" about the mathematical sciences initiative, the fiscal year 2003 budget request would allow the DMS to support 2,000 individual investigators (including some working in teams), 300 postdoctoral scholars, and 1,300 graduate students.

Rankin noted that, when it comes to increases for individual grants, the NSF tends to emphasize upping grant size and duration, but rarely mentions raising the total number of grants. "Nobody ever tries to sell that," he remarked. Now, though, the Coalition for National Science Funding (CNSF) has taken up the cause. The CNSF, which Rankin currently chairs, is an alliance of over ninety universities and scientific and professional societies that have banded together to support the goal of increasing the NSF budget. The CNSF has issued a statement outlining what it believes should be priorities for the fiscal year 2003 NSF budget. At the top of the priority list is an increase of $220 million for funding for core programs in research and education. "Presently, 13 percent of highly rated proposals to NSF are not funded due to lack of funds," the statement says. "The proposed increase would...enable more highly rated proposals to be funded, allowing NSF to meet unrealized opportunities in core research and education."

The main showpiece for the DMS educational theme is the VIGRE program. VIGRE supports innovative projects in mathematical sciences departments, in which research and education are integrated through interactions among undergraduates, graduate students, postdoctoral fellows, and faculty. There are currently thirty-one VIGRE grants active. The DMS recently completed an assessment of the projects funded during the first year of VIGRE and has decided to terminate some of those grants and also to fund some new ones. In fiscal year 2002, the DMS will spend about $16 million on VIGRE. The program will remain an important part of the DMS portfolio, but Tondeur said he cannot anticipate what the level of funding for fiscal year

2003 will be until the proposals come in for the next deadline for the program, which is in July 2002. As Tondeur put it, "there is no prescribed growth model for VIGRE."

The VIGRE program has brought a mixed reaction from the mathematical sciences community. At the Joint Mathematics Meetings in San Diego in January 2002, Rankin went to a VIGRE focus group attended by about twenty-five directors of graduate programs (or their representatives). Based on the reactions at the focus group, Rankin reported, it appears that some departments feel pressure to go after VIGRE grants simply in order to remain competitive with those departments that already have the grants. VIGRE provides good support for graduate students, and departments without the grants find they are at a disadvantage in attracting qualified students. At the same time, because students supported on VIGRE grants must be U.S. citizens, departments that have the grants find that the pool of well-qualified U.S. students is too small. VIGRE-supported students are not permitted to teach, so some departments with VIGRE grants find they have to bring in graduate students from other disciplines to teach mathematics classes. As Rankin summed up the general reaction, "VIGRE presents as many dilemmas and problems as positive attributes."

Math a Priority in 2003

Scanning through the fiscal year 2003 request, one finds that the DMS stands out among the NSF divisions as having one of the highest requested increases. Within the Mathematical and Physical Sciences (MPS) directorate, the DMS is clearly the big winner: The request calls for cuts for all of the other disciplinary divisions in the MPS, and overall the directorate's budget would rise only 2.3 percent. Another big increase is seen in the Math and Science Partnerships program, begun in fiscal year 2002 in the Education and Human Resources directorate (this program is separate from the partnerships established in the DMS). The program's budget would rise from $160 million to

Table 1: National Science Foundation (Millions of Dollars)

	1999 Actual	Change	2000 Actual	Change	2001 Actual	Change	2002 Plan	Change	2003 Request
(1) Mathematical Sciences Research Support	$ 100.7	5.3%	$ 106.0	14.5%	$ 121.4	24.8%	$ 151.5	20.1%	$ 181.9
(2) Other Research Support (Note a)	2777.6	7.2%	2978.9	13.1%	3370.2	6.4%	3586.0	3.9%	3727.6
(3) Education and Human Resources (Note b)	662.5	3.2%	683.6	16.3%	795.4	10.0%	875.0	3.8%	908.1
(4) Salaries and Expenses (Note c)	149.5	3.6%	154.9	11.6%	172.9	6.1%	183.5	18.9%	218.2
(5) Totals	$3690.3	6.3%	$3923.4	13.7%	$4459.9	7.5%	$4795.9	5.0%	$5035.8
(6) (1) as a % of the sum of (1) and (2)	3.50%		3.44%		3.48%		4.05%		4.65%
(7) (1) as a % of (5)	2.73%		2.70%		2.72%		3.16%		3.61%

Note a: Support for research and related activities in areas other than the mathematical sciences. Includes scientific research facilities and instrumentation and the Antarctic program. **Note b:** Support for education in all fields, including the mathematical sciences. Does not include funds collected through H1-B Nonimmigrant Petitioner receipts. **Note c:** Administrative expenses of operating the NSF, including the Office of the Inspector General.

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

	1999		2000		2001		2002		2003	
	Actual	% of Total	Actual	% of Total	Actual	% of Total	Plan	% of Total	Request	% of Total
(1) Mathematical Sciences	$100.7	13.7%	$106.0	14.0%	$121.4	14.2%	$151.5	16.5%	$181.9	19.3%
(2) Astronomical Sciences	118.5	16.1%	122.5	16.2%	148.7	17.4%	165.9	18.0%	161.2	17.1%
(3) Physics	162.7	22.2%	168.3	22.3%	187.5	22.0%	195.9	21.3%	193.3	20.5%
(4) Chemistry	135.3	18.4%	138.6	18.3%	154.3	18.1%	162.9	17.7%	160.8	17.1%
(5) Materials Research	186.4	25.4%	190.5	25.2%	209.7	24.5%	219.5	23.8%	219.3	23.3%
(6) Office of Multidisciplinary Activities	29.9	4.1%	29.9	4.0%	32.4	3.8%	24.8	2.7%	25.0	2.7%
(7) Totals	$733.6	100%	$755.9	100%	$854.1	100%	$920.4	100%	$941.6	100%

$200 million in fiscal year 2003; plans call for funding for the program to reach about $1 billion in five years. "The [Partnerships program] brings states and local school districts together with the science, engineering, mathematics and education departments of institutions of higher education to strengthen pre-K–12 math and science education," the budget request states. "The partnership also aims to increase the number, quality and diversity of pre-K–12 math and science teachers."

The request identifies six main "priority areas," one of them being the mathematical sciences initiative (the change in terminology from "initiative" to "priority area" is due to the new administration's decree that the government take on "no new initiatives"). The other five are Biocomplexity in the Environment; Information Technology Research; Nanoscale Science and Engineering; Learning for the Twenty-first Century; and Social, Behavioral, and Economic Sciences. Among these six, the mathematical sciences initiative has the largest percentage increase, though in dollar amount it is much smaller than some of the others. Funding for the mathematical sciences initiative would increase from $30.0 million in fiscal year 2002 to $60.09 million in fiscal year 2003. The budget request also outlines long-term funding for the initiative, which would reach $109.5 million by 2007. However, given the realities of year-to-year budgeting by the government, such long-term plans are notoriously difficult to carry out.

How does the requested increase for the mathematical sciences initiative relate to the DMS budget? For fiscal year 2002, the entire $30.0 million investment in the initiative went to the DMS, whereas the fiscal year 2003 investment of $60.09 million would be spread across eight NSF directorates; for example, $0.91 million would go to the Biological Sciences directorate, and $2.74 million would go to the Education and Human Resources directorate. Most of the increase, though, would be concentrated in the MPS, whose investment in the mathematical sciences initiative would increase by $17.39 million and total $47.39 million in fiscal year 2003. The entire $17.39 million increase would go to the DMS. The total requested increase for the DMS for fiscal year 2003 is $30.39 million. Therefore, the request provides for a $13.0 million increase for the DMS apart from the mathematical sciences initiative.

New Opportunities Ahead

With the increase for the DMS for fiscal year 2002 and the likelihood of more such increases in coming years, Tondeur sees a bright future for support of the mathematical sciences. "I hope researchers will find it's a wonderful playing field and will do extraordinary things with these extraordinary opportunities," he said. "In particular, I hope the improved landscape will encourage young people to join this glorious profession."

Tondeur's tour of duty in the DMS ends on July 31, 2002, and, despite his clearly successful time there, he has vowed not to stay past that date. Right now the NSF is looking for a replacement. "During the three years of my tenure at the helm of DMS, the NSF leadership has been extremely supportive of the mathematical sciences, increasing the DMS budget requests by 70 percent over this period," he said. "I hope for a successor who will be able to build on this effort."

—*Allyn Jackson*

The NSF fiscal year 2003 budget request is available at the website http://www.nsf.gov/bfa/bud/fy2003/start.htm.

Table 3: Compilation of NSF Budget, 1997–2003 (Millions of Dollars)

	1997 Actual	1998 Actual	1999 Actual	2000 Actual	2001 Actual	2002 Plan	2003 Request	1997–2001 Change	1997–2003 Change
(1) **Mathematical Sciences Research Support**	$ 92.9	$ 93.6	$ 100.7	$ 106.0	$ 121.4	$ 151.5	$ 181.9	30.7%	95.8%
Constant Dollars	*57.9*	*57.4*	*60.4*	*61.6*	*68.5*			*18.3%*	
(2) **Other Research Support (Note a)**	2447.2	2557.2	2777.6	2978.9	3370.2	3586.0	3727.6	37.7%	52.3%
Constant Dollars	*1524.7*	*1568.8*	*1667.2*	*1729.9*	*1903.0*			*24.8%*	
(3) **Education and Human Resources (Note b)**	619.1	633.2	662.5	683.6	795.4	875.0	908.1	28.5%	46.7%
Constant Dollars	*385.7*	*388.5*	*397.7*	*397.0*	*449.1*			*16.4%*	
(4) **Salaries and Expenses (Note c)**	139.6	141.7	149.5	154.9	172.9	183.5	218.2	23.8%	56.3%
Constant Dollars	*87.0*	*86.9*	*89.7*	*89.9*	*97.6*			*12.2%*	
(5) **Totals**	$3298.8	$3425.7	$3690.3	$3923.4	$4459.9	$4795.9	$5035.8	35.2%	52.7%
Constant Dollars	*2055.3*	*2101.7*	*2215.1*	*2278.4*	*2518.3*			*22.5%*	

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

For Notes a, b, and c, see Table 1.

The Universe in a Nutshell

Reviewed by Steven G. Krantz

The Universe in a Nutshell
Stephen Hawking
Bantam Books, New York, 2001
ISBN 0-553-80202-X
$35.00, 216 pages

Along with Andrew Wiles and Linus Pauling, Stephen Hawking is one of the very few modern scientists whose name is a household word. Hawking, the Lucasian Professor of Mathematics (Isaac Newton's chair) at Cambridge University, has an insight and an imagination that soar across the cosmos, devising dreams and schemes of how the universe works. The legend of Hawking is of course immensely augmented by the fact that he is afflicted with motor neurone disease (commonly known in the U.S. as "Lou Gehrig's Disease"). In fact he has known that he had the disease since the age of twenty-one (Hawking is now sixty). He did not expect to live to the age of twenty-five and was tempted to despair. Instead, by his own telling, the knowledge of having this deadly illness gave him courage and hope and a will to live. It took his aimless and futile life (which Hawking himself has described elsewhere in painful and shamefaced detail) and gave it direction and purpose. And he has applied that newfound *Gestalt* to the development of ideas in theoretical physics.

To read any of Hawking's many books, one would never realize just how devastating

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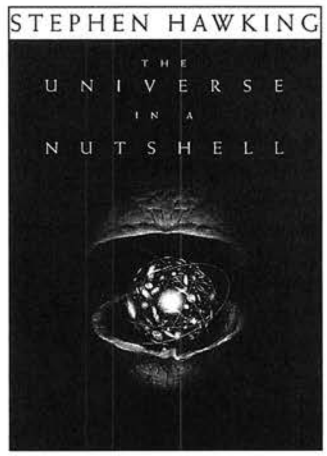

Hawking's illness is. He speaks of it only rarely and as if it were just a minor inconvenience. However, his friend Roger Penrose has told me quite frankly that it requires an army of people just to keep Hawking going: He cannot speak, he cannot walk, he cannot pick up a pen, and he cannot even breathe on his own. Hawking's popular writing is redolent of joy and good humor and great high spirits. One cannot but think that the world would be a better place if we all had the good and optimistic frame of mind of Stephen Hawking. His is truly a profile in courage.

Stephen Hawking's *A Brief History of Time* [HAW] has been a publishing phenomenon. Penned in 1988, it spent more than four years on the bestseller lists and sold more than ten million copies in forty languages. As Hawking's postdoc Nathan Myhrvold (of Microsoft fame) has said, Hawking has sold more books on physics than Madonna has on sex. Part of the appeal of *Time* is the Hawking mystique, but a considerable part of its charm is the breezy and friendly style in which the book is written. Like mathematics, physics is stark and rigorous and forbidding, enshrouded by technical lingo and recondite ideas. Although "relativity", "the uncertainly principle", "the speed of light", and "black holes" hold great charm and fascination for the layman, most writings on these topics are either facile and incorrect or onerous and obscure. Hawking forges a brilliant path between these two extremes. Obviously everything he says is authoritative and accurate; in those instances where he must blow smoke, he is quite honest about it and still gives the reader a sense of what is going on. Hawking uses analogy and humor and example and metaphor to depict his ideas in an attractive and compelling manner.

So if *A Brief History of Time* is the be-all and end-all of the popular conception of cosmology, then why is there any need for another book? Well, publishers like to sell books; and Stephen Hawking is a best-selling author. But let us be more charitable. By Hawking's own telling, *Time* is a tough go for the untrained reader. As I was reading the book's description of the forward and backward light cones, I was struck by how simple and obvious these ideas are to a trained scientist (like myself), and how utterly obscure they must be to a tyro. The rather more expensive "illustrated edition" of *Time* has many attractive graphics, but the original and widely disseminated first edition has only a few simple line drawings. As a result, and in spite of its immense popularity, the book comes off as a bit dry and uninviting. The common wisdom is that millions bought the book, but few have gotten past the first twenty pages.

Enter *The Universe in a Nutshell.* In his preface, Hawking acknowledges the difficulties noted in the preceding paragraph and touts the importance of good pictures. This new book, he claims, will be much more accessible to the lay reader. He points out, wisely I think, that *Time* is written in a linear order—just like a mathematical monograph. Chapter $n + 1$ in *Time* depends strictly on Chapters 1 to n. Of course the mathematical scientist is accustomed to this type of vertical development. The average reader is not. In a much-read article [THU] on mathematics education, William Thurston points out that mathematics is a "tall subject." The student painstakingly climbs up the pole to the point where he loses his grip, and then he falls down (never to rise again). Thurston argues for the value of making mathematics a "wider subject" with a broad-based infrastructure. Hawking has got this message. In his new book, his organization pattern is a tree: After the introductory material, the book branches out in several different directions. The reader may dip into the succeeding chapters at will and jump around as interest and inclination dictate. Perhaps more important is that *Nutshell* has marvelous figures, many of them in full color. These are pictures (very elementary ones) of scientific ideas, or of equations, or of the scientists themselves. There are sidebars on Kurt Gödel and Kip Thorne and Richard Feynman and John Wheeler and *Star Trek* and any number of other familiar people and topics. The book is just plain fun. Even when the casual reader gets lost, and he certainly will, he will be encouraged and carried along by the graphics and by the verbal byplay that accompanies the more serious text proper. An added feature is that the book has a concise and useful glossary. Many a reader will have difficulty keeping track of terms and ideas, and this tool will certainly keep many an aficionado going.

There are perhaps those who will criticize *Nutshell* for not being sufficiently serious. Popular singer/songwriter Neil Sedaka says that people fault him for having too much fun with his music. Certainly Hawking has tremendous fun with his physics. A few sample passages suggest the overall tone:

> Newton occupied the Lucasian chair at Cambridge that I now hold, though it wasn't electrically operated in his time.
>
> This [time dilation as explained by relativity theory] might suggest that if one wanted to live longer, one should keep flying to the east so that the plane's speed is added to the earth's rotation. However, the tiny fraction of a second one would gain would be more than canceled by eating airline meals.
>
> ...I estimate the probability that Kip Thorne could go back and kill his grandfather [using time travel] as less than one in ten with a trillion trillion trillion trillion trillion zeroes after it. That's a pretty small probability, but if you look closely at the picture of Kip, you may see a slight fuzziness around the edges. That corresponds to the faint possibility that some bastard from the future came back and killed his grandfather, so he's not really there.

The reader of this review can surely see that I am a great admirer of Stephen Hawking. His strength and his courage and his exuberance are both infectious and inspiring. But I also appreciate the tremendous intellectual effort that it takes to explain a subject as technical and deep as cosmology to the lay public. It takes real gifts, and tremendous determination, to pull this off. It requires a certain amount of *chutzpah* even to try it. The likelihood of failure is considerable, and the likelihood of embarrassment before one's colleagues is huge. Yet we in the mathematical sciences have suffered in the public eye, have suffered in the derby for funding, and have suffered among the sciences because we have not been willing to take these risks. I can only hope that we will all see Stephen Hawking as a role model and that we will therefore try—even in a small way, perhaps by consenting to an interview with the campus newspaper—to communicate as Hawking has. There is much to be gained, and the risks are well worth it. Now that Hawking has forged the path, it is much easier for the rest of us to follow.

Hawking confesses that when he wrote *A Brief History of Time* he felt that physicists were on the verge of a great overarching theory that would, in particular, reconcile general relativity with quantum mechanics. Part of the purpose of the present book is to bring the reader up to date with progress on this unified theory in the past thirteen years. Hawking addresses this goal by way of describing various avenues of research that he, himself, has pursued. This of course makes perfect sense, and he does a splendid job of giving the reader a feel for p-branes, string theory, Feynman's multiple histories, black holes, and many other cutting edge ideas. I am not at all sure that, having labored through the book, the reader will have a clear idea of where we are now as compared to where we were in 1988. One is tempted at this point to compare Hawking's new book with Brian Greene's *The Elegant Universe* [GRE]. Greene states point blank in his preface that "... physicists believe that they have finally found a framework for stitching these insights together into a seamless whole—a single theory that, in principle, is capable of describing all physical phenomena." He then proceeds to spend 387 pages telling us (by way of superstring theory and the like) how the physicists have achieved this end. Greene is less interested in entertaining us than in telling a very serious story. As a result, his book is rather more cerebral and ponderous than Hawking's. It has nevertheless been well received and has certainly acquainted a broad cross-section of the populace with some important scientific developments. But the book is perhaps more austere than even *A Brief History of Time*. It contains much more solid information than, and will reach a much more limited audience than, *The Universe in a Nutshell*. This is a trade-off with which both authors should be comfortable.

The Universe in a Nutshell has many features going for it. Like *A Brief History of Time*, it has a delightfully wry and enticing title. It draws the reader in quickly and painlessly and sustains him with wit and popular touchstones and fun. The reader of *Nutshell* will know, because Hawking has told him quite explicitly, that we have not yet reached our goal of a unified theory and that we probably never will. To Hawking's mind, and to mine as well, this is all to the good because the journey is much more enthralling than the finish. The reader of *Nutshell* will have been left with many opened doors and unanswered questions, and this is clearly how Hawking wants it. Readers of his next book will have all the necessary prerequisites.

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[THU] W. P. Thurston, Mathematical Education, *Notices* **37** (1990), 844–850.

AWM Awards Presented in San Diego

The Association for Women in Mathematics (AWM) presented two awards during the Joint Mathematics Meetings in San Diego in January 2002.

Louise Hay Award

The Louise Hay Award for Contributions to Mathematics Education was established in 1990 to honor the memory of Louise Hay, who was widely recognized for her contributions to mathematical logic and her devotion to students.

The 2002 Hay Award was presented to ANNIE SELDEN of Tennessee Technological University. She received the award for "her outstanding scholarly contributions to undergraduate mathematics education, her sustained efforts to promote the mathematics community's understanding of the importance of research in mathematics education, and her role as a mentor to young faculty." She has been a key figure in the development of a new professional organization, the Association for Research in Undergraduate Mathematics Education. Her contributions to research in teaching and learning collegiate mathematics include many writings on calculus learning and proof in advanced mathematical thinking. She has also served as a mentor in a project to pair senior mathematics education researchers with mathematicians and other young faculty interested in research in undergraduate mathematics education. "Annie Selden has been a visionary for the promotion of research in collegiate mathematics education and has provided leadership for the professional community of mathematics educators," the citation states.

Schafer Prize

The Alice T. Schafer Prize for Excellence in Mathematics by an Undergraduate Woman was established in 1990. The prize is named in honor Alice T. Schafer, one of the founders of AWM, who also served as AWM president.

The 2002 Schafer Prize was awarded to KAY KIRKPATRICK of Montana State University and MELANIE WOOD of Duke University.

Kay Kirkpatrick is a senior at Montana State University, where she has excelled in many graduate courses. In the summer of 2000, she participated in the Industrial Mathematics Workshop for Graduate Students at the Center for Research in Scientific Computation at North Carolina State University. Her mentor there says that Kirkpatrick "was extremely insightful, very creative in her thinking, and was the intellectual peer of the best graduate students in the program. She is one of the brightest undergraduates I have encountered in more than thirty years in academia." Kirkpatrick also participated in a Research Experiences for Undergraduates program in the summer of 2001 and wrote a paper that has been accepted for publication. Kirkpatrick was awarded a Barry M. Goldwater Scholarship in 2001.

Melanie Wood is a junior at Duke University. In 1999, she was a member of Duke's third-place Putnam team and received an Honorable Mention for her individual Putnam performance. She has excelled in many graduate courses, beginning in the fall of her freshman year and continuing to the present. One of her professors commented that she is "a truly remarkable student, one of the best I have ever encountered in my twenty-one years of teaching"; another commented, "I know that she will become a top-flight mathematician." In the summer of 2000, Wood participated in a Research Experiences for Undergraduates program and wrote a paper that has been submitted for publication. She was awarded a Barry M. Goldwater Scholarship in 2001.

Five students also received honorable mentions in the Schafer Prize competition: KAREN M. LANGE of Swarthmore College, SONJA MAPES of the University of Notre Dame, AMY E. MARINELLO of Swarthmore College, KATHLEEN A. PONTO of the University of Notre Dame, and GRACE C. WANG of the University of California at Berkeley.

—From AWM announcements

MAA Awards Presented in San Diego

The Mathematical Association of America (MAA) presented a number of prizes and awards at the Joint Mathematics Meetings in San Diego in January 2002.

Beckenbach Book Prize

The Beckenbach Book Prize, named in honor of the late Edwin Beckenbach, is awarded for distinguished, innovative books published by the MAA.

The 2002 Beckenbach Book Prize was awarded to JOSEPH KIRTLAND for his book *Identification Numbers and Check Digit Schemes*, published in the MAA Classroom Resource Materials Series. "This book exploits a ubiquitous feature of daily life, identification numbers, to develop a variety of mathematical ideas, such as modular arithmetic, functions, permutations, groups, and symmetries," the citation states, concluding that this book is "an outstanding, distinguished, and innovative expository book." Kirtland is on the faculty of Marist College. He has been selected six times by the students for the Faculty Recognition Award in the School of Computer Science and Mathematics. In the fall of 2000, he was presented with the Board of Trustees' Distinguished Teaching Award.

Chauvenet Prize

The Chauvenet Prize, first awarded to Gilbert Bliss in 1925, is presented for an outstanding expository article on a mathematical topic by a member of the MAA. The prize is named in honor of William Chauvenet, a professor of mathematics at the U.S. Naval Academy.

The 2002 Chauvenet Prize was awarded to ELLEN GETHNER, STAN WAGON, and BRIAN WICK for their paper "A Stroll through the Gaussian primes" (*American Mathematical Monthly* **15** (4) 1998, 327–37).

The article describes the Gaussian moat problem concerning the distribution of the Gaussian primes in the complex plane. As the prize citation puts it, "If one uses the Gaussian primes as stepping stones, can one walk to infinity with steps of bounded length? It is a fascinating and still an unanswered question." The paper discusses the history and motivation of the problem in a "very accessible and pleasant style."

Ellen Gethner received her Ph.D. from Ohio University in 1992 and is in the final stages of another Ph.D. in theoretical computer science at the University of British Columbia. Stan Wagon is a professor of mathematics at Macalester College and the author of several expository books about mathematics. Brian Wick is a professor at the University of Alaska at Anchorage, where he helped to develop the baccalaureate degree in mathematics.

Haimo Award

The Deborah and Franklin Tepper Haimo Awards for Distinguished College or University Teaching of Mathematics, established in 1991, honors college or university teachers who have been widely recognized as extraordinarily successful and whose teaching effectiveness has had influence beyond their own institutions.

The 2002 Haimo Award was presented to DENNIS DETURCK, PAUL J. SALLY JR., and EDWARD SPITZNAGEL JR.

Dennis DeTurck has had "a distinguished career of dedication to the improvement of teaching and learning of mathematics and science," the citation states. "A charismatic classroom teacher who inspires students at all levels to learn and to love the subject, DeTurck is also a talented innovator who has created a variety of programs to enhance teaching." He was the founding director of the Middle Atlantic Consortium for Mathematics and its Applications Throughout the Curriculum and now directs the Access Science program that connects the science and engineering departments of the University of Pennsylvania with K–12 public schools in West Philadelphia. DeTurck chairs the mathematics department at the University of Pennsylvania and is the Davidson Kennedy Professor.

"Paul Sally is a highly respected research mathematician who is enormously committed to the cause of education and excellence at all levels," the citation says. "In the past forty years, his superb classroom teaching and his long-range educational programs have affected thousands of students and teachers from the elementary grades to the Ph.D." As a professor at the University of Chicago, Sally founded the University of Chicago School Mathematics Project and a Young Scholars Program. He also launched SESAME (Seminars for Endorsement of Science and Mathematics Educators), a staff development program for elementary school teachers from Chicago public schools. Recognized for the excellence of his undergraduate teaching, Sally has coached the university's Putnam team and helped to start a mathematics club.

Edward Spitznagel was honored for "his extraordinary success in applying his vast practical experience and great enthusiasm to the classroom." His lively lectures are regularly oversubscribed and feature applications of statistics to many other fields. He collaborates with investigators in such fields as medicine, pharmacology, marketing, engineering, and psychology. "His breadth of scholarship and his feeling for the practical find immediate application to his teaching," the citation states. He is on the faculty of Washington University with a joint appointment in the Department of Mathematics and in the Division of Biostatistics in the Washington University School of Medicine. He has received ten awards for teaching.

Certificates of Meritorious Service

Each year the MAA presents Certificates for Meritorious Service to a section of the MAA. Those honored in 2002 are: Vivian Dennis-Monzingo of Eastfield College, Texas Section; Richard A. Gibbs of Fort Lewis College, Mountain Section; Dennis Luciano of Western New England College, Northeastern Section; John W. Petro of Western Michigan University, Michigan Section; Cynthia J. Woodburn of Pittsburg State University, Kansas Section; and Fredric Zerla of the University of South Florida, Florida Section.

—From MAA announcements

Mathematics People

Prizes of the International Congress of Chinese Mathematicians

A number of mathematical prizes were awarded at the International Congress of Chinese Mathematicians (ICCM), held in Taiwan in December 2001.

Six mathematicians were awarded Morningside Medals of Mathematics. Gold medals went to JUN LI, Stanford University, for his contributions to the study of moduli spaces of vector bundles and to the theory of stable maps and invariants of Calabi-Yau manifolds; and to HORNG-TZER YAU, New York University, for his contributions to the field of mathematical physics. Silver medals were awarded to DAQUING WAN, University of California, Irvine, for his proof of Dwork's conjecture of L-functions over finite fields; to CHIN-LUNG WANG, National Tsing Hua University, for his contributions on the birational model of algebraic varieties with singularities; to SIJUE WU, University of Maryland, for her establishment of local well-posedness of the water wave problems in a Sobolev class in arbitrary space dimensions; and to NANHUA XI, Chinese Academy of Sciences, for his work on solving an important conjecture of Lusztig.

The Morningside Medals were established in 1998 with funding donated by the Morningside Group of Hong Kong. These awards are given to outstanding mathematicians of Chinese descent to encourage them in pursuit of mathematical research. Two gold and four silver medals are awarded every three years. The gold medals carry a cash prize of US$20,000 and the silver medals a cash prize of US$5,000.

In addition to the Morningside Medals of Mathematics, the Morningside Lifetime Achievement Award was given to SHIING-SHEN CHERN for his work on developing the foundations of mathematics in Chinese society, his influential contributions to differential geometry, and his nurturing of leading mathematicians in and outside China. Chern received his B.S. from Nankai University in 1930, his M.S. from Tsing Hua University in 1934, and his Ph.D. from the University of Hamburg in 1936. He has been a member of the Institute for Advanced Study at Princeton University and acting director of the Institute of Mathematics at Academia Sinica in Nanjing. He has also taught at the University of Chicago and at the University of California, Berkeley. He was founder of the Mathematical Sciences Research Institute at Berkeley and served as its director from 1981 to 1984. He was also the founder and director of the Nankai Institute of Mathematics in Tianjin. Chern was awarded the U.S. National Medal of Science in 1975 and the Wolf Prize in 1983. In 1985, he was elected a fellow of the Royal Society of London and became an honorary member of the London Mathematical Society in 1986. He was also elected to both the National Academy of Sciences and the National Academy of Arts and Sciences.

The Chern Prize in Mathematics was established in 2001 in Chern's honor, and the first recipient of the prize is JIU-KANG YU of the University of Maryland. Yu was honored "for his important contributions to number theory, algebraic geometry, and representation theory," in particular his constructions of supercuspidal representations of p-adic groups, and his contributions to the theory of Bruhat-Tits buildings. In addition, the Chern Prize for Public Service was awarded to SONG-SUN LIN of the National Chiao-Tung University, Taiwan, "for his distinguished contributions to the development of nonlinear partial differential equations and dynamical systems in Taiwan." The Chern awards, which carry a cash prize of US$2,000, will be presented every three years to young mathematicians of Chinese descent who have made distinguished contributions either to mathematics research or to public service activities in support of mathematics.

—Chang-Shou Lin,
National Center for Theoretical Sciences, Taiwan,
and
—Shing-Tung Yau,
Harvard University

Kreiss Wins National Academy of Sciences Award

The 2002 National Academy of Sciences (NAS) Award in Applied Mathematics and Numerical Analysis has been given to HEINZ-OTTO KREISS of the University of California, Berkeley. Kreiss, who received both the Licentiate in mathematics and the doctor of technology degree from the Royal Institute of Technology, Stockholm, in 1960, was chosen "for his seminal contribution to the understanding of differential and difference equations and for his many outstanding contributions to numerical analysis, fluid dynamics, and meteorology."

The Award in Applied Mathematics and Numerical Analysis carries a cash prize of $10,000 and is awarded approximately every three years for outstanding work in applied mathematics and numerical analysis.

—From an NAS announcement

Calegari Selected as AIM Five-Year Fellow

The American Institute of Mathematics (AIM) has awarded the 2002 AIM Five-Year Fellowship to FRANK CALEGARI of the University of California, Berkeley.

Calegari received a B.S. with honors in mathematics from the University of Melbourne in 1997. He will complete his dissertation "Aspects of semistable abelian varieties" in 2002 under the direction of Kenneth Ribet. Calegari's research interests include number theory, modular forms, Galois representations, group schemes, and Diophantine equations. His research focuses on the interplay between Galois representations and their deformations.

The AIM five-year fellowships are awarded each year to outstanding new Ph.D. students in an area of pure mathematics. The fellowships cover sixty months of full-time research, as well as funds for travel and equipment. Each fellowship carries a stipend of $4,000 per month, with an additional $4,000 per year allocated for travel and equipment.

—From an AIM announcement

2002 Leibniz Prizes Awarded

The Deutsche Forschungsgemeinschaft (DFG) has selected twelve recipients of the Gottfried Wilhelm Leibniz Prize for 2002. Two of the awardees are mathematical scientists. WOLFGANG DAHMEN of Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen and BRUNO ECKHARDT of Marburg University will receive DM 1.5 million (approximately US$750,000) to support research over a period of five years.

Wolfgang Dahmen, age fifty-two, studied mathematics and physics at RWTH Aachen, from which he received his doctorate in 1976. He did postdoctoral work at IBM and has held positions at Bielefeld University and the Free University of Berlin. He is currently professor of geometry and practical mathematics at RWTH Aachen. His research interests include issues concerning online and real-time optimization that are important in monitoring and controlling processes in sensitive equipment such as chemical reactors in order to prevent disasters. His elaboration of the mathematical theory of wavelets provides the basis for these methods.

Bruno Eckhardt, age forty-one, studied physics, mathematics, and computer science at Kaiserslautern and Atlanta before completing his Ph.D. at the University of Bremen in 1986. He has taught at the University of Oldenburg and has been professor of theoretical physics at Marburg University since 1996. Eckhardt's field of research is nonlinear dynamics, particularly in macroscopic systems such as turbulence in currents. He has developed numerical methods of simulating flow patterns. His research on the dynamics of nonlinear systems has opened up new avenues in the physics of fluid dynamics.

The aim of the Leibniz Prize program, which was instituted by the DFG in 1985, is to improve the working conditions of outstanding scientists and scholars, to broaden their opportunities for research, to relieve them of administrative burdens, and to allow them to hire especially highly qualified young academics. The prizewinners are permitted the greatest possible freedom in the way they use the prize funds. The DFG is the main scientific research funding agency of the German government.

—From a DFG announcement

AWM Essay Contest Winners Announced

The Association for Women in Mathematics (AWM) has announced the winners of its 2001 essay contest "Biographies of Contemporary Women in Mathematics". The grand prize winner was ALEXANDRA MCKINNEY of Londonderry Middle School, Londonderry, New Hampshire, for her essay "Women in Mathematical Sciences: To Infinity and Beyond! A Biographical Essay on Dr. Toni Galvin". McKinney's essay will be published in the AWM Newsletter. The first-place winner in the graduate school category was SUSAN D'AGOSTINO of Dartmouth College for an essay on Vera Pless. CHARLES MOFFIT of the United States Military Academy at West Point won first place in the college division for his essay on Tasha Inniss. The first-place high-school winner was SANA AHMED of Townsend Harris High School, Flushing, New York, who wrote on mathematician Misha E. Kilmer. A complete list of the winners, as well as copies of their essays, can be found on the AWM website `http://www.awm-math.org/biographies/contest/2001.html`.

—From an AWM announcement

Correction

The March 2002 issue of the *Notices*, page 337, carried an announcement about awards of the Humboldt Foundation. Because of incorrect information provided by the foundation, there were errors in the description of the research of the winner of the Sofya Kovalevskaya Prize, Matilde Marcolli of the Max-Planck-Institut für Mathematik in Bonn. Marcolli's research focuses on gauge theory, noncommutative geometry, and arithmetic geometry. Her recent work includes Floer homology, the fractional quantum Hall effect, the holographic AdS/CFT correspondence, and noncommutative geometry of modular curves.

Mathematics Opportunities

NSF Postdoctoral Research Fellowships

The National Science Foundation (NSF) awards Mathematical Sciences Postdoctoral Research Fellowships for research in areas of the mathematical sciences, including applications to other disciplines. Awardees are permitted to choose research environments that will have maximal impact on their future scientific development. Stipends provide support for two nine-month academic years and six summer months, for a total of twenty-four months.

The deadline for applications is **October 18, 2002**. For more information and application instructions, see the NSF website at `http://www.fastlane.nsf.gov/d11/D11Menu.htm`.

—From an NSF announcement

Call for VIGRE Proposals

The Division of Mathematical Sciences (DMS) of the National Science Foundation has announced a new competition for Grants for Vertical Integration of Research and Education in the Mathematical Sciences, known as VIGRE grants.

VIGRE grants are designed to allow departments in the mathematical sciences to carry out innovative educational programs in which research and education are integrated and in which undergraduates, graduate students, postdoctoral fellows, and faculty are mutually supportive. The goals of VIGRE are: (1) to prepare undergraduate students, graduate students, and postdoctoral fellows for the broad range of opportunities available to individuals with training in the mathematical sciences; and (2) to encourage departments in the mathematical sciences to initiate or improve education activities that lend themselves to integration with research, especially activities that promote the interaction of scholars across boundaries of academic age and departmental standing.

The deadline for proposals for the new competition has not been announced, but it will be in late July 2002. At present the DMS funds about thirty VIGRE grants. The number of grants to be awarded in the new competition will be determined based on the quality of proposals received. For further information, consult the DMS website, `http://www.nsf.gov/mps/divisions/dms/`.

—Allyn Jackson

Fulbright Lecturing/Research Grants

The Fulbright Scholar Program is offering lecturing/research awards in some 140 countries for the 2003–04 academic year. Opportunities are available for college and university faculty, professionals from business and government, independent scholars, and others. While foreign language skills are needed in some countries, most Fulbright assignments are in English.

Traditional Fulbright awards are available from two months to an academic year or longer. A new short-term grants program, the Fulbright Senior Specialists Program, offers two-to-six week grants.

Application deadlines for the 2003–04 awards are: **May 1, 2002**, for Fulbright Distinguished Chair awards in Europe, Canada, and Russia; and **August 1, 2002**, for Fulbright traditional lecturing and research grants worldwide. The Fulbright Senior Specialists Program has a rolling deadline.

For further information, contact the Council for International Exchange of Scholars (CIES), 3007 Tilden Street, NW, Suite 5L, Washington, DC 20008-3009; telephone 202-686-7877; e-mail: `apprequest@cies.iie.org`; World Wide Web `http://www.cies.org/`.

The Fulbright Scholar Program is sponsored by the U.S. Department of State, Bureau of Educational and Cultural Affairs.

—From a CIES Announcement

NSF Internships for Public Science Education

In order to promote the involvement of the research community in public educational activities, the Directorate for Mathematical and Physical Sciences (MPS) of the National Science Foundation (NSF) has announced the MPS Internships in Public Science Education (IPSE) program. IPSE is intended to bring current science research results from MPS disciplines to the public by promoting partnerships between the MPS research community and specialists in public science education. The IPSE activity will provide support for undergraduate and graduate students and kindergarten through twelfth-grade teachers to work in conjunction with MPS research scientists and with professionals at science centers and museums on projects in public science education.

Proposals will be accepted from academic institutions in the United States and its territories, from science centers or museums, and from MPS-funded centers, facilities, and institutes. An academic institution is defined as a college or university granting degrees (two- or four-year) in any of the MPS disciplines: astronomy, chemistry, materials research, mathematical sciences, and physics. Science centers or museums are defined to be nonprofit organizations whose primary mission is public science education, that is, science centers, museums, visitor centers, and so forth, with programs or activities in one or more of the MPS disciplines. Proposals must show evidence of partnerships between academic institutions and science centers or museums. Proposals from MPS-funded centers, facilities, or institutes must show the active collaboration of both research scientists and educators from the organization. Partnerships outside the institution are encouraged. A single individual should be designated as principal investigator, with at least one individual from each participating organization either designated as co-PI or in some other way clearly involved at an equivalent level of participation.

The deadline for applications is **May 7, 2002**. For more information, see the NSF website at `http://www.nsf.gov/cgi-bin/getpub?nsf02064/`.

—From an NSF announcement

Research Experiences for Undergraduates

Each summer, the Research Experiences for Undergraduates (REU) program of the National Science Foundation (NSF) provides opportunities for undergraduate students to participate in research projects. REU "sites" are established in all fields of science, mathematics, and engineering. Each site consists of a group of about ten undergraduates who work in research programs of the host institution. Each student is assigned to a specific research project and works closely with faculty, postdoctoral researchers, and graduate students.

Undergraduate students are encouraged to apply. A tentative list of sites in the mathematical sciences for the year 2002 is given below, together with the names of the site directors, who can be contacted for further information.

California Polytechnic State University: Operator theory and combinatorics; Jonathan Shapiro, `jshapiro@calpoly.edu`.

California State University, San Bernardino: Combinatorics, knot theory; Joseph Chavez, `jchavez@csusb.edu`.

Central Michigan University: Combinatorics, geometry, graph theory, and matrix analysis; Sivaram Narayan, `sivaram.narayan@cmich.edu`.

College of William and Mary: Matrix analysis and its applications; David J. Lutzer, `lutzer@math.wm.edu`.

Colorado School of Mines: Computer science, mathematics; Erik Van Vleck, `byoung@mines.edu`.

Cornell University: Analysis on fractals, lattice tilings and coverings, and computational discrete geometry; Robert S. Strichartz, `reu@math.cornell.edu`.

East Tennessee State University: Probability, combinatorics, number theory, statistics, algorithms, and geometry; Anant P. Godbole, `godbolea@etsu.edu`.

Hope College: Algebra, dynamical systems, probability, and number theory; Tim Pennings, `pennings@hope.edu`.

Indiana University: Selected topics in pure and applied mathematics; Allan Edmonds, `edmonds@indiana.edu`.

James Madison University: Abstract algebra, mathematical modeling, statistical inference; Leonard VanWyk, `vanwyk@math.jmu.edu`.

Lafayette College: Applied combinatorics, graph theory, and algebra/geometry/number theory; Gary Gordon, `gordong@lafayette.edu`.

Louisiana State University, Baton Rouge: Braids, groups, number theory, and zeta functions; Neal W. Stoltzfus, `stoltz@math.lsu.edu`.

Mount Holyoke College: Number theory, algebraic geometry, and applied analysis; Alan H. Durfee, `reu@mtholyoke.edu`.

Northern Arizona University: Combinatorics, applied math, statistics; Terence R. Blows, `Terence.Blows@nau.edu`.

Oregon State University: Analysis of algorithms, geometry, population dynamics, and topology; Dennis J. Garity, `reu@math.orst.edu`.

Pennsylvania State University, Erie, The Behrend College: Mathematical biology; Joseph Paullet, `paullet@lagrange.bd.psu.edu`.

Rose-Hulman Institute of Technology: Computational group theory, hyperbolic geometry; S. Allen Broughton, `allen.broughton@rose-hulman.edu`.

Southwest Texas State University: Abstract algebra; Susan Morey, `morey@swt.edu`.

State University of New York, Potsdam: Group theory, graph theory, topology; Kazem Mahdavi, `mahdavk@potsdam.edu`.

Texas A&M University: Algebra and applied analysis; Ed Letzter, `letzter@math.tamu.edu`.

Trinity University: Mathematics; Scott Chapman, `schapman@trinity.edu`.

MATHEMATICS OPPORTUNITIES

University of Houston: Geometry, analysis, number theory, and numerical analysis; Ed Dean, dean@math.uh.edu.

University of Idaho: Discrete mathematics and permutation puzzles; Arie Bialostocki, reu@uidaho.edu.

University of Minnesota, Duluth: Discrete mathematics, combinatorics, and graph theory; Joseph A. Gallian, jgallian@d.umn.edu.

University of Puerto Rico, Humacao: Computational algebra, wavelets, fluid dynamics, Groebner bases; Ivelisse M. Rubio, ive@cuhwww.upr.clu.edu.

University of Tennessee: Selected topics in pure and applied math; Suzanne Lenhart, lenhart@math.utk.edu.

University of Washington: Inverse problems; James A. Morrow, morrow@math.washington.edu.

Williams College: Geometry; Colin Adams, colin.adams@williams.edu.

Worcester Polytechnic Institute: Applied/industrial mathematics; Bogdan Vernescu, vernescu@wpi.edu.

Updated information is available on the website of the NSF's Division of Mathematical Sciences, http://www.nsf.gov/home/crssprgm/reu/reu98dms.htm. General information on the REU program, as well as instructions for submitting proposals, is available on the NSF website, http://www.nsf.gov/home/crssprgm/reu/start.htm.

—From an NSF announcement

News from Oberwolfach

The Mathematisches Forschungsinstitut Oberwolfach (MFO), located in Oberwolfach, Germany, has appointed as director Gert-Martin Greuel of the Universität Kaiserslautern. He replaces Matthias Kreck of the Universität Heidelberg, who has held the post since 1994.

Greuel received his Ph.D. in 1973 from the Universität Göttingen under the direction of Egbert Brieskorn and his *Habilitation* in 1980 from the Universität Bonn. In 1981 Greuel was appointed as a full professor at the Universität Kaiserslautern, and since 1993 he has headed the Center for Computer Algebra there. He has been involved in several research projects that received funding from the German government and the European Community, including serving as the German coordinator for the European Singularity Network. Greuel has organized many conferences in Germany, including four at Oberwolfach. He is also one of the developers of Singular, a computer algebra system for polynomial computations with special emphasis on the needs of commutative algebra, algebraic geometry, and singularity theory. His areas of research are singularity theory, computer algebra, algebraic geometry, and complex analysis.

Greuel started as director of Oberwolfach on February 1, 2002. For more information on the institute and its activities, visit the website http://www.mfo.de/.

—MFO announcement

Inside the AMS

Epsilon Awards for 2002

The AMS Epsilon Fund for Young Scholars was established in 1999 to provide financial assistance to summer programs for mathematically talented high school students in the United States. For many years, these programs have provided mathematically talented youngsters with their first serious mathematical experiences. The name for the fund was chosen in remembrance of the late Paul Erdős, who was fond of calling children "epsilons".

The AMS has chosen eight summer mathematics programs to receive Epsilon grants for activities in the summer of 2002. The grants will support program expenses and student scholarships and, in some cases, scholarships only. The programs were chosen on the basis of mathematical excellence and enthusiasm. The selection committee consisted of Lenore J. Cowen, Tufts University; Alan S. Edelman, Massachusetts Institute of Technology; Joel Spencer, Courant Institute of Mathematical Sciences, New York University (chair); and Karen Vogtmann, Cornell University. Award amounts were governed by the varying financial needs of each program and totaled $80,000.

The programs receiving grants are: All Girls/All Math, University of Nebraska; Hampshire College Summer Studies in Mathematics, Amherst, Massachusetts; Mathcamp, Mathematics Foundation of America; Michigan Math and Science Scholars, University of Michigan, Ann Arbor; PROMYS, Boston University; Ross Mathematics Program, The Ohio State University; SWT Honors Summer Math Camp, Southwest Texas State University; and University of Chicago Young Scholars Program.

The grants for summer 2002 are paid for by the AMS Epsilon Fund for Young Scholars (supplemented by the AMS Program Development Fund). The AMS is continuing to build the endowment for the Epsilon Fund, with a goal of raising $2 million through individual donations and grants. Once the Epsilon Fund endowment has reached the targeted amount, the AMS intends to award a total of $100,000 in Epsilon grants each year.

For further information about the Epsilon Fund for Young Scholars, visit the website `http://www.ams.org/giving-to-ams/`, or contact `development@ams.org`, telephone 800-321-4267, extension 4111, or 401-455-4111. Information about how to apply for Epsilon grants is available at `http://www.ams.org/careers-edu/epsilon.html`. A fairly comprehensive listing of summer programs for mathematically talented high school students (including those with and without Epsilon grants) is available at `http://www.ams.org/careers-edu/mathcamps.html`.

—Allyn Jackson

Deaths of AMS Members

HERBERT M. BARUCH JR., of Pacific Palisades, CA, died on May 10, 2001. He was a member of the Society for 25 years.

MURRAY BELL, University of Manitoba, Canada, died on December 9, 2001. He was a member of the Society for 26 years.

CLAIR J. BLACKALL, of North Baltimore, OH, died on August 19, 2001. Born on December 9, 1909, he was a member of the Society for 60 years.

BERNARD GREENSPAN, of Laguna Hills, CA, died on December 20, 2001. He was a member of the Society for 60 years.

EVAN INNES, of Cambridge, England, died on December 9, 2001. Born on September 11, 1921, he was a member of the Society for 7 years.

M. MIKOLAS, Technical University of Budapest, died on February 2, 2001. Born on April 5, 1923, he was a member of the Society for 29 years.

JOSE MANUEL MENENDEZ SOUTO, of Asturias, Spain, died on December 29, 2001. He was a member of the Society for 27 years.

WOLFGANG J. THRON, professor emeritus, University of Colorado, Boulder, died on August 21, 2001. Born in August 1918, he was a member of the Society for 60 years.

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.*

Contacting the *Notices*

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

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

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

Upcoming Deadlines

April 12, 2002: Applications for Project NExT. See `http://archives.math.utk.edu/projnext/`.

April 15, 2002: Applications for National Research Council Research Associateship Program. See `http://www4.nationalacademies.org/pga/rap.nsf/` or contact the National Research Council, Associateship Programs (TJ 2114), 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2760; fax 202-334-2759; e-mail: `rap@nas.edu`.

April 15, 2002: Proposals for COBASE collaborative grants. For application forms and instructions, see `http://www.nationalacademies.org/oia/`. For more information, telephone 202-334-2644, send a fax to 202-334-2614, or e-mail: `ocee@nas.edu`.

April 30, 2002: Nominations for the Maria Mitchell Women in Science Award. See `http://www.mmo.org/`, or contact the Maria Mitchell Women in Science Award Committee at the Maria Mitchell Association, 2 Vestal

Where to Find It

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

Street, Nantucket, MA 02554; telephone 508-228-9198.

May 1, 2002: Applications for Career Awards for Research Addressing Biological Questions. See http://www.bwfund.org/interfaces_in_science_career_awards.htm.

May 1, 2002: Nominations for Lobachevskii Medal. See http://www.ksu.ru/lobmed/.

May 1, October 1, 2002: Applications for NSF/AWM Travel Grants for Women. See http://www.awm-math.org/travelgrants.html; telephone 301-405-7892; e-mail: awm@math.umd.edu.

May 7, 2002: Applications for NSF Internships for Public Science Education. See "Mathematics Opportunities" in this issue.

May 15, 2002: Applications for fall semester of Math in Moscow and for AMS scholarships. See http://www.mccme.ru/mathinmoscow/ or contact Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax +7095-291-65-01; e-mail: mim@mccme.ru. For information about and application forms for the AMS scholarships, see http://www.ams.org/careers-edu/mimoscow.html or contact Math in Moscow Program, Professional Services Department, American Mathematical Society, 201 Charles Street, Providence RI 02904; e-mail: prof-serv@ams.org.

July 15, 2002: Applications for the AAAS Women's International Science Collaboration Program (WISC). See http://www.aaas.org/international/wiscnew.shtml, or contact WISC Travel Grant, American Association for the Advancement of Science, Directorate for International Programs, 1200 New York Avenue, NW,Washington, D.C., 20005.

August 15, 2002: Applications for National Research Council Research Associateship Program. See http://www4.nationalacademies.org/pga/rap.nsf/ or contact the National Research Council, Associateship Programs (TJ 2114), 2101 Constitution Avenue, NW, Washington, DC 20418; telephone 202-334-2760; fax 202-334-2759; e-mail: rap@nas.edu.

October 15, 2002: Applications for fall semester of Math in Moscow and for AMS scholarships. See http://www.mccme.ru/mathinmoscow/ or contact Math in Moscow, P.O. Box 524, Wynnewood, PA 19096; fax +7095-291-65-01; e-mail: mim@mccme.ru. For information about and application forms for the AMS scholarships, see http://www.ams.org/careers-edu/mimoscow.html or contact Math in Moscow Program, Professional Services Department, American Mathematical Society, 201 Charles Street, Providence RI 02904; e-mail: prof-serv@ams.org.

October 18, 2002: Applications for NSF Postdoctoral Research Fellowships. See "Mathematics Opportunities" in this issue.

Mathematical Sciences Education Board, National Research Council

Judy Ackerman, Montgomery College
Deborah Loewenberg Ball, University of Michigan
Jere Confrey (vice chair), University of Texas, Austin
Jan de Lange, Freudenthal Institute, The Netherlands
Keith Devlin, Stanford University
Louis Gomez, Northwestern University
Doug Grouws, University of Iowa
Arthur Jaffe, Harvard University
Dan Kennedy, The Baylor School, Chattanooga, TN
Joan Leitzel (chair), University of New Hampshire
Jim Lewis, University of Nebraska, Lincoln
Karen Longhart, Flathead High School
George McShan, National School Boards Association
Thomas Moore, Grinnell College
Judith Mumme, WestEd
Casildo Pardo, Valle Vista Elementary School
Sue Parsons, Cerritos College
Deborah Paulson, Hornedo Middle School, El Paso, TX
Marge Petit, National Center for the Improvement of Educational Assessment
Donald Saari, University of California, Irvine
Anthony Scott, Chicago Public Schools
William Steenken, GE Aircraft Engines
Francis Sullivan, Center for Computing Sciences
Hung Hsi Wu, University of California, Berkeley

MSEB Staff

Carole Lacampagne, *Director*

The contact information for the Board is: Mathematical Sciences Education Board, National Research Council, 2101 Constitution Avenue, NW (HA 450), Washington, DC 20418; telephone 202-334-3294; fax 202-334-1453; e-mail: mseb@nas.edu; World Wide Web http://www7.nationalacademies.org/mseb/index.html.

U.S. Delegation to ICM-2002

The United States will sponsor a delegation to the International Congress of Mathematicians, to be held in Beijing, August 20–28, 2002. The delegates were appointed by the U.S. National Committee for Mathematics, the United States' adhering organization to the International Mathematical Union. The names and affiliations of the delegates are listed below.

Salah Baouendi
University of California, San Diego
Jennifer Chayes
Microsoft Research
David Eisenbud
Mathematical Sciences Research Institute
Donald Saari
University of California, Irvine
Yum-Tong Siu
Harvard University

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`.

The Bit and the Pendulum: How the New Physics of Information Is Revolutionizing Science, by Tom Siegfried. John Wiley & Sons, February 2000. ISBN 0-47132-174-5.

The Book of Nothing: Vacuums, Voids, and the Latest Ideas about the Origins of the Universe, by John D. Barrow. Pantheon Books, April 2001. ISBN 0-375-42099-1.

Calculated Bets: Computers, Gambling, and Mathematical Modeling to Win, by Steven S. Skiena. Cambridge University Press, September 2001. ISBN 0-521-00962-6.

Chaotic Elections! A Mathematician Looks at Voting, by Donald G. Saari. AMS, April 2001. ISBN 0-8218-2847-9.

The Colossal Book of Mathematics: Classic Puzzles, Paradoxes, and Problems, by Martin Gardner. W.W. Norton & Company, August 2001. ISBN 0-393-02023-1.

Computers Ltd.: What They Really Can't Do, by David Harel. Oxford University Press, November 2000. ISBN 0-198-50555-8.

A Concise History of Mathematics, by Dirk J. Struik. Dover Publications, 1987. ISBN 0-486-60255-9. (Reviewed June/July 2001.)

Conned Again, Watson! Cautionary Tales of Logic, Math, and Probability, by Colin Bruce. Perseus Publishing, January 2001. ISBN 0-7382-0345-9.

Conquering Statistics: Numbers without the Crunch, by Jefferson Hane Weaver. Perseus Publishing, paperback edition, August 2001. ISBN 0-732-820495-1.

Conversations with a Mathematician: Math, Art, Science, and the Limits of Reason, by Gregory J. Chaitin. Springer, November 2001. ISBN 1-85233-549-1.

Creators of Mathematics: The Irish Connection, by Ken Houston. University College Dublin Press, September 2000. ISBN 1-900-62149-5.

Damned Lies and Statistics: Untangling Numbers from the Media, Politicians, and Activists, by Joel Best. University of California Press, May 2001. ISBN 0-520-21978-3.

* *Does God Play Dice?: The New Mathematics of Chaos*, by Ian Stewart. Blackwell, revised second edition, January 2002. ISBN 0-631-23251-6.

The Difference Engine: Charles Babbage and the Quest to Build the First Computer, by Doron Swade. Viking Press, September 2001. ISBN 0-670-91020-1.

The Dream Machine: J. C. R. Licklider and the Revolution That Made Computing Personal, by M. Mitchell Waldrop. Viking Press, 2001. ISBN 0-670-89976-3.

The Essential John Nash, Harold Kuhn and Sylvia Nasar, editors. Princeton University Press, December 2001. ISBN 0-691-09527-2.

Euclid's Window: The Story of Geometry from Parallel Lines to Hyperspace, by Leonard Mlodinow. Free Press, April 2001. ISBN 0-684-86523-8. (Reviewed in this issue.)

Exploring Randomness, by Gregory J. Chaitin. Springer, December 2000. ISBN 1-852-33-417-7. (Reviewed October 2001.)

Flatterland: Like Flatland, Only More So, by Ian Stewart. Perseus Publishing, May 2001. ISBN 0-7382-0442-0. (Reviewed April 2002.)

Fooled by Randomness: The Hidden Role of Chance in the Markets and Life, by Nassim Nicholas Taleb. Texere, October 2001. ISBN 1-587-99071-7.

The Fractal Murders, by Mark Cohen. E-book published by Southern Cross Review, 2001. World Wide Web: `www.southerncrossreview.org/`.

Fragments of Infinity: A Kaleidoscope of Math and Art, by Ivars Peterson. John Wiley & Sons, October 2001. ISBN 0-471-16558-1.

* *A Gardner's Workout: Training the Mind and Entertaining the Spirit*, by Martin Gardner. A K Peters, June 2001. ISBN 1-56881-120-9.

Geometry: Our Cultural History, by Audun Holme. Springer, to appear March 2002. ISBN 3-540-41949-7.

Gödel: A Life of Logic, by John L. Casti and Werner DePauli. Perseus Publishing, August 2000. ISBN 0-7382-0274-6. (Reviewed September 2001.)

The Hilbert Challenge, by Jeremy J. Gray. Oxford University Press, December 2000. ISBN 0-198-50651-1.

The Hole in the Universe: How Scientists Peered over the Edge of Emptiness and Found Everything, by K. C. Cole. Harcourt Brace, January 2001. ISBN 0-151-00398-X.

How the Other Half Thinks: Adventures in Mathematical Reasoning, by Sherman Stein. McGraw-Hill, July 2001. ISBN 0-071-37339-X.

How to Solve It: Modern Heuristics, by Zbigniew Michalewicz and David B. Fogel. Springer, December 1999. ISBN 3-540-66061-5.

In Code: A Mathematical Journey, by Sarah Flannery and David Flannery. Workman Publishing, May 2001. ISBN 0-761-12384-9.

* *The Lady Tasting Tea: How Statistics Revolutionized Science in the Twentieth Century*, by David Salsburg. W H Freeman & Co, April 2001. ISBN 0-716-74106-7.

Lebesgue's Theory of Integration: Its Origins and Development, by Thomas Hawkins. AMS, September 2001. ISBN 0-8218-2963-7.

Logical Dilemmas: The Life and Work of Kurt Gödel, by John Dawson. A K Peters, December 1997. ISBN 1-56881-025-3. (Reviewed September 2001.)

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AMERICAN MATHEMATICAL SOCIETY

CALL FOR NOMINATIONS

George David Birkhoff Prize

Frank Nelson Cole Prize in Algebra

Levi L. Conant Prize

Ruth Lyttle Satter Prize

The selection committees for these prizes request nominations for consideration for the 2003 awards, which will be presented at the Joint Mathematics Meetings in Baltimore, MD, in January 2003. Information about most of these prizes may be found in the November 2001 *Notices*, pp., 1211–1223. (Also available at http://www.ams.org/secretary/prizes.html)

The George David Birkhoff Prize is awarded jointly by the AMS and SIAM for an outstanding contribution to applied mathematics in its highest and broadest sense. The award was first made in 1968 and usually has been presented every fifth year since then, but future awards will be made on a three-year cycle.

The Frank Nelson Cole Prizes are now presented at three-year intervals for outstanding contributions in algebra and number theory. The award in January 2003 will be the Frank Nelson Cole Prize in Algebra.

The Levi Conant Prize, first awarded in January 2001, is presented annually for an outstanding expository paper published in either the *Notices* or the *Bulletin* of the American Mathematical Society during the preceding five years.

The Ruth Lyttle Satter Prize is presented every two years in recognition of an outstanding contribution to mathematics research by a woman during the previous five years.

Nominations should be submitted to the secretary, Robert J. Daverman, American Mathematical Society, 312D Ayres Hall, University of Tennessee, Knoxville TN 37996-1330. Include a short description of the work that is the basis of the nomination, with complete bibliographic citations. A brief curriculum vita should be included for all nominees. The nominations will be forwarded by the secretary to the appropriate prize selection committee, which will make final decisions on the awarding of the prizes.

Deadline for nominations is June 30, 2002.

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Call for Nominations

E. H. MOORE

Research Article Prize

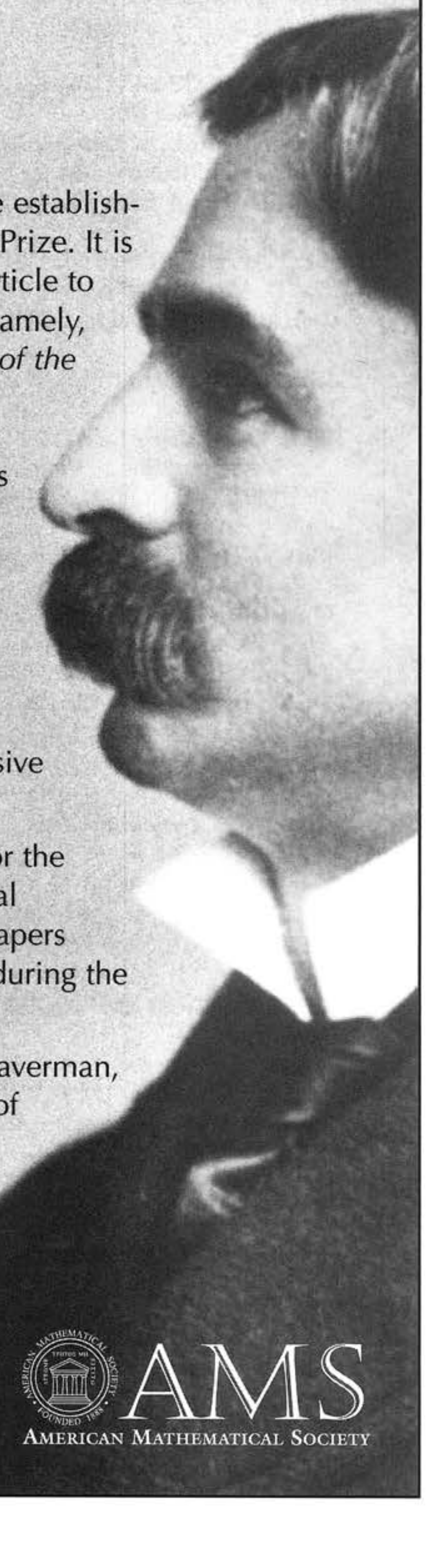
At its meeting of January 2002, the AMS Council approved the establishment of a new award called the E. H. Moore Research Article Prize. It is to be awarded every three years for an outstanding research article to have appeared in one of the AMS primary research journals (namely, the *Journal of the AMS, Proceedings of the AMS, Transactions of the AMS, AMS Memoirs, Mathematics of Computation, Electronic Journal of Conformal Geometry and Dynamics*, and *Electronic Journal of Representation Theory*) during the six calendar years ending a full year before the meeting in which the prize is awarded.

Among other activities, E. H. Moore founded the Chicago branch of the AMS, served as the Society's sixth president (1901–2), delivered the Colloquium Lectures in 1906, and founded and nurtured the *Transactions of the American Mathematical Society*. The name of the prize honors his extensive contributions to the discipline and to the Society.

The Moore Prize Selection Committee requests nominations for the initial award, which will be presented at the Joint Mathematical Meetings in Baltimore, MD, in January 2003. To be specific, papers published in one of the journals named in the first paragraph during the years 1996–2001 are considered eligible for the 2003 award.

Nominations should be submitted to the secretary, Robert J. Daverman, American Mathematical Society, 312D Ayres Hall, University of Tennessee, Knoxville TN 37996-1330. Include a short description of the work that is the basis of the nomination, with complete bibliographic citations. A brief curriculum vita should be included for all nominees. The nominations will be forwarded by the Secretary to the prize selection committee, which will make final decisions on the awarding of this prize.

Deadline for nominations is June 30, 2002.



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Mathematics Calendar

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

May 2002

* 4–6 **PIMS Thematic Programme on Selected Topics in Mathematical and Industrial Statistics, Workshop on the Role of Statistical Modelling in the 21st Century**, PIMS, Simon Fraser University, Burnaby, British Columbia, Canada.

Organizers: R. Lockhart and C. Dean (SFU) and P. Guttorp (Univ. of Washington).

Description: This workshop will bring together leading practitioners and philosophers of scientific, Bayesian, and frequentist modelling statistics with leading researchers in model assessment, validation, and goodness-of-fit. The goals are to identify opportunities and challenges for model development and criticism and to begin to outline approaches to assessment of complex models.

Contact: `pims@pims.math.ca`.

Information: For further details, see `http://www.pims.math.ca/stats/`.

* 6–10 **Advanced Concentrated Course on Long Range Dependence, Heavy Tails and Rare Events with Applications to Finance and Telecommunications**, University of Copenhagen, Denmark.

Lectures: Main lectures by G. Samorodnitsky (Cornell Univ.). Further lectures by S. Asmussen (Lund), P. Albin (Chalmers), M. Taqqu (Boston), and B. Zwart (INRIA).

Organizers: T. Mikosch (Copenhagen), `mikosch@math.ku.dk` and M. Soerensen (Copenhagen), `michael@stat.ku.dk`.

Information: Visit the website at: `http://www.maphysto.dk/events/LongRange2002/`.

* 11–19 **1st PIMS School of Mathematical Biology for Senior Undergraduates**, University of Alberta, Alberta, Canada.

Instructors: M. Lewis, T. Hillen, G. de Vries, and M. Li (Univ. of Alberta).

Brief Description: The aim of this summer school is to introduce students to mathematical modeling and analysis applied to real biological systems.

Contact: R. Bechtel at `rbechtel@ualberta.ca`.

Information: `http://pims.math.ualberta.ca/mathematics_of_biological_system.htm`.

* 12–18 **PIMS Thematic Programme on Selected Topics in Mathematical and Industrial Statistics, International Conference on Robust Statistics (ICORS 2002)**, University of British Columbia, Vancouver, British Columbia, Canada.

Brief Description: This conference will be a forum for new developments and applications of robust statistics and statistical computing. Experienced researchers and practitioners, as well as younger researchers, will come together to exchange knowledge and to build scientific contacts. The conference will center on methods designed for processing large datasets of uneven quality (databases containing outliers, gross errors, missing data, etc.). This conference expects to touch upon many different aspects of data analysis in a fashion which integrates theoretical and applied statistics.

Organizers: L. Fernholz (Temple Univ.), U. Gather (Dortmund), C. Field (Dalhousie), and R. H. Zamar (UBC).

Information: Contact `ruben@stat.ubc.ca` or visit `http://www.pims.math.ca/stats/`.

* 14–19 **2002 EAGER Advanced School in Algebraic Geometry: Cycles on Varieties**, Grand Hotel Bellavista, Levico Terme, Trento, Italy.

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 the AMS website on the World Wide Web. To access the AMS website, use the URL: `http://www.ams.org/`.

Scientific Organizer: G. Bolondi, Milano.
Short Courses: Will be held by H. Clemens (Salt Lake City) and C. Voisin (Paris).
Information: Available at http://www.science.unitn.it/cirm/schooleagerprog02.html.

*15-17 **DIMACS Workshop on Cryptographic Protocols in Complex Environments**, DIMACS Center, Rutgers University, Piscataway, NJ
Sponsors: DIMACS Center.
Contacts: R. Ostrovsky, Telcordia Technologies, rafail@research.telcordia.com.
Local Arrangements: J. Theimann, DIMACS Center, jennifer@dimacs.rutgers.edu, tel: 732-445-5928.
Short Description: This workshop is aimed at bringing together experts on topics related to the design of cryptographic multiparty protocols to present their on-going work, survey previous work, and discuss future research directions, with strong emphasis on the design, analysis, and implementation of protocols that maintain their security in complex adversarial environments and in particular on the Internet.
Information: http://dimacs.rutgers.edu/Workshops/index.html.

*18 **9th Annual East Coast Computer Algebra Day (ECCAD 2002)**, LaGuardia Community College, Long Island City, New York.
Themes: Algebraic algorithms; hybrid symbolic-numeric computation; computer algebra systems and generic programming; mathematical communication; complexity of algebraic problems.
Information: You can preregister and get more information by visiting our World Wide Web site at http://www.lagcc.cuny.edu/Mathematics/ECCAD2002/.

*18-23 **5th PIMS Graduate Industrial Math Modelling Camp**, Simon Fraser University, Burnaby, British Columbia, Canada.
Organizers: J. Maki (Univ. of Alberta), C. Bose (Univ. of Victoria), R. LeVeque (Univ. of Washington), H. Huang (York Univ.), M. Paulhus (Univ. of Calgary), M. Trummer (Simon Fraser Univ.), I. Frigaard (Univ. of British Columbia).
Description: The GIMMC is the first leg of the PIMS Industrial Mathematics Forum which also includes the PIMS Industrial Problem Solving Workshop (IPSW6) to be held at the Univ. of British Columbia, May 27-31, 2002.

The Graduate Mathematics Modelling Camp is designed to give graduate students in the Mathematical Sciences an opportunity to learn techniques of mathematical modeling under the supervision and guidance of experts in the field.

In a first session, the mentors will present the problems, and for the remainder of the week, they will each guide a group of graduate students through to a resolution, culminating in a group presentation and a written document at the end of the week.

The workshop is a preparation for the following IPSW at UBC, and financial support for graduate students is contingent upon their attending both events. Students should arrange for a letter of recommendation from their supervisor.
Contact: sfu@pims.math.ca.
Information: For further details, see http://www.pims.math.ca/industrial/2002/gimmc/.

*19 **Short Course Prior to Conference on Optimization**, Westin Harbour Castle Hotel, Toronto, Canada.
Organizers and Information: Numerical Optimization-Algorithms and Software Organizer: R. Vanderbei, Princeton Univ., Co-instructors: R. Vanderbei, Princeton Univ.; D. F. Shanno, Rutgers Univ.; and H. Y. Benson, Princeton Univ.; Automatic Differentiation Organizer: A. Griewank, The Inst. of Scientific Computing (IWR), Co-instructors: A. Griewank, The Inst. of Scientific Computing (IWR); U. Naumann, INRIA; and A. Walther, Tech. Univ. Dresden.
Information: Contact: meetings@siam.org.

*20-22 **SIAM Conference on Optimization**, Westin Harbour Castle Hotel, Toronto, Canada.
Description: The field of optimization involves a powerful combination of theoretical analysis, algorithm and software development, and scientific computing. The practical scope and utility of optimization continues to grow. The Seventh SIAM Conference on Optimization will address the most important recent advances in linear, nonlinear, and discrete optimization. The meeting will feature the latest research in algorithms and software for the solution of optimization problems. It will also feature important applications of optimization in control, networks, manufacturing, medicine, finance, aeronautical engineering, operations research, and other areas of science and engineering. The conference will bring together mathematicians, operations researchers, computer scientists, engineers, and software developers.
Information: Contact: meetings@siam.org.

*20-24 **Fourth Seminar on Stochastic Analysis, Random Fields and Applications; Fourth Minisymposium on Stochastic Methods in Financial Models**, Centro Stefano Franscini, Ascona, Switzerland.
Organizers: R. Dalang, EPFL (Switzerland); M. Dozzi, Univ. Nancy 2 (France); and F. Russo, Univ. Paris 13 (France).
Information: http://www-math.math.univ-paris13.fr/~russo/Ascona02.html.

*21-24 **International Conference on Modern Algebra**, Vanderbilt University, Nashville, Tennessee.
Description: The conference honors the 60th birthday of Ralph McKenzie and is held in conjunction with the 17th annual Shanks Lectures honoring Baylis and Olivia Shanks. There will be two lectures by the Shanks Lecturer, Efim Zel'manov, as well as twenty-seven other invited lectures and numerous contributed talks.
Topics: Groups, semigroups, lattices, ordered algebraic structures, universal algebra, model theory, and interactions between algebra and logic.
Organizers: J. Farley, R. Freese, M. Gould, P. Jipsen, G. McNulty, M. Maroti, A. Ol'shanskii, M. Sapir, S. Tschantz, C. Tsinakis, and M. Valeriote.
Speakers: V. Artamonov, W. Blok, A. Borovik, S. Burris, R. Freese, A. Glass, G. Gratzer, B. Hart, P. Idziak, P. Jeavons, B. Jonsson, K. Kearnes, O. Kharlampovich, C. Laskowski, R. McKenzie, G. McNulty, D. Monk, D. Mundici, A. Myasnikov, J.B. Nation, P. Palfy, B. Plotkin, H. Priestley, A. Szendrei, M. Valeriote, M. Volkov, R. Willard, and Efim Zel'manov.
Information: Information on abstracts, registration, accommodation, etc.: http://www.math.vanderbilt.edu/~algcon02/.

*23-25 **PIMS Thematic Programme on Selected Topics in Mathematical and Industrial Statistics, 3rd MITACS Annual General Meeting: Statistics for Large Scale Industrial Modelling**, University of British Columbia, Vancouver, British Columbia, Canada.
Information: Contact pims@pims.math.ca or visit http://www.pims.math.ca/stats/.

*23-25 **SIAM Workshop on Validated Computing**, Westin Harbour Castle Hotel, Toronto, Canada.
Description: Validated Computing 2002 will deal with all aspects on validated computing, although we hope for a special emphasis on applications and on tools to support validated computations. There is also a special opportunity to foster interaction between validated computing experts and the optimization community at large. There will be a special session honoring the contributions of Ramon Moore.
Information: Contact: meetings@siam.org.

*23-25 **Workshop in Honour of David F. Andrews and Short Course in Microarray Data Analysis**, The Fields Institute, Toronto, Ontario, Canada.
Invited Speakers: D. Brillinger (Univ. of California, Berkeley), D. Cox (Oxford Univ.), J. Robins (Harvard Univ.), P. McCullagh

(Chicago Univ.), E. Thompson (Washington Univ.), A. Kong (deCode Genetics), M. Newton (Univ. of Wisconsin), R. Tibshirani, (Stanford Univ.), T. Speed and colleagues (Walter & Eliza Hall Institute, Univ. of California, Berkeley).

Information: Please contact Program Coordinator mali@fields.utoronto.ca.

* 26–June 1 **Informal Working Group on Validated Methods for Optimization**, The Fields Institute, Toronto, Canada.

Organizers: G. Corliss, T. Csendes, K. Jackson, B. Kearfott.

Information: Visit http://www.fields.utoronto.ca/programs/scientific/01-02/numerical/optimization/.

* 27–31 **6th PIMS Industrial Problem Solving Workshop**, University of British Columbia, Vancouver, British Columbia, Canada.

Brief Description: Six problems will be posed to the workshop participants by industry experts. The problems are relevant and of current interest to the participating industry. The workshop participants (both faculty and graduate students) then spend the rest of the week working on these unsolved problems with the help of a company representative and some select academic 'mentors'. On the fifth day, oral presentations from each group are made before the whole assembly. We invite graduate students and faculty to participate in this exciting and educational event.

Organizers: J. Maki (Univ. of Alberta), C. Bose (Univ. of Victoria), R. LeVeque (Univ. of Washington), H. Huang (York Univ.), M. Paulhus (Univ. of Calgary), M. Trummer (Simon Fraser Univ.), and I. Frigaard (Univ. of British Columbia).

Information: Contact: ipsw@pims.math.ca or visit http://www.pims.math.ca/industrial/2002/ipsw/.

* 28–31 **International Conference on Functional Analysis and its Applications Dedicated to the 110th Anniversary of Stefan Banach**, Lviv National Unversity, Lviv, Ukraine.

Topics: Geometry, analysis, and approximations in Banach spaces; Spectral methods of functional analysis and mathematical physics; Differential equations in functional and abstract Banach spaces; Function theory; Topology and its applications in functional analysis.

Invited Speakers: Yu. M. Berezanskii (Kyiv), Cz. Bessaga (Warsaw), B. Bojarski (Warsaw), V. I. Bogachev (Moscow), R. Cauty (Paris), V. V. Fedorchuk (Moscow), M. L. Gorbachuk (Kyiv), A. Ya. Helemskii (Moscow), V. M. Kadets (Kharkiv), H. Langer (Vienna), A. M. Plichko (Kirovohrad), Ya. Radyno (Minsk), I. V. Skrypnyk (Kyiv), I. A. Shevchuk (Kyiv), A. A. Shkalikov (Moscow), W. Zelazko (Warsaw).

Information: http://www.banach.lviv.ua/; e-mail: banach_conf@franko.lviv.ua; banach_conf@mebm.lviv.ua; tel.: +380(322) 741107, +380(322)740352.

June 2002

* 1–7 **Minimal Varieties in Geometry and Physics**, SUNY at Stony Brook, Stony Brook, New York.

Organizing Committee: M. Anderson, D. Gromoll, C. LeBrun, M. Rocek, A. Phillips, S. Simanca.

Description: A conference on the occasion of Blaine Lawson's 60th birthday.

Confirmed Speakers: S. Bloch, J. P. Bourguignon, R. Bryant, J. Cheeger, T. Colding, J. Figueroa-O'Farrill, E. Friedlander, H. Gillet, H. Gluck, P. Griffiths, M. Gromov, R. Harvey, D. Hoffman, P. Lima-Filho, R. MacPherson, W. Meeks, W. Minicozzi, R. Osserman, M. Rocek, J. Rosenberg, R. Schoen, I. Singer, G. Tian.

Information: http://www.math.sunysb.edu/varieties/ or send an e-mail to: varieties@math.sunysb.edu.

* 10–14 **PIMS-MITACS Summer School on Applications of Computational Geometry**, Simon Fraser University, Burnaby, BC, Canada.

Information: Contact: pims@pims.math.ca.

* 10–15 **Quantum Probability and Infinite Dimensional Analysis**, Levico Terme, Trento, Italy.

Scientific Organizer: L. Accardi (Roma II). The Centro Interdipartimentale Vito Volterra of the University of Roma Tor Vergata also sponsors this conference.

Information: http://www.science.unitn.it/cirm/.

* 10–16 **NS2002 "Nonstandard Methods and Applications in Mathematics"**, Pisa, Italy.

Description: The congress will consist of two segments. The first one is a satellite conference, June 10-12. The second one is a special session of the joint meeting AMS-UMI, June 12-16. (UMI is the Italian Mathematical Society.) A subsession "Reuniting the Antipodes: Nonstandard and Constructive Views of the Continuum, II" is scheduled as part of the NS2002 congress.

Sponsors: INDAM-GNSAGA, D. Galilaeana.

Organizers: A. Berarducci (Pisa, Italy), N. J. Cutland (Hull, UK), M. Di Nasso (Pisa, Italy), D. Ross (Hawaii, USA).

Invited Speakers Include: S. Albeverio, J. Bell, V. Benci, N. Cutland, K. Hrbacek, R. Jin, H.J. Keisler, P. Loeb, W.A.J. Luxemburg, A. MacIntyre, T. Nakamura, H. Osswald, D. Ross, M. Wolff.

Call for papers: To contribute a talk, submit the title and abstract to: pisa2002@infinitesimals.org.

Information: Please visit our website at: http://docenti.ing.unipi.it/~o18933/Pisa2002/.

* 16–18 **PIMS-MITACS Workshop on Facility Location Problems**, Simon Fraser University, Burnaby, British Columbia, Canada.

Information: Contact: pims@pims.math.ca.

* 16–21 **Current Trends in Commutative Algebra**, Grand Hotel Bellavista, Levico Terme, Trento, Italy.

Scientific Organizers: G. Boffi (Pescara), J. Herzog (Essen), and M. E. Rossi (Genova).

Information: Announcement at http://www.dima.unige.it/~rossim/Levico.html.

* 17–20 **Second Haifa Workshop on Interdisciplinary Applications of Graph Theory, Combinatorics and Algorithms**, University of Haifa, Israel.

The Rothschild Lecture: R. Tarjan (Princeton Univ.) will deliver the second annual Rothschild Lecture.

Invited Plenary Speakers: R. Connelly (Cornell Univ., Ithaca), A. Hartman (IBM Research, Haifa), A. Hoffman (IBM Research, Yorktown Heights), A. Itai (Technion, Haifa), M. Lewenstein (IBM Research, Yorktown Heights), R. McConnell (Univ. of Colorado, Denver), I. Newman (Univ. of Haifa), G. Sabidussi (Univ. of Montreal), M. Sharir (Tel Aviv Univ.), G. Turan (Univ. of Illinois, Chicago), S. Whitesides (McGill Univ., Montreal).

Information: http://www.rothschild.haifa.ac.il/graphs02/.

* 17–21 **Second MaPhySto and StocLab Summer School on Stereology and Geometric Tomography**, Sandbjerg Manor, Soenderborg, Denmark.

Speakers: A. Baddeley (Univ. of Western Australia), R. Gardner (Western Washington Univ.), H. J. G. Gundersen (Univ. of Aarhus), E. B. V. Jensen (Univ. of Aarhus), M. Kiderlen (Univ. of Karlsruhe), K. Kieu (Inst. Nat. de la Recherche Agronomique, Versailles).

Organizer: E. B. V. Jensen (Univ. of Aarhus), eva@imf.au.dk.

Information: Further information at http://www.maphysto.dk/events/S-and-GT2002/.

* 17–28 **MSRI Summer Graduate School on "Excursions in Computational Number Theory–Polynomials with Integer Coefficients"**, PIMS-SFU, Burnaby, British Columbia, Canada.

Organizers: P. Borwein (Simon Fraser Univ.) and M. Filaseta (Univ. of South Carolina).

Information: Visit http://zeta.msri.org/calendar/programs/ProgramInfo/70/show_program/.

* 18–19 **The Fields Institute 10th Anniversary Celebrations**, The Fields Institute, Toronto, Ontario, Canada.

Program: The Institute will be celebrating its 10th anniversary with two days of lectures and visual displays celebrating the mathematicians and activities which have made Fields a unique research facility. Also scheduled is a reception for Fields alumni and friends and a banquet with keynote speaker W. Pulleyblank.

Speakers: S. Cook, Univ. of Toronto; P. Diaconis, Stanford Univ.; M. Golubitsky, Univ. of Houston; V. Jones, Univ. of California at Berkeley; A. MacIntyre, Univ. of Edinburgh; W. Pulleyblank, IBM; C. Rogers, Univ. of Bath; K. Rubin, Stanford Univ.

Information: Please email us at programs@fields.utoronto.ca to be informed of when registration is available or for additional information.

* 19–23 **2nd Canadian Conference on Nonlinear Solid Mechanics**, SFU Harbour Centre, Vancouver, British Columbia, Canada.

Sponsor: PIMS.

Organizers: E. M. Croitoro, cochair (Univ. of Victoria), C. Graham, cochair (Simon Fraser Univ.), R. Choksi (Simon Fraser Univ.), M. Epstein (Univ. of Calgary), M. S. Gadala (Univ. of British Columbia), J. B. Haddow (Univ. of Victoria), T. B. Moodie (Univ. of Alberta), N. Rajapakse (Univ. of British Columbia), P. Schiavone (Univ. of Alberta), and D. J. Steigmann (Univ. of California at Berkeley, USA).

Brief Description: CanCNSM conferences are intended to provide an international forum for communicating recent and projected advances in various areas of nonlinear solid mechanics and materials, to assemble researchers working on common themes from complementary perspectives, and to provide an opportunity for direct information exchange among delegates from academia, research laboratories, and industry. The framework of CanCNSM conferences is truly multidisciplinary.

Scientists from all over the world are encouraged to participate in the conference. All areas of nonlinear solid mechanics as well as areas of linear solid mechanics that are bridging nonlinear aspects are included. The aim of the conference is to have a rich, exciting technical program and an enjoyable social program.

Contact and Information: CanCNSM@pims.math.ca; for further details, see http://www.pims.math.ca/CanCNSM/.

* 24–28 **Symposium on Partial Differential Equations To Celebrate the Seventy-Fifth Birthday of James Serrin**, Università degli Studi di Perugia, Italy.

Information: Registration is mandatory, and the conference fee is 100 Euro. The deadline for registration is May 31, 2002. Webpage: http://dipmat.unipg.it/iniziative/serrin/. For further information, contact symposium.serrin@dipmat.unipg.it.

* 24–29 **Conference on Geometry and Its Application in Technology**, Aristotle University of Thessaloniki, Greece

Organizers: Balkan Society of Geometers (Prof. Tsagas, president; Prof. A. Anastasiei, vice president; Prof. C. Udriste, vice president; Prof. R. Miron, honorary president), Aristotle Univ. of Thessaloniki, Politehnica Univ. of Bucharest.

Scientific Conference Committee: Gr. Tsagas, A. Anastasiei, C. Udriste, R. Mirron, W. Klingenberg, Gh. Atanasiu, A. Asada, P. Popescu, V. Balan, Z. Shen.

Program: The scientific sessions of the conference will consist of general lectures and contributed paper sessions. Contributed papers are solicited in all areas of differential geometry, global analysis, and Lie algebras. The conference scientific committee will make final selection of contributed papers for presentation by April 30, 2002.

Abstract Submission: Prospective presenters are invited to mail or e-mail (preferred mode of submission), a one-page abstract. It should include the author's name(s), address(es), e-mail(s), phone and fax numbers, and key words. Papers and abstracts should be submitted by April 1, 2002. See addresses below.

Information: Inquiries regarding the conference should be addressed to: Balkan Society of Geometers, Aristotle University of Thessaloniki, School of Technology, Mathematics Division, Thessaloniki 54006 Greece, Prof. Gr. Tsagas, Tel: 3-0310-995973, Fax: 3-0310-996155, e-mail: Tsagkas@vergina.eng.auth.gr.

July 2002

* 1–5 **PIMS Thematic Programme on Asymptotic Geometric Analysis, Conference on Convexity and Asymptotic Theory of Normed Spaces**, PIMS-UBC, Vancouver, British Columbia, Canada.

Organizers: E. Lutwak (New York), A. Pajor (Marne-La-Valle).

Workshop Topics: Topics include classical convexity, Radon transform and Fourier methods in convexity, asymptotic theory of high dimensional convex bodies, geometric functional inequalities, probabilistic methods in convexity, isoperimetric-type inequalities.

Contact: pims@pims.math.ca.

Information: For further details, see http://www.pims.math.ca/aga/.

* 1–5 **AISC'2002: Sixth International Conference on Artificial Intelligence and Symbolic Computation Theory, Implementations and Applications (In conjunction with CALCULEMUS'2002)**, Marseille, France.

Organizer: Universite de Provence, Universite de Mideterrannee, Faculte des sciences de Saint-Jerome, and the LSIS laboratory.

Information: More information is available on the website of the conference: http://www.cmi.univ-mrs.fr/aisc2002/.

* 1–6 **Workshop on Optimal Stopping and Stochastic Games**, Banach Center, Mathematical Research and Conference Center, Bedlewo, Poland.

Description: The workshop will be devoted to the classical but still rapidly developing field of stopping of stochastic processes and stochastic games. It has important applications both in real life and other fields of probability theory.

Information: Contact address: Conference OSSG2002, Institute of Mathematics, Wroclaw University of Technology, Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland; fax: (+48-71) 328 07 51; e-mail: ossg2002@im.pwr.wroc.pl; http://neyman.im.pwr.wroc.pl/ossg2002/.

* 2–6 **5th Conference of the European Society of Mathematica and Theoretical Biology on Mathematical Modelling and Computing in Biology and Medicine**, Università and Politecnico di Milano, Milano, Italy.

Topics: Biotechnology and bioengineering; bioinformatics and computational biology; biomedical imaging; cardiovascular system; cell signalling; cellular organisation; ecology; environmental sciences; evolution; immunology; infectious diseases; individual based models; computational neuroscience; visualization; regulatory gene networks.

Program: ECMTB2002 is organized in sections, all of which comprise an invited speaker; minisymposia (2 hours). Posters can also be presented in special sessions.

Information: http://ecmtb.mat.unimi.it/; ecmtb@mat.unimi.it.

* 7–24 **32nd Probability Summer School**, Saint-Flour, France.

Program: J. Pitman, Combinatorial stochastic processes; B. Tsirelson, nonclassical diffusions, stochastic flows, and product systems in the light of stability; W. Werner, Conformal invariance and critical exponents for two-dimensional random curves.

Deadline: The deadline for registration is March 31, 2002. The number of participants is limited.

Organizer: J. Picard, Laboratoire de Mathematiques Appliquees, Univ. Blaise Pascal and CNRS, France.

Information: More information and the online registration form can be found at http://wwwlma.univ-bpclermont.fr/stflour/; e-mail: stflour@math.univ-bpclermont.fr.

*8–12 **PIMS Thematic Programme on Asymptotic Geometric Analysis, Concentration Period on Measure Transportation and Geometric Inequalities**, PIMS-UBC, Vancouver, British Columbia, Canada.
Organizers: R. McCann (Univ. of Toronto).
Workshop Topics: This concentration period will focus on transportation of measure methods and their applications; concentration of measure phenomenon, geometric functional inequalities (Brascamp-Lieb, Sobolev, entropy, Cramer-Crao, and like), "isomorphic" form of geometric inequalities; probabilistic methods.
Contact: pims@pims.math.ca.
Information: http://www.pims.math.ca/aga/.

*8–12 **SIAM 50th Anniversary and 2002 Annual Meeting**, Philadelphia Marriott Hotel, Philadelphia, Pennsylvania.
Information: A celebration of SIAM's 50th birthday, this special annual meeting will look at the strides made by industrial and applied mathematics during the past 50 years and will peek as far as we can see into the next 50. The meeting themes cover SIAM's interests, a partial list of which ranges from analysis to applications, from computing to control to computational science, from dynamics to design, from linear algebra to life sciences, from optimization to outreach.

The program features plenary lectures, topical presentations, contributed talks, prizes, minitutorials, the community lecture, and, of course, minisymposia, along with diversity day, an evening of professional development, and a gala dinner.
Information: Contact: meetings@siam.org.

*8–12 **Workshop on Nonself-adjoint Operator Algebras**, The Fields Institute, Toronto, Ontario, Canada.
Organizer: K. R. Davidson.
List of Confirmed Participants: K. Davidson, The Fields Inst.; A. Donsig, Univ. of Nebraska; A. Hopenwasser, Univ. of Alabama; A. Katavolos, Athens Univ.; E. Katsoulis, East Carolina Univ.; D. Kribs, Univ. of Iowa; L. Marcoux, Univ. of Waterloo; V. Paulsen, Univ. of Houston; J. Peters, Iowa State Univ.; D. Pitts, Univ. of Nebraska; S. Power, Lancaster Univ.; H. Radjavi, Dalhousie Univ. & Univ. of New Hampshire; P. Rosenthal, Univ. of Toronto; B. Solel, Technion Inst.
Information: For further information, please contact Program Coordinator Maryam Ali, mali@fields.utoronto.ca.

*14–18 **PIMS Thematic Programme on Selected Topics in Mathematical and Industrial Statistics, Design and Analysis of Experiments 1 (DAE 1)**, Coast Plaza Suite Hotel, Vancouver, British Columbia, Canada.
Brief Description: Many industrial problems are not well explored in the statistical literature. To help North American industry compete globally, advanced statistical methods suitable for real applications need to be further developed. Statistical experimental designs, developed by Sir Ronald Fisher in the 1920s, largely originated from agricultural problems. Although the design of experiments for industrial and scientific problems may have the same basic concerns as design for agricultural problems, there are many differences: (i) industrial problems tend to require investigation of a much larger number of factors and usually involve a much smaller total number of runs (observations), (ii) industrial results are more reproducible, (iii) industrial experimenters are obliged to run their experimental points in sequence and are thus able to plan their follow-up experiments guided by previous results, unlike agriculture, in which all results are often harvested at one time, and (iii) models can be very complicated in industrial and scientific experimentation, sometimes requiring the need for nonlinear models or for computer modelling and finite element analysis.
Organizers: R. Sitter (SFU), D. Bingham (Michigan), B. Ankenman (Northwestern), and A. Herzberg (Queen's Univ.)
Information: Contact pims@pims.math.ca or visit http://www.pims.math.ca/stats/.

*14–23 **PIMS Thematic Programme on Asymptotic Geometric Analysis, Conference on Phenomena of Large Dimension**, PIMS-UBC, Vancouver, British Columbia, Canada.
Organizers: V. Milman (Tel Aviv), M. Krivelevich (Tel Aviv), L. Lovasz (Microsoft Research), and L. Pastur (Univ. Paris VII).
Workshop Topics: Topics include different phenomena observed in complexity theory, asymptotic combinatorics, asymptotic convexity, statistical physics, and other theories of very high parametric families (or large dimensional spaces); similarities and differences.
Contact: pims@pims.math.ca.
Information: http://www.pims.math.ca/aga/.

*22–August 6 **PIMS-APCTP-PI Frontiers in Mathematical Physics: Brane Worlds and Supersymmetry Workshop**, University of British Columbia, Vancouver, British Columbia, Canada.
Organizers: A. Karch (Univ. of Washington), J. Ng (TRIUMF, Univ. of British Columbia), M. Rozali (Univ. of British Columbia), A. Rutherford (PIMS), and G. W. Semenoff (Univ. of British Columbia).
Brief Description: This workshop is the seventh in the Frontiers in Mathematical Physics Series. As in previous years, it is jointly sponsored by PIMS and the Asia Pacific Center for Theoretical Physics. This workshop will explore the theory and phenomenology of brane-world scenarios, large extra dimensions scenarios, and supersymmetry. These represent different approaches to solving the traditional problems of physics beyond the standard model.
Contact: fmp@pims.math.ca.
Information: http://www.pims.math.ca/science/2002/fmp/.

*24–August 5 **PIMS Thematic Programme on Asymptotic Geometric Analysis, Focused Research Groups on Random Methods and High Dimensional Systems**, PIMS-UBC, Vancouver, British Columbia, Canada.
Organizers: V. Milman (Tel Aviv) and N. Tomczak-Jaegermann (Univ. of Alberta).
Workshop Topics: Topics include the asymtotic behavior of different parameters when the dimension, or a number of other relevant free parameters, increases to infinity. The main direction is the study of the asymptotic theory of convex bodies and normed spaces as well as their applications to combinatorics and phase transition phenomena.
Contact: pims@pims.math.ca.
Information: http://www.pims.math.ca/aga/.

*25–30 **PIMS Thematic Programme on Selected Topics in Mathematical and Industrial Statistics, Filtering Theory and Applications**, University of Alberta and Jasper, Alberta, Canada.
Brief Description: Filtering theory is an active and current research field attracting many applied probabilists. In particular, there is increasing interest in applying filtering theory to real-world problems in areas such as mathematical finance, target detection and tracking, communication networks, pollution tracking, weather prediction, traffic management, search and rescue. We believe that the proposed meeting will help to advance scientific developement of filtering theory and its applications and offer benefits to industry. In particular, this meeting will encourage local research activity in this field and identify additional industrially-motivated filtering problems.
Organizers: R. Elliott (Univ. of Calgary), M. Kouritzin, H. Long (Univ. of Alberta), T. Kurtz (Wisconsin-Madison).
Information: Contact pims@pims.math.ca or visit http://www.pims.math.ca/stats/.

*28–August 9 **4th PIMS School of Environmental and Industrial Fluid Dynamics**, University of Alberta, Edmonton, Alberta, Canada.
Brief Description: Participants will attend a comprehensive series of lectures and will be given hands-on experience performing and analyzing experiments in the Environmental and Industrial Fluid Dynamics Laboratory, as well as running numerical simulations using research-level codes.

Topics will include fluid dynamics fundamentals, industrial and environmental flows, geophysical fluid dynamics, turbulence modelling, and computational fluid dynamics. Subjects will be taught at a graduate level.
Information: Contact fdss@math.ualberta.ca or visit http://fdss.math.ualberta.ca/.

August 2002

* 4–8 **PIMS Symposium on Aperiodic Order, Dynamical Systems, Operator Algebras, and Toplogy**, University of Victoria, Victoria, British Columbia, Canada.
Information: Contact: pims@pims.math.ca.

* 4–9 **International Conference on Mathematics in Finance**, Berg-en-Dal, Kruger National Park, South Africa.
Scope: The conference will focus on various aspects within the field, with special attention given to the interaction between the different areas, and in particular emphasizing the role of mathematics and statistics. Topics that would be covered include among others: stochastic models; modern methods of risk analysis; quantitative and computational models and methods; methods of financial mathematics; in particular the role of measure theory, functional analysis, and modern stochastics in finance.
Keynote Speakers: The following is a list of keynote speakers who have indicated that they will attend: T. Bjoör, Dept. of Finance, Stockholm School of Economics; F. Delbaen, Dept. of Mathematics, ETH, Zurich; P. Embrechts, Dept. of Mathematics, ETH, Zurich; D. Heath, Dept. of Math. Sci., Carnegie Mellon Univ., Alexander McNiel, Dept. of Mathematics, ETH, Zuüric; M. Monoyios, Dept. of Economics & Finance, Brunel Univ., United Kingdom; E. Platen, School of Finance & Economics, UTS, Sydney; G. Samorodnitsky, School of Operations Research and Industrial Engineering, Cornell Univ.
Information: http://www.mif.up.ac.za/, e-mail: mif@math.up.ac.za.

* 5–9 **Stark's Conjectures and Related Topics**, Johns Hopkins University, Baltimore, Maryland.
Description: A conference funded by the National Science Foundation, the Number Theory Foundation, and Johns Hopkins University.
Confirmed Participants: M. Flach (Caltech), B. H. Gross (Harvard), D. Hayes (Amherst), H. M. Stark (San Diego), J. Tate (Austin), K. Rubin (Stanford).
Organizing Committee: D. Burns (david.burns@kcl.ac.uk, King's College, London U.K.); C. Popescu (cpopescu@math.jhu.edu, Johns Hopkins Univ., Baltimore, MD); J. Sands (sands@math.uvm.edu, Univ. Vermont at Burlington, VT); D. Solomon (solomon@mth.kcl.ac.uk, King's College, London U.K.).

* 6–9 **PIMS Thematic Programme on Asymptotic Geometric Analysis, Conference on Noncommutative Phenomena and Random Matrices**, PIMS-UBC, Vancouver, British Columbia, Canada.
Organizers: G. Pisier (Univ. Paris VI and Texas A&M) and S. Szarek (Univ. Paris VI and Case Western Reserve).
Workshop Topics: Topics include the distribution of eigenvalues of random matrices, norms of such matrices, some aspects of free and quantum information theories, applications in many fields, quantized functional analysis and operator spaces, noncommutative L_p spaces.
Contact: pims@pims.math.ca.
Information: http://www.pims.math.ca/aga/.

* 7–11 **Workshop on Geometry, Dynamics, and Mechanics in Honour of the 60th Birthday of J. E. Marsden**, The Fields Institute, Toronto, Ontario, Canada.
Organizing Committee: A. Bloch, P. Newton, T. Ratiu, S. Shkoller, A. Weinstein.
Overview: The workshop will be organized along the seven main themes of Professor Marsden's work: (1) Geometric mechanics, (2) Fluid mechanics, (3) Elasticity and analysis, (4) Numerical algorithms, (5) Relativity and quantum mechanics, (6) Geometric control theory, (7) Dynamical systems.
Information: Please contact the program coordinator at marsden60@fields.utoronto.ca for information regarding registration.

* 8–9 **Beyond the Formula Statistics Conference**, Monroe Community College, Rochester, New York.
Description: A conference for teachers of introductory statistics. The central focus will be "How does a classroom instructor actually use the new curriculum ideas and modern techniques to teach a beginning statistics course?" To attend conferences and learn about all the wonderful new ideas presented is great, but it does not go far enough for many instructors. There needs to be more emphasis on exactly how instructors can incorporate these ideas into their course, into their curriculum, into their teaching techniques, into their evaluations. There will be several presentations in the areas of curriculum, teaching techniques, technology usage, and applications.
Information: Please check out our Beyond the Formula website for information about our history and the plans for this year's conference as they develop: http://www.monroecc.edu/go/beyondtheformula/.

* 11–14 **SIAM Conference on Discrete Mathematics**, Handlery Hotel and Resort, San Diego, California.
Description: The purpose of this conference is to highlight the major theoretical advances in the field, the development of new tools for discrete mathematics, and the most significant of the new applications of discrete mathematics to problems arising in industry and business. The conference also seeks to bring together participants from the many different environments where discrete mathematics is developed and applied.
Information: Contact: meetings@siam.org.

* 11–16 **Geometric and Algebraic Combinatorics 2**, Oisterwijk, The Netherlands.
Organizers: A. Blokhuis (Eindhoven Univ. of Technology), W. Haemers (Tilburg Univ.)
Topics: Algebraic graph theory, finite geometry, and combinatorial designs.
Invited speakers: A. Brouwer (Eindhoven Univ. of Tech.), G. Ebert (Univ. of Delaware), D. Fon-Der-Flaass (Novosibirsk Inst. of Math.), N. Sloane (AT&T Shannon Lab), H. Van Maldeghem (Univ. of Gent).
Information: http://few.kub.nl/gac2/.

* 11–19 **International School "Inverse Problems: Theory and Applications"**, Khanty-Mansiysk, Russia.
School Themes: Theoretical basics for investigation of inverse problems; inverse problems of mechanics, geophysics, tomography, ecology; numerical analysis of inverse problems and applications.
Organizers: Government of Khanty-Mansiysk Autonomous Okrug, Ugra Research Institute of Informational Technologies, Sobolev Institute of Mathematics, Institute of Computational Mathematics and Mathematical Geophysics.
Program: Academicians M. M. Lavrent'ev and A. S. Alekseev will preside the scientific work of the School. The School consists of lectures delivered by invited speakers in the mornings and research seminars in the afternoons where the participants will get a chance to make their reports.
Information: Further information is available at http://www.math.nsc.ru/conference/invconf.

* 12–15 **PIMS Thematic Programme on Asymptotic Geometric Analysis, Conference on Banach Spaces**, PIMS-UBC, Vancouver, British Columbia, Canada.
Organizers: B. Johnson (Texas A&M) and T. Odell (Univ. of Texas, Austin).
Workshop Topics: This conference will focus on the asymptotic theory of Banach spaces and other applications of local theory to

the geometry of infinite dimensional Banach spaces.
Contact: pims@pims.math.ca.
Information: http://www.pims.math.ca/aga/.

* 12-15 **The 2002 Workshop on the Solution of Partial Differential Equations on the Sphere**, The Fields Institute, Toronto, Canada.
Organizers: J. Drake, K. Jackson, P. Swarztrauber, D. Williamson.
Information: Visit http://www.fields.utoronto.ca/programs/scientific/01-02/numerical/pde_workshop/.

* 13-19 **Discrete, Combinatorial, and Computational Geometry, an ICM Satellite Conference**, Beijing, China.
Description: The conference will provide an opportunity for people working in these three areas of geometry to meet, share ideas and recent results, and work together.
Organizers: J. E. Goodman, R. Pollack, and C. Zong.
Sponsors: Peking University and the National Science Foundation of China.
Invited Speakers: Among those who have confirmed so far are I. Bárány, P. Brass, C. Buchta, R. Connelly, E. D. Demaine, R. Gardner, S. Golomb, E. Grinberg, P. M. Gruber, T. Hales, M. Henk, W.-Y. Hsiang, J. C. Lagarias, D. G. Larman, J. Pach, I. Streinu, G. Tóth, H. Tverberg, J. M. Wills, T. Zamfirescu, G. Zhang, and G. M. Ziegler.
Call for Papers: If you are interested in presenting a short talk (up to 30 minutes), please send an abstract to the local organizer, Chuanming Zong (cmzong@math.pku.edu.cn). The organizers will select the short talks to be presented on the basis of the abstracts submitted.
Information: For information on the conference fee and on possible financial support, please write to C. Zong (cmzong@math.pku.edu.cn).

* 20-27 **Summer School: From Levy Processes to Semimartingales—Recent Theoretical Developments and Applications to Finance**, University of Aarhus, Denmark.
Program: Introduction to Semimartingales and their Basic Algebra, lectures by A. N. Shiryaev, Stek. Inst., Moscow; Change of Time and Measure, lectures by Albert N. Shiryaev, Stek. Inst., Moscow; Stochastic Volatility Models and Some of Their Applications, lectures by N. Shephard, Nuffield College, Oxford; O. E. Barndorff-Nielsen, MaPhySto, Aarhus; and F. Hubalek, Vienna Univ. of Tech. In addition there will be tutorial classes and a number of special invited lectures.
Organizers: O. E. Barndorff-Nielsen, Univ. of Aarhus, e-mail: oebn@imf.au.dk; B. J. Christensen, Univ. of Aarhus, e-mail: bjchristensen@econ.au.dk.
Information: http://www.maphysto.dk/events/LPS2002/.

* 25-September 1 **40th International Symposium on Functional Equations**, Gronów, Poland.
Program: We are planning 10 regular sessions, each of them consisting of 7 talks of at most 20 minutes duration, a special session about mean values, a 45-minute survey lecture on iterative functional equations, and about 10 problems and remarks sessions.
Workshop Topics: Functional equations in one and several variables, functional inequalities and mean values, functional equations on algebraic structures, Hyers-Ulam stability, regularity properties of solutions, conditional functional equations and equations on restricted domain, iteration theory, functional-differential equations.
Organizers: Inst. of Math., Univ. of Zielona Góra, Poland.
Speakers: We expect about 70 speakers invited by the Scientific Committee consisting, among others, of J. Aczél (Honorary Chairman; Waterloo, Canada), Z. Daróczy (Debrecen, Hungary), R. Ger (Katowice, Poland), L. Reich (Graz, Austria), A. Sklar (Chicago, USA).
Information: Participation is by invitation only. Those wishing to be invited should send details of their interest and, preferably, publications on the subject to the organizers and/or to a member of the scientific committee before the end of May 2002.
Information: isfe40@uz.zgora.pl.

* 29-September 3 **First Sino-German Meeting on Stochastic Analysis (Satellite Conference to the ICM 2002)**, Beijing, China.
Sections: 1) Geometry on path space (organizer: R. Léandre, e-mail: leandre@iecn.u-nancy.fr), 2) Infinite dimensional analysis, measure-valued processes and Dirichlet forms (organizer: K.-T. Sturm, e-mail: sturm@uni-bonn.de), 3) Noncommutative and quantum probability (organizer: M. Schuermann, e-mail: schurman@uni-greifswald.de), 4) Pseudodifferential operators and jump processes (organizer: N. Jacob, e-mail: N.Jacob@swansea.ac.uk), 5) Random media (organizer: A. Bovier, e-mail: bovier@wias-berlin.de), 6) Statistical mechanics and particle systems (organizer: Yu. Kondratiev, e-mail: kondrat@mathematik.uni-bielefeld.de), 7) Stochastic finance (organizer: M. Schweizer, e-mail: martin.schweizer@mathematik.uni-muenchen.de), 8) Stochastic methods in quantum field theory and hydrodynamics (organizers: P. Blanchard, e-mail: blanchard@physik.uni-bielefeld.de and L. Streit, e-mail: streit@physik.uni-bielefeld.de), 9) Stochastic partial differential equations (organizer: L. Tubaro, e-mail: tubaro@science.unitn.it).
Invited Speakers: L. Accardi, L. Bogachev, V. I. Bogachev, E. Bolthausen, Z. Brzezniak, A. B. Cruzeiro, M. F. Chen, A. Debussche, J. D. Deuschel, B. Driver, A. Eberle, D. Elworthy, S. Fang, B. Ferrario, D. Filipovic, U. Franz, H. Gottschalk, A. Guionnet, I. Gyongy, F. Götze, M. Hino, W. Hoh, P. Hsu, K. Kuwae, X. M. Li, Y. G. Lu, S. Lotoski, F. Merkl, B. Ruediger, A. Sengupta, M. Skeide, W. Stannat, A. Thalmaier, F. Y. Wang, L. M. Wu, A. Zegarlinski, T. S. Zhang.
Information: If you are interested in participating, please contact the organizer of the section closest to your interest and send a copy of your communcation to the following address: M. L. Wang (wang@uni-bonn.de).

* 30-September 2 **33rd Iranian Mathematics Conference**, Ferdowsi University, Mashhad, Iran.
Scope: The aim of the Annual Iranian Mathematics Conference is to bring together established and new researchers and graduate students for an exchange of ideas and discussions on all aspects of mathematics. The conference will consist of a series of invited plenary lectures and session for contributed papers.
Organizer: Department of Mathematics, Ferdowsi University of Mashhad.
Chair: A. Niknam.
Invited Speaker: A tentative list can be found on the webpage.
Call for Paper: The abstract should be typed in Latex and sent to the Secretary.
Address and deadline: Secretary of the Conference, Department of Mathematics, Ferdowsi University, P. O. BOX 1159, Mashhad 91775, Iran; e-mail: imc33@math.um.ac.ir; imc33@ferdowsi.um.ac.ir; home: http://www1.um.ac.ir/~imc33/; May 5, 2002, to register and submit abstract.

September 2002

* September-December 2002 **Thematic Program on Set Theory and Analysis**, The Fields Institute, Toronto, Canada.
Information: Visit http://www.fields.utoronto.ca/programs/scientific/02-03/set_theory/.

* 1-8 **17th International Workshop on Differential Geometric Methods in Theoretical Mechanics**, Levico Terme, Trento, Italy.
Scientific Organizer: E. Pagani (Trento).
Information: First Announcement at http://www.science.unitn.it/cirm/DGMTM.1ann.html.

* 5 **PIMS Numerical Analysis Potlatch 2002**, University of Victoria, Victoria, British Columbia, Canada.
Information: Contact: pims@pims.math.ca.

* 20-21 **AD-HOC NetwOrks and Wireless (ADHOC-NOW)**, The Fields Institute, Toronto, Ontario, Canada.

Scope: We are interested in work in progress, experimental and theoretical research in Ad-Hoc, Mobile and Wireless Networks.

Program Co-chairs: M. Barbeau and E. Kranakis, Carleton University, School of Computer Science, Ottawa, Ontario, K1S 5B6, Canada.

Information: For more information see website `http://www.scs.carleton.ca/%7Eadhocnow/`.

October 2002

* 4–5 **SIAM Symposium on Computational Models and Simulation for Intra-Cellular Processes**, Hilton Garden Inn, Washington, DC.

Information: The interaction between the mathematical and computational sciences and biology has been growing in importance in the last decade, but it is still a beginning. There is tremendous room for progress. For example, major advances are needed in mathematical and statistical methods to have significant impact on the prediction and control of spatio-temporal cellular behavior. Some specific processes that are amenable to mathematical methods are networks of molecular interactions such as gene-gene, gene-protein, and protein-protein. Applications of such interactions include discovery of functional modules in cellular systems, and rapid and precise identification of targets and design of intervention methods that influence molecular dynamics.

Information: Contact: `meetings@siam.org`.

November 2002

* 2–3 **PIMS Cascade Topology Conference**, University of British Columbia, Vancouver, British Columbia, Canada.

Information: Contact: `pims@pims.math.ca`.

December 2002

* 9–13 **FICOFEST, A Conference in Low-dimensional Topology to Celebrate the Sixtieth Birthday of Francisco Javier "Fico" Gonzalez Acuna**, Universidad Autonoma de Yucatan, Merida, Yucatan, Mexico.

Organizers: M. Eudave-Munoz (UNAM), V. Nunez (CIMAT), L. Armas-Sanabria (UNAM), M. Neumann-Coto (UNAM), J. Seade (UNAM), J. C. Gómez-Larrañaga (CIMAT).

Speakers: M. Boileau, D. Gabai, S. Gitler, C. Gordon, J. Hempel, L. Kauffman, R. Kirby, R. Lickorish, S. López de Medrano, J. Luecke, L. Montejano, K. Murasugi, R. Myers, D. Rolfsen, D. Roseman, M. Scharlemann, P. Scott, H. Short, J. Simon, De Witt Sumners, A. Verjovsky, E. Winkelnkemper

Information: `http://www.matem.unam.mx/ficofest/` or contact M. Eudave-Munoz at: `ficofest@cimat.mx`.

January 2003

* 4–6 **SIAM Conference on Imaging Science**, Boston, Massachusetts.

Information: Current developments in the technology of imaging have led to an explosive growth in the interdisciplinary field of imaging science. With the advent of new devices capable of seeing objects and structures not previously imagined, the reach of science and medicine has been extended in a multitude of different ways. The impact of this technology has been to generate new challenges associated with the problems of formation, acquisition, compression, transmission, and analysis of images. By their very nature, these challenges cut across the disciplines of physics, engineering, mathematics, biology, medicine, and statistics. While the primary purpose of this conference is to focus on mathematical issues, the biomedical aspects of imaging will also play an important role.

Information: Contact: `meetings@siam.org`.

* 12–14 **ACM-SIAM Symposium on Discrete Algorithms**, Hyatt Regency, Baltimore, Maryland.

Information: Contact: `meetings@siam.org`.

February 2003

* 9 **Short Course Prior to Conference on Computational Science and Engineering**, Hyatt Regency Islandia Hotel and Marina, San Diego, California.

Information: Contact: `meetings@siam.org`.

* 10–14 **Permutation Patterns**, University of Otago, Dunedin, New Zealand.

Topics: The unifying theme of the conference is permutation patterns. The topics addressed will include enumeration questions, excluded pattern questions, study of the involvement order, algorithms for computing with permutation patterns, applications and generalizations of permutation patterns, and others.

Speaker: H. Wilf.

Registration: $100 NZ by November 1, 2002, and $150 thereafter.

Submissions: Extended abstracts (at most 6 pages) of papers to be presented at the conference should be sent to the Program Chair by December 31, 2002.

Program Chair: M. Albert.

Information: See `http://www.cs.otago.ac.nz/staffpriv/mike/PP2003/FirstAnnouncement.html`.

March 2003

* 17–20 **SIAM Conference on Mathematical and Computational Issues in the Geosciences**, Radisson Hotel and Suites Austin, Austin, Texas.

Information: Contact: `meetings@siam.org`.

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.

May 2003

* 1–3 **SIAM International Conference on Data Mining**, Cathedral Hill Hotel, San Francisco, California.

Information: Contact: `meetings@siam.org`.

* 20–24 **Fourth Seminar on Stochastic Analysis, Random Fields and Applications Fourth Minisymposium on Stochastic Methods in Financial Models**, Centro Stefano Franscini, Ascona, Switzerland.

Organizer: R. Dalang EPFL (Switzerland), M. Dozzi (Univ. Nancy 2, France), and F. Russo (Univ. Paris 13, France).

Information: `http://www-math.math.univ-paris13.fr/~russo/Ascona02.html`.

* 27–31 **SIAM Conference on Applications of Dynamical Systems**, Snowbird Ski and Summer Resort, Snowbird, Utah.

Information: Contact: `meetings@siam.org`.

June 2003

* 16–20 **2003 SIAM Annual Meeting**, Queen Elizabeth Hotel, Montreal, Quebec, Canada.

Information: Contact: `meetings@siam.org`.

July 2003

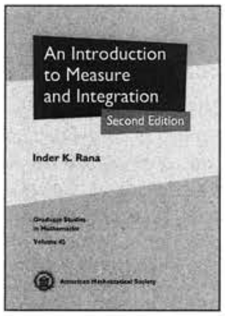
* 15–19 **SIAM Conference on Applied Linear Algebra**, William and Mary College, Williamsburg, Virginia.

Information: Contact: `meetings@siam.org`.

New Publications Offered by the AMS

Analysis

Recommended Text



An Introduction to Measure and Integration
Second Edition

Inder K. Rana, *Indian Institute of Technology, Powai, Mumbai*

From reviews for the First Edition:

Distinctive features include: 1) An unusually extensive treatment of the historical developments leading up to the Lebesgue integral ... 2) Presentation of the standard extension of an abstract measure on an algebra to a sigma algebra prior to the final stage of development of Lebesgue measure. 3) Extensive treatment of change of variables theorems for functions of one and several variables ... the conversational tone and helpful insights make this a useful introduction to the topic ... The material is presented with generous details and helpful examples at a level suitable for an introductory course or for self-study.

—Zentralblatt MATH

A special feature [of the book] is the extensive historical and motivational discussion ... At every step, whenever a new concept is introduced, the author takes pains to explain how the concept can be seen to arise naturally ... The book attempts to be comprehensive and largely succeeds ... The text can be used for either a one-semester or a one-year course at M.Sc. level ... The book is clearly a labor of love. The exuberance of detail, the wealth of examples and the evident delight in discussing variations and counter examples, all attest to that ... All in all, the book is highly recommended to serious and demanding students.

—Resonance

Integration is one of the two cornerstones of analysis. Since the fundamental work of Lebesgue, integration has been interpreted in terms of measure theory. This introductory text starts with the historical development of the notion of the integral and a review of the Riemann integral. From here, the reader is naturally led to the consideration of the Lebesgue integral, where abstract integration is developed via measure theory. The important basic topics are all covered: the Fundamental Theorem of Calculus, Fubini's Theorem, L_p spaces, the Radon-Nikodym Theorem, change of variables formulas, and so on.

The book is written in an informal style to make the subject matter easily accessible. Concepts are developed with the help of motivating examples, probing questions, and many exercises. It would be suitable as a textbook for an introductory course on the topic or for self-study.

For this edition, more exercises and four appendices have been added.

The AMS maintains exclusive distribution rights for this edition in North America and nonexclusive distribution rights worldwide, excluding India, Pakistan, Bangladesh, Nepal, Bhutan, Sikkim, and Sri Lanka.

Contents: Prologue: The length function; Riemann integration; Recipes for extending the Riemann integral; General extension theory; The Lebesgue measure on $\mathbb{R}$ and its properties; Integration; Fundamental theorem of calculus for the Lebesgue integral; Measure and integration on product spaces; Modes of convergence and L_p-spaces; The Radon-Nikodym theorem and its applications; Signed measures and complex measures; Extended real numbers; Axiom of choice; Continuum hypotheses; Urysohn's lemma; Singular value decomposition of a matrix; Functions of bounded variation; Differentiable transformations; Index of symbols; References; Index.

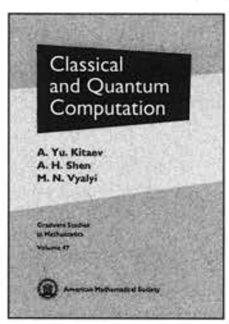
Graduate Studies in Mathematics, Volume 45

July 2002, approximately 456 pages, Hardcover, ISBN 0-8218-2974-2, LC 2002018244, 2000 *Mathematics Subject Classification*: 28-01; 28A05, 28A10, 28A12, 28A15, 28A20, 28A25, 28A33, 28A35, 26A30, 26A42, **All AMS members $47**, List $59, Order code GSM/45N

Applications

Recommended Text

Available in Hardcover and Softcover Editions



Classical and Quantum Computation

A. Yu. Kitaev, *California Institute of Technology, Pasadena,* and **A. H. Shen** and **M. N. Vyalyi**, *Independent University of Moscow, Russia*

This book is an introduction to a new rapidly developing topic: the theory of quantum computing. It begins with the basics of classical theory of computation: Turing machines, Boolean circuits, parallel algorithms, probabilistic computation, NP-complete problems, and the idea of complexity of an algorithm. The second part of the book provides an exposition of quantum computation theory. It starts with the introduction of general quantum formalism (pure states, density matrices, and superoperators), universal gate sets and approximation theorems. Then the authors study various quantum computation algorithms: Grover's algorithm, Shor's factoring algorithm, and the Abelian hidden subgroup problem. In concluding sections, several related topics are discussed (parallel quantum computation, a quantum analog of NP-completeness, and quantum error-correcting codes).

Rapid development of quantum computing started in 1994 with a stunning suggestion by Peter Shor to use quantum computation for factoring large numbers—an extremely difficult and time-consuming problem when using a conventional computer. Shor's result spawned a burst of activity in designing new algorithms and in attempting to actually build quantum computers. Currently, the progress is much more significant in the former: A sound theoretical basis of quantum computing is under development and many algorithms have been suggested.

In this concise text, the authors provide solid foundations to the theory—in particular, a careful analysis of the quantum circuit model—and cover selected topics in depth. Some of the results have not appeared elsewhere while others improve on existing works. Included are a complete proof of the Solovay-Kitaev theorem with accurate algorithm complexity bounds, approximation of unitary operators by circuits of doubly logarithmic depth. Among other interesting topics are toric codes and their relation to the anyon approach to quantum computing.

Prerequisites are very modest and include linear algebra, elements of group theory and probability, and the notion of a formal or an intuitive algorithm. This text is suitable for a course in quantum computation for graduate students in mathematics, physics, or computer science. More than 100 problems (most of them with complete solutions) and an appendix summarizing the necessary results are a very useful addition to the book. It is available in both hardcover and softcover editions.

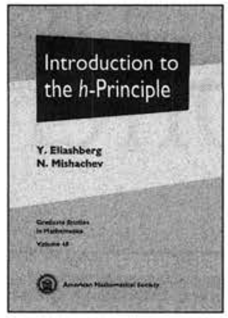
Contents: Introduction; Classical computation; Quantum computation; Solutions; Elementary number theory; Bibliography; Index.

Graduate Studies in Mathematics, Volume 47

July 2002, approximately 272 pages, Hardcover, ISBN 0-8218-2161-X, LC 2002016686, 2000 *Mathematics Subject Classification*: 68–02, 81–02; 68Qxx, 81P68, **All AMS members $47**, List $59, Order code GSM/47N
July 2002, approximately 272 pages, Softcover, ISBN 0-8218-3229-8, LC 2002016686, 2000 *Mathematics Subject Classification*: 68–02, 81–02; 68Qxx, 81P68, **All AMS members $29**, List $36, Order code GSM/47.SN

Geometry and Topology

Recommended Text



Introduction to the h-Principle

Y. Eliashberg, *Stanford University, CA,* and
N. Mishachev, *Lipetsk Technical University, Russia*

One of the most powerful modern methods of solving partial differential equations is Gromov's h-principle. It has also been, traditionally, one of the most difficult to explain. This book is the first broadly accessible exposition of the principle and its applications.

The essence of the h-principle is the reduction of problems involving partial differential relations to problems of a purely homotopy-theoretic nature. Two famous examples of the h-principle are the Nash-Kuiper C^1-isometric embedding theory in Riemannian geometry and the Smale-Hirsch immersion theory in differential topology. Gromov transformed these examples into a powerful general method for proving the h-principle. Both of these examples and their explanations in terms of the h-principle are covered in detail in the book.

The authors cover two main embodiments of the principle: *holonomic approximation* and *convex integration*. The first is a version of the method of continuous sheaves. The reader will find that, with a few notable exceptions, most instances of the h-principle can be treated by the methods considered here. There are, naturally, many connections to symplectic and contact geometry.

The book would be an excellent text for a graduate course on modern methods for solving partial differential equations. Geometers and analysts will also find much value in this very readable exposition of an important and remarkable technique.

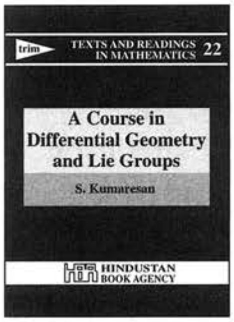
This item will also be of interest to those working in analysis.

Contents: Intrigue; *Holonomic approximation:* Jets and holonomy; Thom transversality theorem; Holonomic approximation; Applications; *Differential relations and Gromov's h-principle:* Differential relations; Homotopy principle; Open Diff V-invariant differential relations; Applications to closed manifolds; *Homotopy principle in symplectic geometry:* Symplectic and contact basics; Symplectic and contact structures on open manifolds; Symplectic and contact structures on closed manifolds; Embeddings into symplectic and contact manifolds; Microflexibility and holonomic $\mathcal{R}$-approximation; First applications of microflexibility; Microflexible $\mathfrak{A}$-invariant differential relations; Further applications to symplectic geometry; *Convex integration:* One-dimensional convex integration; Homotopy principle for ample differential relations; Directed immersions and embeddings; First order linear differential operators; Nash-Kuiper theorem; Bibliography; Index.

Graduate Studies in Mathematics, Volume 48

June 2002, approximately 198 pages, Hardcover, ISBN 0-8218-3227-1, 2000 *Mathematics Subject Classification*: 58Axx,
All AMS members $24, List $30, Order code GSM/48N

Recommended Text



A Course in Differential Geometry and Lie Groups

S. Kumaresan, *University of Mumbai, India*

A publication of the Hindustan Book Agency.

This book arose out of courses taught by the author. It covers the traditional topics of differential manifolds, tensor fields, Lie groups, integration on manifolds and basic differential and Riemannian geometry. The author emphasizes geometric concepts, giving the reader a working knowledge of the topic. Motivations are given, exercises are included, and illuminating nontrivial examples are discussed.

Important features include the following:

- Geometric and conceptual treatment of differential calculus with a wealth of nontrivial examples.
- A thorough discussion of the much-used result on the existence, uniqueness, and smooth dependence of solutions of ODEs.
- Careful introduction of the concept of tangent spaces to a manifold.
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- A motivated and highly geometric proof of the Frobenius theorem.
- A constant reconciliation with the classical treatment and the modern approach.
- Simple proofs of the hairy-ball theorem and Brouwer's fixed point theorem.
- Construction of manifolds of constant curvature à la Chern.

This text would be suitable for use as a graduate-level introduction to basic differential and Riemannian geometry.

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

Distributed worldwide except in India by the American Mathematical Society.

Contents: Differential calculus; Manifolds and Lie groups; Tensor analysis; Integration; Riemannian geometry; Tangent bundles and vector bundles; Partitions of unity; Bibliography; List of symbols; Index.

Number 9

January 2002, 295 pages, Hardcover, ISBN 81-85931-29-1, 2000 *Mathematics Subject Classification*: 22-01, 53-01, **All AMS members $30**, List $38, Order code HIN/9N

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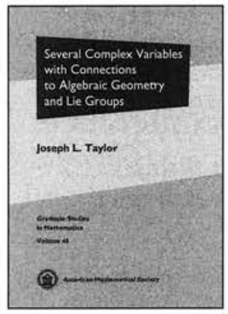

Several Complex Variables with Connections to Algebraic Geometry and Lie Groups

Joseph L. Taylor, *University of Utah, Salt Lake City*

This text presents an integrated development of core material from several complex variables and complex algebraic geometry, leading to proofs of Serre's celebrated GAGA theorems relating the two subjects, and including applications to the representation theory of complex semisimple Lie groups. It includes a thorough treatment of the local theory using the tools of commutative algebra, an extensive development of sheaf theory and the theory of coherent analytic and algebraic sheaves, proofs of the main vanishing theorems for these categories of sheaves, and a complete proof of the finite dimensionality of the cohomology of coherent sheaves on compact varieties. The vanishing theorems have a wide variety of applications and these are covered in detail.

Of particular interest are the last three chapters, which are devoted to applications of the preceding material to the study of the structure theory and representation theory of complex semisimple Lie groups. Included are introductions to harmonic analysis, the Peter-Weyl theorem, Lie theory and the structure of Lie algebras, semisimple Lie algebras and their representations, algebraic groups and the structure of complex semisimple Lie groups. All of this culminates in Miličić's proof of the Borel-Weil-Bott theorem, which makes extensive use of the material developed earlier in the text.

There are numerous examples and exercises in each chapter. This modern treatment of a classic point of view would be an excellent text for a graduate course on several complex variables, as well as a useful reference for the expert.

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

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Graduate Studies in Mathematics, Volume 46

July 2002, approximately 528 pages, Hardcover, ISBN 0-8218-3178-X, LC 2002018346, 2000 *Mathematics Subject Classification*: 34-01, 14-01, 22-01, 43-01, **All AMS members $59**, List $74, Order code GSM/46N

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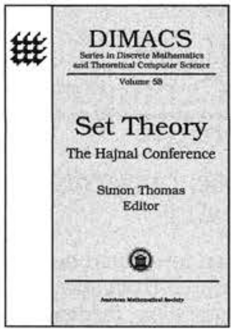


Set Theory
The Hajnal Conference

Simon Thomas, *Rutgers University, New Brunswick, NJ*, Editor

This volume presents the proceedings from the Mid-Atlantic Mathematical Logic Seminar (MAMLS) conference held in honor of András Hajnal at the DIMACS Center, Rutgers University (New Brunswick, NJ). Articles include both surveys and high-level research papers written by internationally recognized experts in the field of set theory.

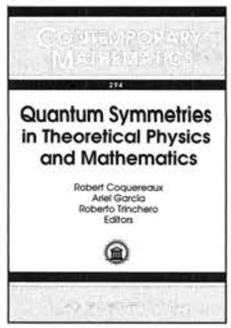
Many of the current active areas of set theory are represented in this volume. It includes research papers on combinatorial set theory, set theoretic topology, descriptive set theory, and set theoretic algebra. There are valuable surveys on combinatorial set theory, fragments of the proper forcing axiom, and the reflection properties of stationary sets. The book also includes an exposition of the ergodic theory of lattices in higher rank semisimple Lie groups—essential reading for anyone who wishes to understand much of the recent work on countable Borel equivalence relations.

Contents: S. Adams, Containment does not imply Borel reducibility; **J. E. Baumgartner**, Hajnal's contributions to combinatorial set theory and the partition calculus; **C. Darby** and **J. A. Larson**, Multicolored graphs on countable ordinals of finite exponent; **M. Džamonja**, On D-spaces and discrete families of sets; **I. Farah**, Analytic Hausdorff gaps; **M. D. Foreman**, Stationary sets, Chang's conjecture and partition theory; **I. Juhász**, **L. Soukup**, and **Z. Szentmiklóssy**, A consistent example of a hereditarily $\mathfrak{c}$-Lindelöf first countable space of size $> \mathfrak{c}$; **P. Komjáth**, Subgraph chromatic number; **S. Shelah**, Superatomic Boolean algebras: Maximal rigidity; **S. Thomas**, Some applications of superrigidity to Borel equivalence relations; **S. Todorčević**, Localized reflection and fragments of PFA; **B. Velickovic**, The basis problem for CCC posets.

DIMACS: Series in Discrete Mathematics and Theoretical Computer Science, Volume 58

June 2002, 162 pages, Hardcover, ISBN 0-8218-2786-3, 2000 *Mathematics Subject Classification*: 03E02, 03E15, 03E35, 03E55; 03G05, 37A20, 54A35, **Individual member $35,** List $59, Institutional member $47, Order code DIMACS/58N

Mathematical Physics



Quantum Symmetries in Theoretical Physics and Mathematics

Robert Coquereaux, *Centre de Physique Théorique, Marseille, France, and Centre de International de Rencontres Mathématiques, Marseille, France*, **Ariel García**, *Max-Planck-Institut für Physik, München, Germany*, and **Roberto Trinchero**, *Centro Atómico Bariloche and Instituto Balseiro, Argentina*, Editors

This volume presents articles from several lectures presented at the school on "Quantum Symmetries in Theoretical Physics and Mathematics" held in Bariloche, Argentina. The various lecturers provided significantly different points of view on several aspects of Hopf algebras, quantum group theory, and noncommutative differential geometry, ranging from analysis, geometry, and algebra to physical models, especially in connection with integrable systems and conformal field theories.

Primary topics discussed in the text include subgroups of quantum $SU(N)$, quantum ADE classifications and generalized Coxeter systems, modular invariance, defects and boundaries in conformal field theory, finite dimensional Hopf algebras, Lie bialgebras and Belavin-Drinfeld triples, real forms of quantum spaces, perturbative and non-perturbative Yang-Baxter operators, braided subfactors in operator algebras and conformal field theory, and generalized (d^N) cohomologies.

Contents: N. Andruskiewitsch, About finite dimensional Hopf algebras; **M. Dubois-Violette**, Lectures on differentials, generalized differentials and on some examples related to theoretical physics; **J. Böckenhauer** and **D. E. Evans**, Modular invariants from subfactors; **A. Ocneanu**, The classification of subgroups of quantum $SU(N)$; **O. Ogievetsky**, Uses of quantum spaces; **J.-B. Zuber**, CFT, BCFT, ADE and all that.

Contemporary Mathematics, Volume 294

June 2002, 230 pages, Softcover, ISBN 0-8218-2655-7, 2000 *Mathematics Subject Classification*: 16W30, 17B37, 20G42, 81R50, 46L87, 46L37, 81T40, 82B20, 81Txx, 18G60, **Individual member $41**, List $69, Institutional member $55, Order code CONM/294N

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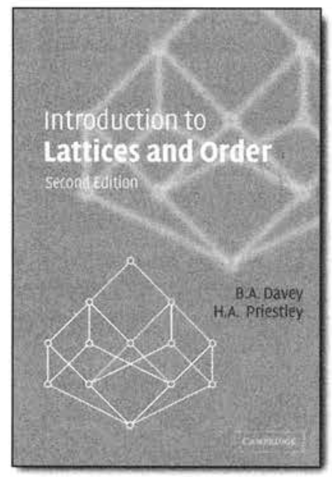

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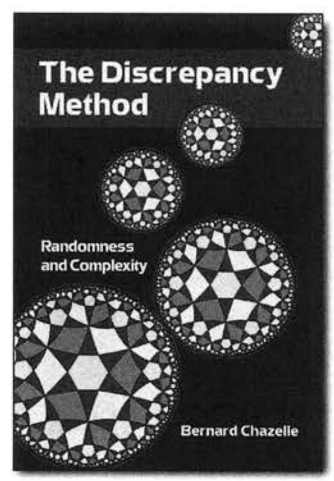

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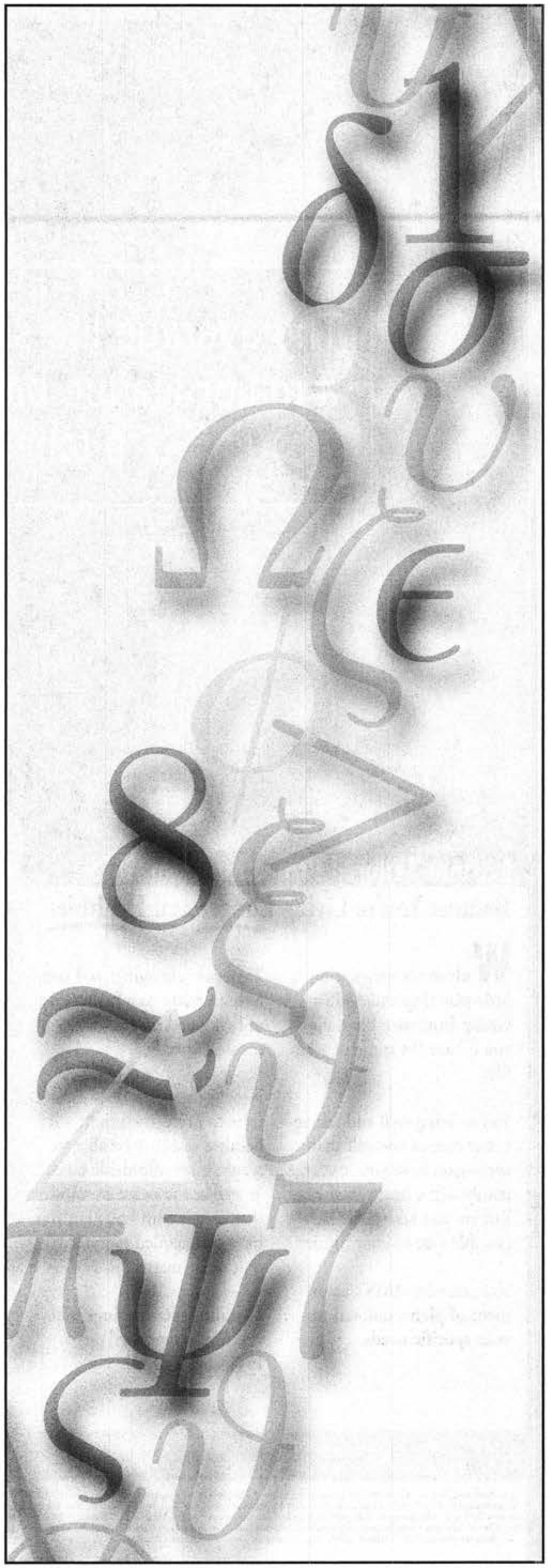

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- ☐ Society of Associations of Mathematicians & Computer Science of Macedonia
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- ☐ Ukrainian Mathematical Society
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- ☐ Union of Bulgarian Mathematicians
- ☐ Union of Czech Mathematicians and Physicists
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AMS Textbooks: Books marked "Recommended Text" are available as examination copies for possible course adoption. To request an exam copy, please write to us on departmental letterhead specifying the book requested, course title and number, term taught, anticipated enrollment, expected decision date, and the text currently in use.

VISIT THE AMS BOOKSTORE AT www.ams.org/bookstore

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

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MATHFEST 2002

BURLINGTON, VERMONT AUGUST 1–3, 2002

THE ANNUAL SUMMER MEETING OF THE MATHEMATICAL ASSOCIATION OF AMERICA

THE TWO-DAY SHORT COURSE
THE MATHEMATICS OF CRYPTOLOGY

For millennia cryptology and mathematics followed separate paths. Now they are intimately entwined, with cryptology influencing the development of mathematics and vice versa. In this short course we shall visit some of the mathematics that has been stimulated by cryptology, some of the cryptology that has arisen out of mathematical problems, and some of the real-world issues that arise when cryptosystems are actually implemented. Most talks will supplement what is usually found in an undergraduate text on cryptology. The listed talks will be given at the short course. They are listed in alphabetical order by speaker. The actual order will be different. To sign up for this course, go to `www.maa.org` and download the MathFest registration form.

ORGANIZED BY

Carl Pomerance, *Lucent Technologies, Bell Labs*

PART I: TUESDAY, JULY 30, 9:00 AM–5:00 PM

PART II: WEDNESDAY, JULY 31, 9:00 AM–5:00 PM

IMPLEMENTING PUBLIC KEY CRYPTOLOGY: THE DEVIL IS IN THE DETAILS
Daniel Bleichenbacher, *Lucent Technologies, Bell Labs*

HOW HARD IS FACTORING?
Carl Pomerance, *Lucent Technologies, Bell Labs*

HOW HARD ARE DISCRETE LOGARITHMS?
Carl Pomerance, *Lucent Technologies, Bell Labs*

ELLIPTIC CURVES AND CRYPTOLOGY
Joe Silverman, *Brown University and NTRU Cryptosystems, Inc.*

LATTICES AND CRYPTOLOGY
Joe Silverman, *Brown University and NTRU Cryptosystems, Inc.*

THE GIVE AND TAKE OF MAKING AND BREAKING CRYPTOSYSTEMS
Mike Szydlo, *RSA Security, Inc.*

TEXTBOOK CRYPTOGRAPHY AND THE REAL WORLD
Mike Szydlo, *RSA Security, Inc.*

COMBINATORIAL CRYPTOGRAPHY AND THE 'TWO SHERIFFS PROBLEM'
Peter Winkler, *Lucent Technologies, Bell Labs*

COMPARISON WITHOUT DISCLOSURE (OR AVOIDING CRYPTOGRAPHY FOR FUN AND PROFIT)
Peter Winkler, *Lucent Technologies, Bell Labs*

CMS Summer Meeting 2002

Université Laval, Quebec City, Quebec, June 15–17, 2002

On behalf of Laval University, the Department of Mathematics and Statistics invites all researchers, educators and students to the Summer 2002 Meeting of the Canadian Mathematical Society (CMS).

Following the usual format, the meeting will include fourteen symposia, contributed papers, five plenary speakers, as well as the Jeffery-Williams and Krieger-Nelson lecturers and a public lecture presented by Jean-Marie De Koninck.

Laval University is also very pleased to announce that, during the meeting, Professor Robert P. Langlands (IAS) will receive a honoris causa doctorate.

All pre-meeting activities and scientific talks will be held at Pavillon Palasis-Prince and Pavillon Alexandre-Vachon, home of Laval's Faculty of Science and Engineering.

The most up-to-date information concerning the programmes, including scheduling, will be made available at the following world wide web address:

`http://www.cms.math.ca/Events/summer02/`

Meeting registration forms and hotel accommodation forms are published in the February 2002 issue of the *CMS Notes* and are also available on the website, along with on-line forms for registration and submission of abstracts.

Public Lecture

Jean-Marie De Koninck (Laval University)

Plenary Speakers

David W. Henderson (Cornell University); **Nikolai Nikolski** (University of Bordeaux 1, Steklov Inst.); **Christophe Reutenauer** (Université du Québec à Montréal; **Paul D. Seymour** (Princeton University); **Isadore M. Singer** (MIT).

Prizes and Awards

The **CMS Jeffery-Williams Lecture** will be given by **Edwin Perkins**, University of British Columbia.

The **CMS Krieger-Nelson Lecture** will be given by **Priscilla Greenwood**, University of British Columbia, Arizona State University.

Honorary Degree

Laval University is very pleased to announce that **Robert P. Langlands** (IAS) will receive a honoris causa doctorate. The presentation will be made during the banquet on Sunday, June 16, 2002.

Symposia

By invitation of the Meeting Committee, there will be symposia in the following areas. Here is the preliminary list of speakers. If you are interested in being an invited speaker in one of the symposia, it may be possible to do so by contacting one of the organizers of that symposium. (*) Indicates tentative.

Analysis (Org: **T. Ransford**, Laval University).

L. Baribeau (Laval), A. Boivin* (Western), T. Bloom* (Toronto), A. Brudnyi (Calgary), Y. Chen (Lakehead), B. Cole* (Brown), D. Coman* (Syracuse), G. Dafni (Concordia), R. Fournier (Montreal), A. Fraser* (Dalhousie), P. Gauthier (Montreal), F. Larusson* (Western), N. Levenberg* (Syracuse), J. Mashreghi (Laval), E. Poletsky (Syracuse), D. Rochon* (UQTR), J. Rostand (CRD, Ottawa), Z. Slodkowski (Illinois-Chicago), P. Vitse (Bordeaux/Laval), J. Wermer (Brown).

Arithmetic Algebraic Geometry (Org: **Kumar Murty** and **P. Sastry**, University of Toronto).

D. Arapura (Purdue), N. Boston (Illinois-Urbana), B. Conrad* (Michigan), H. Darmon (McGill), E. Goren (McGill), H. Kisilevsky (Concordia), J. Lewis (Alberta), R. Murty (Queen's), R. Takloo-Bighash (Princeton), Y. Zarhin (Penn State).

Associative Algebras (Org: **I Assem**, University of Sherbrooke, and **F. Huard**, Bishop's University).

I. Assem (Sherbrooke), J. Bilodeau (Toronto), R.-O. Buchweitz* (Toronto), J. C. Bustamante* (Sherbrooke), F. Huard (Bishop's), M. Kleiner (Syracuse), M. Lanzilotta (Republica, Uruguay), J. Lévesque (Sherbrooke), S. Liu* (Sherbrooke), A. Martsinkovsky (Northeastern), R. Raphael* (Concordia), D. Zacharia* (Syracuse).

Category Theory (Org: **R. Paré**, Dalhousie University).

M. Barr (McGill), R. Blute (Ottawa), M. Bunge (McGill), R. Cockett (Calgary), R. Dawson (Saint Mary's), J. Duskin (SUNY-Buffalo), P. Freyd (Pennsylvania), D. Garraway (Colby), A. Joyal (UQAM), F. Linton (Wesleyan), W. MacCaull (St Francis Xavier), J. MacDonald (British Columbia), M. Makkai (McGill), S. Niefield (Union), R. Paré (Dalhousie), D. Pronk (Dalhousie), R. Rosebrugh (Mount Allison), P. Scott (Ottawa), R. Seely (McGill), J. Wick Pelletier (York), R. Wood (Dalhousie).

Combinatorics (Org: **C. Chauvre**, UQAM, **S. Corteel**, CNRS and UQAM, and **P. Leroux**, UQAM).

F. Bergeron (UQAM), M. Bousquet (UQAM), M. Bousquet-Melou (UQAM/Bordeaux), I. Gessel (Waltham), I. Goulden (Waterloo), A. Goupil (UQAM), G. Labelle (UQAM), P. Lalonde (UQAM), V. Liskovets (Minsk), J. Morse (Penn State), I. Pak (Boston), J. Propp* (Wisconsin), F. Ruskey (Victoria), C. Savage (North Carolina), G. Schaeffer (Nancy), R. Stanley (MIT), J.-Y. Thibon (Paris), B. van Rensburg (Toronto), X. Viennot (Bordeaux), T.R. Walsh (UQAM), J. West (Victoria), C. Yan (College Station), D. Zeilberger (Princeton), J. Zeng (Lyon).

Cryptography (Org: **D. Stinson**, University of Waterloo, and **H. Williams**, University of Calgary).

M. Bauer (Waterloo), D. Bernstein (Illinois-Chicago), I. Blake (Toronto), D. Brown (Certicom), P. D'Arco (Waterloo), G. Gong (Waterloo), S. Hamdy (Calgary), A. Hasan (Waterloo), M. Jacobson (Manitoba), R. LaFlamme (Waterloo), S. Magliveras (Florida Atl.), R. Mollin (Calgary), K. Murty (Toronto), N. Pippenger (UBC), R. Scheidler (Calgary), A. Silverberg (Ohio State), A. Stein (Illinois-Urbana), S. Tavares (Queen's), E. Teske (Waterloo), G. Walsh (Ottawa), R. Wei (Lakehead).

Differential Geometry (Org: **J. Chen**, University of British Columbia).

C. Arezzo (Università di Parma), J. Bryan (UBC), X. Chen (Princeton), A. Fraser (Brown), X. Liu (Notre Dame), P. Lu (McMaster), Z. Lu (California-Irvine), D. Matessi (Montréal), W. Minicozzi* (Johns Hopkins), M. Minoo (McMaster), G. Tian* (MIT), J. Viaclovsky (MIT), J. Wang (Minnesota), M. Wang (McMaster), R. Wentworth (Johns Hopkins).

Dynamical Systems (Org: **Michael Radin**, RIT).

B. Brooks (RIT), S. A. Campbell (Waterloo), M. G. Cojocaru (Queen's), B. Dionne* (Ottawa), C. Kent (VCU), W. Kosmala (ASU), V. LeBlanc (Ottawa), S. Maggelakis (RIT), A. Novruzi (UBC), M.A. Radin (RIT), H. Sedaghat (VCU), C. Stoica (Victoria).

Graph Theory (Org: **B. Alspach**, University of Regina).

P. Balister* (Memphis), E. Dobson (Mississippi State), L. Goddyn (Simon Fraser), P. Hell (Simon Fraser), J. Janssen* (Dalhousie), D. Marusic (Ljubljana), M. Muzychuk* (Netanya), M. Sajna (Regina), M. Schultz (UNLV), D. Witte (Oklahoma State), X. Yu (Georgia Tech), C.-Q. Zhang (West Virginia).

Mathematical Education The teaching and learning of geometry: Why, what, how (Org: **F. Gourdeau** and **B. R. Hodgson**, Laval University).

J. Baracs (Montréal), D. W. Henderson (Cornell), M. Sinclair (York), W. Whiteley (York).

Those interested in contributing to the Mathematical Education session are invited to contact F. Gourdeau (fredg@mat.ulaval.ca) or B. R. Hodgson (bhodgson@mat.ulaval.ca).

Mathematics of Finance (Org: **Hassan Manouzi**, Laval University).

Those interested in contributing to the Mathematics of Finance session are invited to contact H. Manouzi (hm@mat.ulaval.ca).

Number Theory (Org: **A. Akbary** and **O. Kihel**, University of Lethbridge).

E. Benjamin* (Maine), D. Bradley (Maine-Orono), S. Choi (Simon Fraser), A. Cojocaru (Queen's), C. Cummins (Concordia), C. Cunningham (Calgary), H. Darmon (McGill), C. David (Concordia), L. Davison (Laurentian), J.-M. De Koninck (Laval), S. El Morchid* (Casablanca), E. Goren (McGill), J. G. Huard (Canisius C.), C. Ingalls (New Brunswick), R. Mollin (Calgary), R. Murty (Queen's), A. Ozluk (Maine), D. Roy (Ottawa), A. Sebbar (Ottawa), C. Stewart (Waterloo), F. Thaine (Concordia), G. Walsh (Ottawa).

Probability Theory (Org: **D. Dawson**, Carleton University and **G. Slade**, University of British Columbia).

M. Barlow (UBC), T. Cox (Syracuse), D. Dawson (Carleton/McGill), R. Durrett (Cornell), W. Hong (Carleton), N. Madras (York), C. Mueller (Rochester), J. Quastel (Toronto), A. Sakai (UBC), G. Slade (UBC), J. Walsh (UBC), X. Zhou (Concordia).

Universal Algebra (Org: **J. Hyndman** and **S. Wismath**, University of Lethbridge).

C. Bergman (Iowa State), G. Gratzer (Manitoba), L. Haddad* (RMCC), B. Larose (Concordia), G. McNulty* (South Carolina), J. B. Nation (Hawaii), B. Sands (Calgary), M. Valeriote (McMaster), R. Willard* (Waterloo), J. Young (Iowa State).

Contributed Papers Session (Org: **N. Lacroix** and **C. Levesque**, Laval University).

Contributed papers of 15 minutes duration are solicited. In order to provide a broader audience, there will be parallel sessions of and only of contributed papers: (no lecture in the 13 other sessions). Abstracts for CMS contributed papers should be prepared as specified below. For an abstract to be eligible, the abstract must be received before **May 15, 2002**. The abstract must be accompanied by its contributor's registration form and payment of the appropriate fees.

Travel Grants for Graduate Students

Limited funds are available to partially fund the travel and accommodation costs for graduate students. For more information, please contact the Meeting Committee at gradtravel-summer02@cms.math.ca. Further details regarding deadlines and application procedures are available on our website.

Social Events and Exhibits

A **welcoming reception** will be held Friday, June 14, from 7:00 to 9:00 p.m. in the lobby of Pavillon Palasis-Prince of Laval University. The **Delegates' Luncheon** will be held on Saturday, June 15, from 12:00 to 2:00 p.m. (location to be announced). A ticket to this luncheon is included in all registration fee categories. A **banquet** will be held on Sunday, June 16, from 7:30 p.m. at the Musée du Québec, Parc des Champs-de-Bataille, preceded by a cash bar at 6:30 p.m. in le Grand hall. Tickets to this event are available at $50.00 each. Coffee and juice will be available during the scheduled breaks.

Exhibits will be open during specified hours during the conference.

Business Meetings

The CMS will be holding business meetings during the course of the meeting. Additional information will be provided in later announcements and may be found on the Society's website.

Submission of Abstracts

Abstracts for all talks will be published in the meeting programme and will also be available at `http://cms.math.ca/CMS/Events/summer02/`.

Detailed instructions on the submission of abstracts may be found on the website.

Important deadlines for submission of abstracts:

Invited Speakers : April 1, 2002

Contributed Papers : May 15, 2002.

Registration

The registration form will appear in the **February 2002** issue of the *CMS Notes*. **Electronic pre-registration** is also available at `http://www.cms.math.ca/CMS/Events/summer02/forms.html`.

Payment for preregistration may be made by cheque, or by VISA or MasterCard. Although registration fees are given in Canadian dollars, delegates may send cheques in US dollars by contacting their financial institution for the current exchange rate.

Please note that **payment must be RECEIVED IN OTTAWA on or before May 1 in order to qualify for reduced rates.** In order for your payment to be processed before the meeting, it should be received by May 31.

	Before May 1	After May 1
Delegate's Luncheon included		
Plenary speakers/prize lecturers	$ 0	$ 0
Session speakers	215	215
Organizers	145	145
Non-members	430	560
CMS/AMS/MAA members with grants	290	375
CMS/AMS/MAA members without grants	145	190
One-day fee	195	255
Postdocs, retired	110	145
Teachers (K-12, CEGEP), students, unemployed	55	70
Banquet (free for plenary/prize speakers)	50	50

CMS = Canadian Mathematical Society
AMS = American Mathematical Society
MAA = Mathematical Association of America

Refund Policy

Delegates wishing to cancel their registration must notify the CMS Executive Office **in writing before May 31** to receive a refund less a $40 processing fee. Those whose contributed paper has not been accepted will upon request be fully refunded.

Accommodation

It is recommended that those attending the conference book early to avoid disappointment. Blocks of rooms have been reserved at the locations given below and will be held until the deadlines specified below. Reservations not made by that date will be on a request only, space available basis. Rates are per room, per night and are quoted in Canadian dollars. Where applicable, and in order for your room to be applied against our block, please quote the group code. More detailed information about accommodation choices and reservation forms are available on the website.

Chateau Bonne Entente
3400, chemin Sainte-Foy,
Québec (Québec) Canada G1X 1S6
Check-in: 3:00 p.m.; Check-out: 1:00 p.m.
Applicable taxes: GST (7%), PST (7.5%)
Deadline: May 4, 2002—Group Code: ULMATHS
Phone: 418-653-5221; toll-free: 800-463-4390
FAX: 418-653-3098
`http://www.chateaubonneentente.com/`
E-mail: `hotel@chateaubonneentente.com`
Parking: free
Rates: $79, motel section, single/double occupancy
$135, luxury section, single/double occupancy
$165, superior section, single/double occupancy
Other room types and suites are also available.
(Children 12 yrs old and under sharing parents' accommodation are complimentary.)

Hotel Quartier
2955, Boulevard Laurier,
Sainte-Foy (Québec) Canada G1V 2M2
Check-in: 3:00–4:00 p.m.; Check-out: 12:00 noon
Applicable taxes: GST (7%), PST (7.5%)
Deadline: May 10, 2002—Group Code: 1306soc
Phone: 418-650-1616; Toll-free: 1-888-818-5863
FAX: 418-650-6611
`http://www.hotelquartier.com/`
E-mail: `info@hotelquartier.com`
Parking: free; Local calls: free
Rates: $69, single/double occupancy
(Children 11 yrs old and under sharing parents' accommodation are complimentary.)

Hotel Universel
2300, chemin Ste-Foy,
Sainte-Foy (Québec) Canada G1V 1S5
Check-in: 3:00 p.m.; Check-out: 12:00 noon
Applicable taxes: Hotel tax ($2 per night) + GST (7%), PST (7.5%)
Deadline: May 10, 2002—Group Code: Réunion d'été 2002
Phone: 418-653-5250, toll-free: 800-463-4495
FAX: 418-653-4486
`http://www.hoteluniversel.qc.ca/`
E-mail: `info@hoteluniversel.qc.ca`

Parking: free
Rates: $75, single/double occupancy
$10, each additional person
(Children 16 yrs old and under sharing parents' ccommodation are complimentary.)

Laval University Residences
Summer Housing, Local 1618,
pavillon Alphonse-Marie-Parent
Cité universitaire, Québec (Québec) Canada G1K 7P4
Check-in: 2:00 p.m.; Check-out: 11:00 a.m.
Applicable taxes: GST (7%), PST (7.5%)
Deadline: May 10, 2002 Group Code: 80181
Phone: 418-656-5632
FAX: 418-656-2335
`http://www.ulaval.ca/sres/`
E-mail: `hebergement@sres.ulaval.ca`
Parking: free (ask for parking permit)
Rates: $38, single occupancy, (incl. breakfast & daily linen change)

Child Care

The following information was provided by the three meeting hotels. Advance research and arrangements are recommended. The **Chateau Bonne Entente** does provide in house child care services. Please contact the hotel directly at 418-653-5221 to make enquiries. Both the **Hotel Quartier** and **Hotel Universel** recommend the firm of Service de gardiennes et d'aides familiale de Québec, 1323 Ave Maguire, local 102, Sillery G1T 1Z2. Please contact them directly at 418-659-3778. After normal business hours, please call 418-576-8258. There is no current information regarding child care options at the **University Residences**. Updates will be posted to our website as they become available.

Travel and Parking

This historic city is a great vacation spot and we hope you will take the opportunity to bring your family, stay a few extra days, and really enjoy this beautiful city. Detailed information regarding Laval University and Québec City, including links to tourism information are available on the website. For those not staying at Laval Residences, campus parking near the conference site is by means of a Pay and Display system. We recommend that you have change available for the parking permit dispensers.

Acknowledgements

Support from the following is gratefully acknowledged:
- Université Laval, Department of Mathematics & Statistics
- The National Programme Committee (a joint funding body of the Centre de recherches mathématiques, The Fields Institute for Research in Mathematical Sciences, and The Pacific Institute for the Mathematical Sciences)

Meeting Committee

Programme
Meeting Director: Claude Levesque (Laval); A. Akbary (Lethbridge), B. Alspach (Regina), I. Assem (Sherbrooke), C. Chauve (UQAM), J. Chen (UBC), S. Corteel (CNRS et UQAM), D. Dawson (Carleton U.), F. Gourdeau (Laval), B. R. Hodgson (Laval), F. Huard (Bishop's), J. Hyndman (UNBC), O. Kihel (Lethbridge), N. Lacroix (Laval), P. Leroux (UQAM), H. Manouzi (Laval), K. Murty (Toronto), R. Paré (Dalhousie), M. Radin (RIT), T. Ransford (Laval), P. Sastry (Toronto), G. Slade (UBC), D. Stinson (Waterloo), H. Williams (Calgary), S. Wismath (Lethbridge), Graham Wright (CMS ex-officio).

Local Arrangements
Chair: Jean-Pierre Carmichael (Laval); Monique Bouchard (CMS ex-officio).

Meetings & Conferences of the AMS

IMPORTANT INFORMATION REGARDING MEETINGS PROGRAMS: AMS Sectional Meeting programs do not appear in the print version of the *Notices*. However, comprehensive and continually updated meeting and program information with links to the abstract for each talk can be found on the AMS website. See `http://www.ams.org/meetings/`. Programs and abstracts will continue to be displayed on the AMS website in the Meetings and Conferences section until about three weeks after the meeting is over. Final programs for Sectional Meetings will be archived on the AMS website in an electronic issue of the *Notices* as noted below for each meeting.

Montréal, Quebec Canada

Centre de Recherches Mathématiques, Université de Montréal

May 3–5, 2002

Meeting #976

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: March 2002
Program first available on AMS website: March 21, 2002
Program issue of electronic *Notices*: May 2002
Issue of *Abstracts*: Volume 23, Issue 3

Deadlines

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

Invited Addresses

Nicholas M. Ercolani, University of Arizona, *Title to be announced.*

Lars Hesselholt, Massachusetts Institute of Technology, *Title to be announced.*

Niky Kamran, McGill University, *Wave equations in Kerr geometry.*

Rafael de la Llave, University of Texas at Austin, *Title to be announced.*

Special Sessions

Asymptotics for Random Matrix Models and Their Applications, **Nicholas M. Ercolani**, University of Arizona, and **Kenneth T.-R. McLaughlin**, University of North Carolina at Chapel Hill and University of Arizona.

Combinatorial Hopf Algebras, **Marcelo Aguiar**, Texas A&M University, and **François Bergeron** and **Christophe Reutenauer**, Université du Québec á Montréal.

Combinatorial and Geometric Group Theory, **Olga G. Kharlampovich**, McGill University, **Alexei Myasnikov** and **Vladimir Shpilrain**, City College, New York, and **Daniel Wise**, McGill University.

Commutative Algebra and Algebraic Geometry, **Irena Peeva**, Cornell University, and **Hema Srinivasan**, University of Missouri-Columbia.

Curvature and Topology, **Regina Rotman**, Courant Institute, New York University, **Christina Sormani**, Lehman College, CUNY, and **Kristopher R. Tapp**, SUNY at Stony Brook.

Function Spaces in Harmonic Analysis and PDEs, **Galia D. Dafni** and **Jie Xiao**, Concordia University.

Potential Theory, **Paul M. Gauthier**, Université de Montréal, **K. Gowri Sankaran**, McGill University, and **David H. Singman**, George Mason University.

Shape Theory in Dynamics, **Alex Clark**, University of North Texas, and **Krystyna M. Kuperberg**, Auburn University.

Spectral Geometry, **Dmitry Jakobson**, McGill University, and **Yiannis Petridis**, McGill University and Centre de Recherches Mathématiques.

Pisa, Italy

June 12–16, 2002

Meeting #977

First Joint International Meeting between the AMS and the Unione Matematica Italiana.
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: March 2002
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

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

Invited Addresses

Luigi Ambrosio, Scuola Normale Superiore, *Title to be announced.*

Luis A. Caffarelli, University of Texas at Austin, *Title to be announced.*

Claudio Canuto, Politecnico of Torino, *Title to be announced.*

L. Craig Evans, University of California Berkeley, *Title to be announced.*

Giovanni Gallavotti, University of Rome I, *Title to be announced.*

Sergiu Klainerman, Princeton University, *Title to be announced.*

Rahul V. Pandharipande, California Institute of Technology, *Title to be announced.*

Claudio Procesi, University of Roma, *Title to be announced.*

Special Sessions

Advances in Complex, Contact and Symplectic Geometry, **Paolo De Bartolomeis**, University of Firenze, **Yakov Eliashberg**, Stanford University, **Gang Tian**, MIT, and **Giuseppe Tomassini**, Scuola Normale Superiore, Pisa.

Advances in Differential Geometry of PDEs and Applications, **Valentin Lychagin**, New Jersey Institute of Technology, and **Agostino Prastaro**, University of Roma, La Sapienza.

Algebraic Logic and Universal Algebra, **Paolo Agliano**, University of Siena, **Keith A. Kearnes**, University of Colorado, **Franco Montagna**, University of Siena, **Don Pigozzi**, Iowa State University, and **Aldo Ursini**, University of Siena.

Algebraic Vector Bundles, **Vincenzo Ancona**, University of Firenze, **Mohan Kumar**, Washington University, **Giorgio Maria Ottaviani**, University of Firenze, **Christopher Peterson**, Colorado State University, and **Prabhakar Rao**, University of Missouri.

Analytic Aspects of Convex Geometry, **Stefano Campi**, University of Modena, **Richard Gardner**, Western Washington University, **Erwin Lutwak**, Polytechnic University Brooklyn, and **Alijosa Volcic**, University of Trieste.

Classification Theory and Topology of Algebraic Varieties, **Fabrizio Catanese**, University of Gottingen, **Janos Kollar**, Princeton University, and **Shing-Tung Yau**, Harvard University.

Commutative Algebra and the Geometry of Projective Varieties, **Ciro Ciliberto**, University of Roma II, **Anthony Geramita**, University of Genova, **Rick Miranda**, Colorado State University, and **Ferruccio Orecchia**, University of Napoli.

Commutative Algebra: Hilbert Functions, Homological Methods and Combinatorial Aspects, **Aldo Conca**, University of Genova, **Anna Guerrieri**, University of L'Aquila, **Claudia Polini**, University of Oregon, and **Bernd Ulrich**, Michigan State University.

Commutative Rings and Integer-valued Polynomials, **Stefania Gabelli**, University of Roma III, and **Thomas G. Lucas**, University of North Carolina Charlotte.

Complex, Contact and Quaternionic Geometry, **David E. Blair**, Michigan State University, and **Stefano Marchiafava**, University of Roma, La Sapienza.

Contemporary Developments in Partial Differential Equations and in the Calculus of Variations, **Irene Fonseca**, Carnegie Mellon University, and **Paolo Marcellini**, University of Firenze.

Didattica della Dimostrazione, **Ferdinando Arzarello**, University of Torino, **Guershon Harel**, Purdue University, and **Vinicio Villani**, University of Pisa.

Dynamical Systems, **Antonio Giorgilli**, University of Milano-Bicocca, **Stefano Marmi**, Scuola Normale Superiore, Pisa, and **John Norman Mather**, Princeton University.

Elliptic Partial Differential Equations, **Angelo Alvino**, University of Napoli, **Luis Caffarelli**, University of Texas, **Giorgio Talenti**, University of Firenze, and **Vladimir Oliker**, Emory University.

Equazioni di Evoluzione Nonlineari, **Alberto Tesei**, University of Roma, La Sapienza, and **Wei-Ming Ni**, University of Minnesota, Minneapolis.

Free Boundary Problems, **Ricardo Horacio Nochetto**, University of Maryland, College Park, and **Augusto Visintin**, University of Trento.

Geometric Properties of Solutions to PDEs, **Donatella Danielli**, Purdue University, and **Sandro Salsa**, Politecnico of Milano.

Harmonic Analysis, **Fulvio Ricci**, Scuola Normale Superiore, Pisa, and **Elias M. Stein**, Princeton University.

Higher Dimensional Algebra, **John Baez**, University of California, Riverside, and **Giuseppe Rosolini**, University of Genova.

History of Mathematics, **Piers Bursil-Hall**, Cambridge University, **Enrico Giusti**, University of Firenze, and **James J. Tattersall**, Providence College.

Hyperbolic Equations, **Sergiu Klainerman**, Princeton University, and **Sergio Spagnolo**, University of Pisa.

Hyperbolic Systems of Conservation Laws, **Alberto Bressan**, SISSA, Trieste, and **Shi Jin**, University of Wisconsin.

Inverse Boundary Problems and Applications, **Giovanni Alessandrini**, University of Trieste, and **Gunther Uhlmann**, University of Washington.

Jump Processes in Option Pricing Theory, **Claudio Albanese**, University of Toronto, and **Marco Isopi**, University of Bari.

Kolmogorov Equations, **Giuseppe Da Prato**, Scuola Normale Superiore, Pisa, and **Nicolai V. Krylov**, University of Minnesota.

Logarithmic De Rham Cohomology and Dwork Cohomology, **Alan Adolphson**, Oklahoma State University, Stillwater, **Francesco Baldassarri**, University of Padova, **Arthur Ogus**, University of California Berkeley, and **Steven Sperber**, University of Minnesota, Minneapolis.

Mathematical Problems in Soft Matter Modelling, **Eugene C. Gartland**, Kent State University, and **Epifanio Virga**, University of Pavia.

Mathematical Problems in Transport Theory, **Carlo Cercignani**, Politecnico of Milano, and **Irene Gamba**, University of Texas.

Mathematical Schools: Italy and the United States at the Turn of the Twentieth Century, **Umberto Bottazzini**, University of Palermo, and **Karen Hunger Parshall**, University of Virginia.

Mathematics in Polymer Science, **Antonio Fasano**, University of Firenze, and **Kumbakonam R. Rajagopal**, Texas A&M University.

Microlocal Analysis and Applications to PDE, **Daniele Del Santo**, University of Trieste, **M. K. Venkatesha Murthy**, University of Pisa, and **Daniel Tataru**, Northwestern University.

Nonlinear Analysis, **Antonio Ambrosetti**, SISSA, Trieste, **Vieri Benci**, University of Pisa, **Haim Brezis**, Rutgers University, and **Paul Rabinowitz**, University of Wisconsin.

Nonlinear Elliptic and Parabolic Equations and Systems, **Gary Lieberman**, Iowa State University, and **Antonio Maugeri**, University of Catania.

Nonstandard Methods and Applications in Mathematics, **Alessandro Berarducci**, University of Pisa, **Nigel Cutland**, University of Hull, **Mauro Di Nasso**, University of Pisa, and **David Ross**, University of Hawaii.

Operator Algebras, **Sergio Doplicher**, University of Roma, La Sapienza, and **Edward George Effros**, University of California Los Angeles.

Optimization and Control, **Roberto Triggiani**, University of Virginia, and **Tullio Zolezzi**, University of Genova.

Partial Differential Equations of Mixed Elliptic-Hyperbolic Type and Applications, **Daniela Lupo**, Politecnico of Milano, **Cathleen S. Morawetz**, Courant Institute, and **Kevin R. Payne**, University of Milano.

Periodic Solutions of Differential and Difference Equations, **Massimo Furi**, University of Firenze, and **Mario Umberto Martelli**, Claremont McKenna College.

Poisson Geometry and Integrable Systems, **Franco Magri**, University of Milano, and **Ping Xu**, Pennsylvania State University.

Quantum Cohomology and Moduli Spaces, **Angelo Vistoli**, University of Bologna, and **Aaron Bertram**, University of Utah.

Scaling Limits and Homogenization Problems in Physics and Applied Sciences, **Mario Pulvirenti**, University of Roma, and **George Papanicolaou**, Stanford University.

Semigroups of Operators and Applications, **Francesco Altomare**, University of Bari, and **Frank Neubrander**, Louisiana State University.

Semigroups, Automata and Formal Languages, **Alessandra Cherubini**, Politecnico of Milano, and **John Meakin**, University of Nebraska-Lincoln.

Some Mathematics Around Composites, **Robert V. Kohn**, Courant Institute, and **Vincenzo Nesi**, University of Roma, La Sapienza.

Structured Matrix Analysis with Applications, **Dario Andrea Bini**, University of Pisa, and **Thomas Kailath**, Stanford University.

The Topology of 3-manifolds, **Ricardo Benedetti** and **Carlo Petronio**, University of Pisa, **Dale Rolfsen**, University of British Columbia, Vancouver, and **Jeffrey Weeks**, Canton, New York.

Variational Analysis and Applications, **Franco Giannessi**, University of Pisa, **Boris S. Mordukhovich**, Wayne State University, Detroit, **Biagio Ricceri**, University of Catania, and **R. Tyrrell Rockafellar**, University of Washington.

Viscosity Methods in PDEs and Applications, **Piermarco Cannarsa**, University of Roma II, **Italo Capuzzo Dolcetta**, University of Roma, La Sapienza, and **Panagiotis Souganidis**, University of Texas, Austin.

White Noise Theory and Quantum Probability, **Luigi Accardi**, University of Roma, Tor Vergata, and **Hui-Hsiung Kuo**, Louisiana State University.

Portland, Oregon

Portland State University

June 20–22, 2002

Meeting #978

Meeting held in conjunction with the Pacific Northwest Section of the Mathematical Association of America.
Western Section
Associate secretary: Bernard Russo

Announcement issue of *Notices*: April 2002
Program first available on AMS website: May 9, 2002
Program issue of electronic *Notices*: June 2002
Issue of *Abstracts*: Volume 23, Issue 2

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: Expired
For abstracts: April 30, 2002
For summaries of papers to MAA organizers: Various

Joint Invited Addresses

Kenneth A. Ribet, University of California Berkeley, *Title to be announced* (AMS-MAA Invited Address).

AMS Invited Addresses

Richard W. Montgomery, University of California Santa Cruz, *Variational methods for the N-body problem.*

Edriss S. Titi, University of California Irvine, *Title to be announced.*

Michael Wolf, Rice University, *Minimal surfaces, flat structures, and moduli spaces.*

MAA Invited Addresses

Edward B. Burger, Williams College, *Innovative Experiments...and how I Survived Them.*

Tina H. Straley, Mathematical Association of America, *The MAA's Role in the Future of Undergraduate Mathematics.*

Jim H. Valerio, Intel Desktop Architecture Labs, *Improving PC Graphics.*

AMS Special Sessions

Algebraic Geometry and Combinatorics (Code: AMS SS B1), **Eric Babson** and **Rekha Thomas**, University of Washington, and **Sergey Yuzvinsky**, University of Oregon.

Association Schemes and Distance-Regular Graphs (Code: AMS SS J1), **John S. Caughman**, Portland State University, and **Paul M. Terwilliger**, University of Wisconsin.

Flat Structures, Moduli Spaces, and Minimal Surfaces (Code: AMS SS F1), **Matthias Weber**, Indiana University, and **Michael Wolf**, Rice University.

Low Dimensional Homotopy and Combinatorial Group Theory (Code: AMS SS H1), **F. Rudolf Beyl** and **Paul Latiolais**, Portland State University, **William A. Bogley**, Oregon State University, and **Micheal N. Dyer**, University of Oregon.

Mathematical Biology (Code: AMS SS D1), **Richard S. Gomulkiewicz**, Washington State University, and **Sebastian Schreiber**, Western Washington University.

Matroid Theory (Code: AMS SS E1), **Jennifer M. McNulty**, University of Montana, and **Nancy Ann Neudauer**, Pacific University.

Qualitative Properties and Applications of Functional Equations (Code: AMS SS A1), **Theodore A. Burton**, Southern Illinois University.

Quantum Topology (Code: AMS SS G1), **Douglas G. Bullock**, **Joanna M. Kania-Bartoszynska**, and **Uwe Kaiser**, Boise State University.

The Quintic Equation: Algebra and Geometry (Code: AMS SS C1), **Jerry Shurman**, Reed College, and **Scott Crass**, California State University, Long Beach.

Boston, Massachusetts

Northeastern University

October 5–6, 2002

Meeting #979

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: August 2002
Program first available on AMS website: August 22, 2002
Program issue of electronic *Notices*: October 2002
Issue of *Abstracts*: Volume 23, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 18, 2002
For abstracts: August 13, 2002

Invited Addresses

Lou P. van den Dries, University of Illinois, Urbana-Champaign, *Title to be announced.*

Hillel Furstenberg, Einstein Institute of Mathematics, *Title to be announced* (Erdős Memorial Lecture).

Diane Henderson, Pennsylvania State University, *Title to be announced.*

Christopher K. King, Northeastern University, *Title to be announced.*

Xiaobo Liu, University of Notre Dame, *Title to be announced.*

Special Sessions

Developments and Applications in Differential Geometry (Code: AMS SS C1), **Chuu-Lian Terng**, Northeastern University, and **Xiaobo Liu**, University of Notre Dame.

Ergodic Theory and Dynamical Systems (Code: AMS SS B1), **Stanley J. Eigen**, Northeastern University, and **Vidhu S. Prasad**, University of Massachusetts, Lowell.

Hilbert Schemes (Code: AMS SS G1), **Mark De Cataldo**, SUNY at Stony Brook, and **Anthony A. Iarrobino**, Northeastern University.

Modern Schubert Calculus (Code: AMS SS A1), **Frank Sottile**, University of Massachusetts, Amherst, and **Christopher T. Woodward**, Rutgers University.

Number Theory and Arithmetic Geometry (Code: AMS SS D1), **Matthew A. Papanikolas**, Brown University, and **Siman Wong**, University of Massachusetts, Amherst.

Quantum Information Theory (Code: AMS SS J1), **Christopher K. King**, Northeastern University, and **Mary Beth Ruskai**, University of Massachusetts Lowell.

Quivers and Their Generalizations (Code: AMS SS E1), **Alex Martsinkovsky**, **Gordana G. Todorov**, **Jerzy M. Weyman**, and **Andrei V. Zelevinsky**, Northeastern University.

Recent Developments in the Orbit Method for Real and p-adic Groups (Code: AMS SS F1), **Donald R. King**, Northeastern University, and **Alfred G. Noel**, University of Massachusetts, Boston.

Singularities in Algebraic and Analytic Geometry (Code: AMS SS H1), **Terence Gaffney** and **David B. Massey**, Northeastern University, and **Caroline Grant Melles**, U. S. Naval Academy.

The Mathematics of Water Waves (Code: AMS SS K1), **Diane Henderson**, Pennsylvania State University, and **Gene Wayne**, Boston University.

The History of Mathematics (Code: AMS SS L1), **Adrian C. Rice**, Randolph-Macon College, and **Amy E. Shell**, U. S. Military Academy.

Madison, Wisconsin

University of Wisconsin-Madison

October 12–13, 2002

Meeting #980

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: August 2002
Program first available on AMS website: August 29, 2002
Program issue of electronic *Notices*: October 2002
Issue of *Abstracts*: Volume 23, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: June 25, 2002
For abstracts: August 20, 2002

Invited Addresses

Lawrence Ein, University of Illinois at Chicago, *Title to be announced.*

Eleny Ionel, University of Wisconsin, *Title to be announced.*

Mikhail Safonov, University of Minnesota, *Title to be announced.*

John Sullivan, University of Illinois, Urbana-Champaign, *Title to be announced.*

Special Sessions

Arithmetic Algebraic Geometry (Code: AMS SS A1), **Ken Ono** and **Tonghai Yang**, University of Wisconsin-Madison.

Arrangements of Hyperplanes (Code: AMS SS E1), **Daniel C. Cohen**, Louisiana State University, **Peter Orlik**, University of Wisconsin-Madison, and **Anne Shepler**, University of California Santa Cruz.

Biological Computation and Learning in Intelligent Systems (Code: AMS SS S1), **Shun-ichi Amari**, RIKEN, **Amir Assadi**, University of Wisconsin-Madison, and **Tomaso Poggio**, Massachusetts Institute of Technology.

Characters and Representations of Finite Groups (Code: AMS SS U1), **Martin Isaacs**, University of Wisconsin, Madison, and **Mark Lewis**, Kent State University.

Combinatorics and Special Functions (Code: AMS SS T1), **Richard Askey** and **Paul Terwilliger**, University of Wisconsin-Madison.

Dynamical Systems (Code: AMS SS P1), **Sergey Bolotin** and **Paul Rabinowitz**, University of Wisconsin-Madison.

Effectiveness Questions in Model Theory (Code: AMS SS J1), **Charles McCoy**, **Reed Solomon**, and **Patrick Speissegger**, University of Wisconsin-Madison.

Geometric Methods in Differential Equations (Code: AMS SS H1), **Gloria Mari Beffa**, University of Wisconsin-Madison, and **Peter Olver**, University of Minnesota.

Geophysical Waves and Turbulence (Code: AMS SS M1), **Paul Milewski**, **Leslie Smith**, and **Fabian Waleffe**, University of Wisconsin-Madison.

Group Cohomology and Homotopy Theory (Code: AMS SS G1), **Alejandro Adem**, University of Wisconsin-Madison, and **Jesper Grodal**, Institute for Advanced Study.

Harmonic Analysis (Code: AMS SS C1), **Alex Ionescu** and **Andreas Seeger**, University of Wisconsin-Madison.

Hyperbolic Differential Equations and Kinetic Theory (Code: AMS SS K1), **Shi Jin**, **Marshall Slemrod**, and **Athanassios Tzavaras**, University of Wisconsin-Madison.

Lie Algebras and Related Topics (Code: AMS SS N1), **Georgia Benkart** and **Arun Ram**, University of Wisconsin-Madison.

Multiresolution Analysis and Data Presentation (Code: AMS SS F1), **Amos Ron**, University of Wisconsin-Madison.

Partial Differential Equations and Geometry (Code: AMS SS D1), **Sigurd Angenent** and **Mikhail Feldman**, University of Wisconsin-Madison.

Probability (Code: AMS SS R1), **David Griffeath**, University of Wisconsin-Madison, and **Timo Seppalainen**, Iowa State University.

Ring Theory and Related Topics (Code: AMS SS L1), **Don Passman**, University of Wisconsin-Madison.

Several Complex Variables (Code: AMS SS B1), **Pat Ahern**, **Xianghong Gong**, **Alex Nagel**, and **Jean-Pierre Rosay**, University of Wisconsin-Madison.

Salt Lake City, Utah

University of Utah

October 26–27, 2002

Meeting #981

Western Section
Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: September 2002
Program first available on AMS website: September 16, 2002
Program issue of electronic *Notices*: October 2002
Issue of *Abstracts*: Volume 23, Issue 4

Deadlines

For organizers: Expired
For consideration of contributed papers in Special Sessions: July 10, 2002
For abstracts: September 4, 2002

Invited Addresses

Yakov Eliashberg, Stanford University, *Title to be announced.*

Hart F. Smith, University of Washington, *Title to be announced.*

Michael Ward, University of British Columbia, *Title to be announced.*

Amie Wilkinson, Northwestern University, *Title to be announced.*

Special Sessions

Area-Minimization and Minimal Surfaces (Code: AMS SS A1), **Michael Dorff**, **Denise Halverson**, and **Gary R. Lowler**, Brigham Young University.

Orlando, Florida

University of Central Florida

November 9–10, 2002

Meeting #982

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: September 2002
Program first available on AMS website: September 26, 2002
Program issue of electronic *Notices*: November 2002
Issue of *Abstracts*: Volume 23, Issue 4

Deadlines

For organizers: April 10, 2002
For consideration of contributed papers in Special Sessions: July 23, 2002
For abstracts: September 17, 2002

Invited Addresses

Steven J. Cox, Rice University, *Title to be announced.*

James Haglund, University of Pennsylvania, *Title to be announced.*

Marius Mitrea, University of Missouri-Columbia, *Title to be announced.*

Ricardo H. Nochetto, University of Maryland, College Park, *Title to be announced.*

Baltimore, Maryland

Baltimore Convention Center

January 15–18, 2003

Meeting #983

Joint Mathematics Meetings, including the 109th Annual Meeting of the AMS, 86th Annual Meeting of the Mathematical Association of America (MAA), annual meetings of the Association for Women in Mathematics (AWM) and the National Association of Mathematicians (NAM), and the winter meeting of the Association for Symbolic Logic (ASL).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: October 2002
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 15, 2002
For consideration of contributed papers in Special Sessions: August 6, 2002
For abstracts: October 1, 2002
For summaries of papers to MAA organizers: To be announced

Baton Rouge, Louisiana

Louisiana State University

March 14–16, 2003

Southeastern Section
Associate secretary: John L. Bryant
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 14, 2002
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Bloomington, Indiana

Indiana University

April 4–6, 2003

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 4, 2002
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

New York, New York

Courant Institute

April 12–13, 2003

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: September 12, 2002
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Seville, Spain

June 18–21, 2003

First Joint International Meeting between the AMS and the Real Sociedad Matematica Española (RSME).
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: Not applicable
Program issue of electronic *Notices*: Not applicable
Issue of *Abstracts*: Not applicable

Deadlines

For organizers: May 15, 2002
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Invited Addresses

Xavier Cabre, Universidad Politécnica de Cataluña, Barcelona, *Title to be announced.*

Charles Fefferman, Princeton University, *Title to be announced.*

Michael Hopkins, Massachusetts Institute of Technology, *Title to be announced.*

Ignacio Sols, Universidad Complutense, Madrid, *Title to be announced.*

Luis Vega, Universidad del Pais Vasco, Bilbao, *Title to be announced.*

Efim Zelmanov, Yale University, *Title to be announced.*

Special Sessions

Banach Spaces of Analytic Functions, **Daniel Girela**, University of Malaga, and **Michael Stessin**, SUNY at Albany.

Biomolecular Mathematics, **Thomas J. Head** and **Fernando Guzman**, SUNY at Binghamton.

Classical and Harmonic Analysis, **Nets Katz**, Washington University, **Carlos Perez**, Universidad de Sevilla, and **Ana Vargas**, Universidad Autonoma de Madrid.

Commutative Algebra: Geometric, Homological, Combinatorial and Computational Aspects, **Alberto Corso**, University of Kentucky, **Philippe Gimenez**, Universidad de Valladolid, and **Santiago Zarzuela**, Universitat de Barcelona.

Computational Methods in Algebra and Analysis, **Eduardo Cattani**, University of Massachusetts, Amherst, and **Francisco Jesus Castro-Jimenez**, Universidad de Sevilla.

Constructive Approximation Theory, **Antonio Duran**, University de Sevilla, and **Edward B. Saff**, Vanderbilt University.

History of Modern Mathematics—Gauss to Wiles, **Jose Ferreiros**, Universidad de Sevilla, and **David Rowe**, Universitat Mainz.

Interpolation Theory, Function Spaces and Applications, **Fernando Cobos**, University Complutense de Madrid, and **Pencho Petrushev**, University of South Carolina.

Mathematical Fluid Dynamics, **Diego Cordoba**, CSIC, Madrid, and Princeton University, and **Susan Friedlander**, University of Illinois, Chicago.

Nonlinear Dispersive Equations, **Gustavo Ponce**, University of California Santa Barbara, and **Luis Vega**, Universidad del Pais Vascos.

Operator Theory and Spaces of Analytic Functions, **Jose Bonet**, Universidad Politecnica de Valencia, **Pedro Paul**, Universidad de Sevilla, and **Cora S. Sadosky**, Howard University.

The Mathematics of Electronmicroscopic Imaging, **Jose-Maria Carazo**, Centro Nacional de Biotecnologia-CSIC, and **Gabor T. Herman**, City University of New York.

Variational Problems for Submanifolds, **Frank Morgan**, Williams College, and **Antonio Ros**, Universidad de Granada.

Binghamton, New York

SUNY-Binghamton

October 10–12, 2003

Eastern Section
Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: March 10, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Special Sessions

Biomolecular Mathematics (Code: AMS SS A1), **Thomas J. Head** and **Dennis G. Pixton**, SUNY at Binghamton, **Mitsunori Ogihara**, University of Rochester, and **Carlos Martin-Vide**, Universitat Rovira i Virgili.

Phoenix, Arizona

Phoenix Civic Plaza

January 7–10, 2004

Associate secretary: Michel L. Lapidus
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 2, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced
For summaries of papers to MAA organizers: To be announced

Athens, Ohio

Ohio University

March 26–27, 2004

Central Section
Associate secretary: Susan J. Friedlander
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: August 26, 2003
For consideration of contributed papers in Special Sessions: To be announced
For abstracts: To be announced

Atlanta, Georgia

Atlanta Marriott Marquis and Hyatt Regency Atlanta

January 5–8, 2005

Associate secretary: Lesley M. Sibner
Announcement issue of *Notices*: To be announced
Program first available on AMS website: To be announced
Program issue of electronic *Notices*: To be announced
Issue of *Abstracts*: To be announced

Deadlines

For organizers: April 5, 2004
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: Michel L. Lapidus, Department of Mathematics, University of California, Sproul Hall, Riverside, CA 92521-0135; e-mail: lapidus@math.ucr.edu; telephone: 909-787-3113.

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@duke.poly.edu; telephone: 718-260-3505.

Southeastern Section: John L. Bryant, Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510; e-mail: bryant@math.fsu.edu; telephone: 850-644-5805.

The Meetings and Conferences section of the *Notices* gives information on all AMS meetings and conferences approved by press time for this issue. Please refer to the page numbers cited in the table of contents on this page for more detailed information on each event. Invited Speakers and Special Sessions are listed as soon as they are approved by the cognizant program committee; the codes listed are needed for electronic abstract submission. For some meetings the list may be incomplete. **Information in this issue may be dated. Up-to-date meeting and conference information** at www.ams.org/meetings/.

Meetings:

Important Information regarding AMS Meetings

Potential organizers, speakers, and hosts should refer to page 175 in the January 2002 issue of the *Notices* for general information regarding participation in AMS meetings and conferences.

Abstracts

Several options are available for speakers submitting abstracts, including an easy-to-use interactive Web form. No knowledge of LaTeX is necessary to submit an electronic form, although those who use LaTeX may submit abstracts with such coding. To see descriptions of the forms available, visit http://www.ams.org/abstracts/instructions.html, or send mail to abs-submit@ams.org, typing help as the subject line; descriptions and instructions on how to get the template of your choice will be e-mailed to you.

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Paper abstract forms may be sent to Meetings & Conferences Department, AMS, P.O. Box 6887, Providence, RI 02940. There is a $20 processing fee for each paper abstract. There is no charge for electronic abstracts. Note that all abstract deadlines are strictly enforced. Close attention should be paid to specified deadlines in this issue. Unfortunately, late abstracts cannot be accommodated.

Conferences: (See http://www.ams.org/meetings/ for the most up-to-date information on these conferences.)

May 20-25, 2002: 6th International Conference on Clifford Algebras and Their Applications to Mathematical Physics, Cookeville, TN.

June 3-8, 2002: Abel Bicentennial Conference 2002, University of Oslo, Norway.

June 7-August 1, 2002: Joint Summer Research Conferences in the Mathematical Sciences, Mount Holyoke College, South Hadley, MA. See pages 1289-1291, November 2001 issue, for details.

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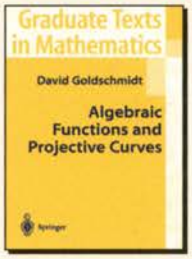

D. GOLDSCHMIDT, IDA Center for Communications Research, Princeton, NJ

This is a self-contained introduction to algebraic functions and projective curves. It covers a wide range of material by dispensing with the machinery of algebraic geometry and proceeding directly via valuation theory to the main results on function fields. The author also develops the theory of singular curves by studying maps to projective space, including topics such as Weierstrass points in characteristic p, and the Gorenstein relations for singularities of plane curves.

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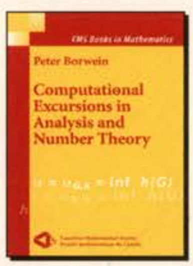

P. BORWEIN, Simon Fraser University, Burnaby, Canada

This book presents computational number theory, based around a number of difficult problems that lie at the interface of analytic, computational and Diophantine number theory. The techniques for tackling these problems are various and include probabilistic methods, combinatorial methods, Diophantine and analytic techniques. This book provides an introduction with many exercises and open research problems included. Indeed, the primary aim of the book is to tempt the able reader into the rich open possibilities for research in this area.

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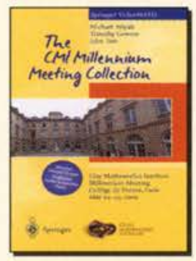

M. ATIYAH, The University of Edinburgh, UK; **T. GOWERS,** University of Cambridge, UK; **J. TATE,** University of Texas, Austin, TX; and **F. TISSEYRE,** Ecoutez Voir, Paris, France

In May 2000, the Clay Mathematics Institute (CMI) held its Paris Millennium Event at the College de France. On this occasion, CMI unveiled the "Millennium Prize Problems", seven mathematical quandaries that have long resisted solution. Excerpts from interviews explain the significance of the prize problems and the challenges they pose. The video of T. Gowers' Keynote Address at the CMI Millenium Meeting is a lucid, dynamic presentation of the deep and important question of the relevance of mathematics to society, delivered by one of the best mathematicians of the modern age. The Problems were set forth by two of the greatest mathematicians of the 20th century, J. Tate and M. Atiyah. The set of two lectures by Tate and Atiyah together comprise a complete description of the Millenium Prize Problems, presented in an entertaining style.

CONTENTS: 1. The Millenium Meeting. A Film by Francoise Tisseyre.- 2. The Importance of Mathematics. A Lecture by Timothy Gowers.- 3. The Millenium Prize Problems. A Lecture by John Tate.- 4. The Millenium Prize Problems. A Lecture by Michael Atiyah

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