1986 Steele Prizes Awarded at Annual Meeting in San Antonio

Three Leroy P. Steele Prizes were awarded at the Society's ninety-third Annual Meeting in San Antonio, Texas.

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

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

The recipients of the Steele Prizes for 1986 are DONALD E. KNUTH for the expository award; RUDOLF E. KALMAN for research work of fundamental importance; and SAUNDERS MAC LANE for the career award.

The Steele Prizes are awarded by the Council of the Society, acting through a selection committee whose members at the time of these selections were Richard W. Beals, Jerry L. Bona, Charles W. Curtis, Harold M. Edwards (Chairman), Hermann Flaschka, Frederick W. Gehring, John P. Hempel, Lawrence E. Payne, George B. Seligman, and Patricia Lilaine Sipe.

The text that follows contains the Committee's citations for each award, the recipients' responses to the award, and a brief biographical sketch of each of the recipients. Professors Kalman and Knuth were unable to attend the Annual Meeting to receive the prize in person. They did, however, send written responses.

Expository Writing

Donald E. Knuth

Citation

The 1986 Steele Prize for expository writing is awarded to DONALD E. KNUTH for his book *The Art of Computer Programming* which has made as great a contribution to the teaching of mathematics to the present generation of students as any book on mathematics proper in recent decades. The book is intended to be accessible to readers with very little mathematical background—readers with no more than high school algebra are told to skip the more mathematical sections—but it is hard to imagine an intelligent reader spending much time with the book without markedly improving his or her mathematical background as a result. Problems of real interest and substance in combinatorics, number theory, algebra, asymptotic series, and statistics are posed in compelling ways and handled with clarity, sophistication, and an open-endedness that stimulates further thought and new problems. The carefully thought-out exercises have inspired many papers in journals of mathematics as well as in journals of computer science.

Knuth says in his Preface, "Much of the published mathematics about computer programming has been very faulty, and one of the purposes of this book is to instruct readers in proper mathematical approaches to this subject. Since I myself profess to be a mathematician, it is my duty to maintain mathematical integrity as well as I can." His devotion to mathematical integrity has produced a book of outstanding mathematical quality; in professing to be a mathematician he honors the profession.

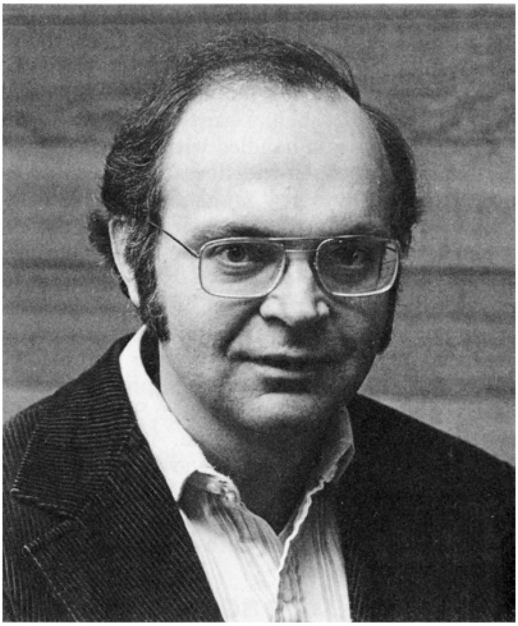
Response

It is wonderful to discover a beautiful corner of mathematics, and even more wonderful to learn later that you have helped others to discover this same beauty. Therefore it was a special pleasure for me to learn that my books on computer programming had been selected for a Steele Prize.

When I began work on *The Art of Computer Programming*, I wanted to find appropriate mathematical underpinnings by which programmers could understand the behavior of important algorithms. This quest opened up a rich vein of new questions that were fascinating both because of their inherently interesting mathematical structure and because of their importance in practical applications.

After 25 years of research on the analysis of algorithms, I still am struck by the "unreasonable effectiveness of mathematics"—by the fact that these new questions almost always have answers that can be formulated in terms of classical concepts. For example, the problem of "largest stack height when traversing a random binary tree" reduces to a calculation involving Euler's gamma function times the square of Riemann's zeta function!

On the other hand, I was not taught much about these "good old" mathematical tools when I was a college student; they had gone out of fashion. For want of a better term, I began referring to them as 'concrete mathematics', a blending of 'continuous' and 'discrete', and I began teaching a course with this title at Stanford in 1970. Other people independently came to similar conclusions. I'm glad to see that concrete mathematics is once again resuming its rightful place, amid many other beautiful theories, in the affections of modern mathematicians.



Donald E. Knuth

Biographical Sketch

Donald Ervin Knuth was born in Milwaukee, Wisconsin on January 10, 1938. He received both a B.S. and an M.S. in 1960 from Case Institute of Technology, and a Ph.D. in 1963 from the California Institute of Technology. In that year he became an assistant professor of mathematics at the California Institute of Technology, and he advanced to the rank of professor by 1968. He has been a professor of computer science at Stanford University since 1968 and has held the Fletcher Jones chair of computer science since 1977.

He began writing a manuscript in 1962 that has grown into a series of books entitled *The Art of Computer Programming.* Three volumes in this series have been published so far (1968, 1969, 1973); four more volumes are projected. Knuth is also the author of a five-volume series entitled *Computers & Typesetting* (1986); these books describe his TeX and METAFONT systems for computer typesetting, on which he began work in 1977. He published a mathematical novelette, *Surreal Numbers*, in 1974; a monograph in French, *Mariages Stables*, in 1976; and (with Daniel H. Greene) an advanced textbook, *Mathematics for the Analysis of Algorithms*, in 1981. His books have been translated into Chinese, Czech, German, Hungarian, Japanese, Romanian, Russian, and Spanish.

Professor Knuth gave an invited address at the International Congress of Mathematicians in 1970, and he delivered the Josiah William Gibbs lecture of the American Mathematical Society in 1978. He has received the Grace M. Hopper Award (1971), the Alan M. Turing Award (1974), the Computer Science Education Award (1986), and the Software Systems Award (1986) of the Association for Computing Machinery. He is a member of the American Academy of Arts and Sciences (1973), the National Academy of Sciences (1975), and the National Academy of Engineering (1981). President Carter awarded him the National Medal of Science in 1979.

Fundamental Paper

Rudolf E. Kalman

Citation

The 1986 Steele Prize for a paper, whether recent or not, that has proved to be of fundamental or lasting importance in its field, or a model of important research, is awarded to RUDOLF E. KALMAN for his papers:

> *A new approach to linear filtering and prediction problems*, Journal of Basic Engineering, volume **82** (1960), pages 35-45.
>
> *Mathematical description of linear dynamical systems*, SIAM Journal on Control and Optimization, volume **1** (1963), pages 152-192.

and for his contribution to the paper:

> (with R. S. Bucy) *New results in linear filtering and prediction theory*, Journal of Basic Engineering, volume **83D** (1961), pages 95-108.

The ideas presented in these papers are a cornerstone of the modern theory and practice of systems and control. Not only have they led to eminently useful developments, such as the Kalman-Bucy filter, but they have contributed to the rapid progress of systems theory, which today draws upon mathematics ranging from differential equations to algebraic geometry.

Response

To be awarded the STEELE Prize is a totally unexpected honor. I am truly grateful for it. And I regret very much that I cannot be here in person, impeded by commitments that go back, in principle, at least ten years.

I have been aware from the outset (end of January 1959, the birthdate of the second paper in the citation) that the results of the deep analysis of something that is now called *Kalman filtering* were of major importance. But even with this immodesty I did not quite anticipate all the reactions to this work. Up to now there have been some 10^4 related publications, at least two Citation Classics, etc. There is something to be explained.

To look for an explanation, let me suggest a historical analogy, at the risk of further immodesty. I am thinking of NEWTON, and specifically of his most spectacular achievement, the Law of Gravitation. NEWTON received very ample "recognition" (as it is called today) for this work. It astounded—really floored—all his contemporaries. But I am quite sure, having studied the matter and having added something to it, that nobody then (1700) really understood *what* NEWTON's contribution was.

Indeed, it seemed an absolute miracle to his contemporaries that someone, an Englishman, actually a human being, in some magic and ununderstandable way, could harness mathematics, an impractical and ethereal something, and so use mathematics as to discover with it something fundamental about the Universe. The technical discussion of why and how this was done must be left to a future publication. Right now I want merely to say that NEWTON showed that

$$\text{mathematics} + \text{reality} >> \text{zero-sum game}.$$

This is symbiosis between mathematics and physical reality. After Newton mathematics advanced quickly but the symbiosis has gradually vanished. Physics cannot be done today without electronics but mathematics hardly matters. (This is, of course, a purely personal observation.)

Yet there *is* new symbiosis between mathematics and reality. We have a new game and it is nonzero sum. Miraculous, if you like. The new magic is that mathematics helps to conceive machines, systems, before they can be actually built. Unlike at the time of NEWTON, there are many today who understand this process. Perhaps this is why my papers that you have so kindly cited turned out to be so influential.

There has been much noise lately about the "relevance" of mathematics. I do not share this worry and I try to explain why not. NEWTON turned out to be a difficult role model to follow. But then, through the advancement of technology—which is neither mathematics, nor physics, something quite different though not unrelated—a substitute has appeared. Its name is system theory. With system theory there is a new and harmonious relationship of mathematics to reality. Without having to veil any of her unbelievable but delicate intellectual beauty, mathematics has become the much-loved partner of a new kind of relevance.

Thank you again.

Biographical Sketch

Rudolf Emil Kalman was born in Budapest, Hungary on May 19, 1930. He was educated at the Massachusetts Institute of Technology (S.B., 1953; S.M., 1954) and Columbia University (D.Sci., 1957).

Professor Kalman was an instructor at Columbia University (1955–1957), a staff engineer at IBM (1957–1958), and a staff mathematician at the Research Institute for Advanced Studies, Baltimore (1958–1964). At Stanford University he was Professor of Engineering Mechanics and Electrical Engineering (1964–1972). Since 1971, he has been Graduate Research Professor and Director of the Center for Mathematical System Theory at the University of Florida. Since 1973 he is also Professor of Mathematical System Theory at the Swiss Federal Institute of Technology in Zurich.

Professor Kalman's awards include the IEEE Medal of Honor (1974), the ASME Rufus Oldenburger Medal (1976), and the Kyoto Prize (1985).

Career Award

Saunders Mac Lane

Citation

The 1986 Steele Prize for cumulative influence is awarded to SAUNDERS MAC LANE for his many contributions to algebra and algebraic topology, and in particular for his pioneering work in homological and categorical algebra.

Response

First of all, may I express my deep gratitude for the award of this Steele Prize.

This inevitably brings me to think about the advantages which I have enjoyed in the course of my career. I am particularly grateful to all those who helped me. First of all to my family, who instilled in me a love of learning and a sense of independence. Next, to a third grade teacher, who gave me and my classmates a striking diagrammatic introduction to fractions. A high school teacher, Olive Greensfelder, went to great trouble to teach me how to write. When I was a freshman at Yale, Lester Hill, an instructor working for his doctorate, persuaded me that Calculus was more exciting than Chemistry. Later at Yale, Wallace Wilson taught me both rigor and point set topology. Bert Miles showed me how to make the writing of Mathematics clear and persuasive, while Oyestein Ore taught me algebra very well, but could never recover from his dislike of Logic. At Chicago, Eliakim H. Moore was the major influence, while in Göttingen there were Hermann Weyl, Paul Bernays, and Emmy Noether. What a fortunate start!

The ideas of abstract Algebra emphasized again the observation that Mathematics can be clear, precise, and understandable—and this has been reflected in much of my work, both in the agreeable task of training graduate students, beginning with Irving Kaplansky, and in various books, such as the *Survey of Modern Algebra*, written with Garrett Birkhoff.

My retiring address as President of this Society was entitled "Topology and Logic as a Source of Algebra." These remarkable interconnections continue to fascinate me. Here is topology, beginning with a soup of continuous deformations, which turn out to require all sorts of algebraic concepts, both known ones and new ones which first turn up in the topological situation. For example, it was Otto Schilling who had taught me about class field theory, crossed product algebras, and group extensions. These extensions then turned out to be just the tool needed to express the dependance of cohomology on homology, by a "universal coefficient" theorem. Because Eilenberg and I had to explain the exact sense in which that theorem was "natural," we had to go on to discover categories. On the other hand, Eilenberg had recently brought singular homology theory to an understandable form, by using simplices with ordered vertices. This made it possible to handle those group extensions better, and to get a cohomology of groups which could then apply back to algebra—crossed products and class field theory. These topological ideas also led to homological algebra—Ext, Tor, and resolutions.

On the other hand, those singular simplices had to appear in the homology of a product of spaces, even though a simplex is not naturally a product of lower dimensional simplices. This required a comparison with tensor products, by the Eilenberg-Zilber theorem, crucial to the use of acyclic models and to the study of Spaces with just one Homotopy group (Eilenberg-Mac Lane spaces). That in turn required more algebra—a Bar construction, a W construction, and their comparison. What a wealth of algebra is hidden here in the geometry—for example the Steenrod algebra. I am still trying to better understand that transition from the W to the Bar construction.

But I have not yet formulated in adequate philosophical terms why it is that algebra and topology interpenetrate in this remarkable manner. Much the same sort of interconnection occurs now between other parts of mathematics. I am somewhat saddened to see that some mathematics has become so specialized and some parts of it so isolated that the chance for interconnections and for general conceptual analysis is likely to be lost.

The progress of mathematics does also depend on a better understanding of what our subject really is about. It is not just about empirical facts and the applications, nor is it just about some abstract platonic ideas, full of truth and beauty. No, Mathematics arises rather as the interaction of the empirics and the ideas—in a fashion which I have ventured (in a recent book) to call "Formal functionalism." It seems to me good to combine the pleasure of doing mathematics with the clear and general formulation of what we are doing and what it means. For the preparation of that book, as in the preceding 51 years, my wife, Dorothy Jones Mac Lane, gave me unstinting support.

Thank you again.

Additional Remarks

At the award ceremony, I was reminded how much the AMS did to help the start of my career. The Secretary stated that the Steele prize fund had been established to honor the work of three Harvard professors: William Fogg Osgood, George David Birkhoff, and William Casper Graustein. As it happens, I knew the last two well.

It happened as follows. In the fall of 1933 I had a new Ph.D. and a new wife; I desperately needed a job for the next year. So I did what young Ph.D.'s still do: I went to the winter meeting of the AMS, held that year late in December in Cambridge, Massachusetts. I gave a 10-minute paper (there was then only one session at a time, and everyone attended). Then I met George David Birkhoff and told him about my interests; I am sure that he was aware that I was looking for a job.

After that meeting, I returned home; with no visible prospects for a teaching position in a college or university, I made application for a position as a master at a well-known private preparatory school for boys. (It was then the height of the depression). A few months later William Casper Graustein, Chairman of the Department of Mathematics at Harvard, wrote to offer me a two year appointment as a Benjamin Pierce Instructor at Harvard. I accepted with alacrity; the ensuing two years made an excellent start for my career—a start mediated by the AMS and Professors Birkhoff and Graustein.

I turn again to mathematics, where Homological Algebra still fascinates me. Forty years ago, Samuel Eilenberg and I found and formulated the cohomology of groups in terms of a simple chain complex, the "Bar construction". We found it from a topological model—the minimal singular complex of a space whose only non-trivial homotopy group is a fundamental group π_1; that is an Eilenberg-Mac Lane space $K(\pi_1, 1)$. Since that time that chain complex has been widely used, in algebra and topology. Five years later our complicated but strictly algebraic analysis of the homology of a space $K(\pi, n)$ led us to formulate a much more general bar construction which applied to differential graded algebras, in particular to $K(\pi, n)$ with its shuffle product. This construction has also been widely used, for example to directly construct $K(\pi, n)$—but its boundary formula seemed to have a purely algebraic origin. Just last month (36 years later), I found a natural geometric explanation for this boundary formula in terms of singular prisms in a space $K(\pi, n)$. So I am much pleased to report that algebra and topology, as in this case, still belong together.

Saunders Mac Lane

Biographical Sketch

Saunders Mac Lane was born in Norwich, Connecticut on August 4, 1909. He was educated at Yale University (Ph.B., 1930), the University of Chicago (M.A., 1931), and the University of Göttingen (D.Phil., 1934). In addition, he has received several honorary degrees: the D.Sc. degree from Purdue University (1965); Yale University (1969); Coe College (1974); the University of Pennsylvania (1977); and an LLD from Glasgow University (1971).

At the start of his career, Professor Mac Lane was a Pierce Instructor at Harvard (1934–1936) and an instructor of mathematics at Cornell (1936–1937) and at the University of Chicago (1937–1938). He returned to Harvard in 1938, where he moved from the rank of assistant to full professor between the years of 1938 and 1947. In 1947 he returned to the University of Chicago where, in 1963, he became Max Mason Distinguished Service Professor of Mathematics. He retired in June, 1982.

In addition to his work at these universities, Professor Mac Lane has served as the Director of the Applied Mathematics Group at Columbia University (1944–1945), as a member of the Executive Committee, International Mathematical Union (1954-1958), and as a member of the National Science Board (1974-1980). As a visiting professor, he has taught and studied at the University of Heidelberg (1958, 1965, 1976), at the University of Frankfurt (1960), and at Tulane University (1969). He has been a Guggenheim Fellow in 1947–1948 (Paris and Zurich) and in 1972–1973 (Cambridge, England and Aarhus, Denmark), and a Fulbright Fellow at the Australian National University (1967).

Since 1933 Mac Lane has been a member of the American Mathematical Society. He has served the AMS at various times as a member of the Council (1939–1941), Colloquium Lecturer (1963), Editor of the *Bulletin* (1943–1947), Editor of the *Transactions* (1949–1954), Vice-President (1946–1947), Editor of the *Colloquium Series* (1966–1972), and finally as President (1973–1974). He is also a member of other professional societies, including the Association for Symbolic Logic since about 1935, and the American Association for the Advancement of Science. Professor Mac Lane was also Vice-President (1948) and President (1950) of the Mathematical Association of America (MAA). Among the awards he has received are the Chauvenet Prize of the MAA (1941) and the Distinguished Service Award from the MAA (1975). His research interests include algebra, topology, algebraic topology, logic, and category theory. He has directed forty doctoral dissertations and has written five books, including *Algebra* (with Garrett Birkhoff).

In 1949 Mac Lane was elected to membership in the National Academy of Sciences. He served as an elected member of the Council of that Academy from 1958-1961, and again from 1969-1972. From 1960–1968 he was Chairman of the Editorial Board of the *Proceedings* of the National Academy of Sciences. In 1973 he was elected to a four-year term as Vice-President of the National Academy of Sciences, and in this connection concurrently served as Chairman of the Report Review Committee of that Academy. In 1977 he was reelected to a second four-year term as Vice-President of the Academy.