# Ivo Babuška and S. R. S. Varadhan Share 1994 Birkhoff Prize

The George David Birkhoff Prize is awarded every five years to a recipient selected by a joint committee of the AMS and the Society for Industrial and Applied Mathematics (SIAM). The prize recognizes outstanding contributions to "applied mathematics in the highest and broadest sense". Sharing the 1994 Birkhoff Prize are IVO BABUŠKA of the Institute for Physical Science and Technology at the University of Maryland and S. R. S. VARADHAN of the Courant Institute of Mathematical Sciences at New York University. The prizes will be presented on July 27, 1994, at the SIAM Annual Meeting in San Diego.

The Birkhoff Prize Fund was originally created in 1967 by the family of George David Birkhoff. The awards are currently augmented by monies from the AMS Leroy P. Steele Fund (presented to the AMS for prizes in honor of George David Birkhoff, William Fogg Osgood, and William Caspar Graustein). Professors Babuška and Varadhan will share the $4,000 award.

Previous recipients of the Birkhoff Prize are: Jürgen K. Moser (1968), Fritz John (1973), James B. Serrin (1973), Garrett Birkhoff (1978), Mark Kac (1978), Clifford A. Truesdell III (1978), Paul R. Garabedian (1983), and Elliott H. Lieb (1988).

The Birkhoff Prize is awarded by action of the Councils of the AMS and SIAM on the recommendation of the AMS-SIAM Committee to Select Winners of the Birkhoff Prize. On the committee for the 1994 prize were Michael Aizmenan, Princeton University; Thomas G. Kurtz, University of Wisconsin at Madison (chair); and Mary Fanett Wheeler, Rice University.

The following presents the citation for each recipient, his response upon receiving the award, and a brief biographical sketch.

## Ivo Babuška

### Citation

Ivo Babuška is an internationally distinguished numerical analyst. For over forty years—first in Czechoslovakia and since 1968 in the U.S.—he has produced a steady stream of seminal work.

Babuška's most important contributions have been to the reliability of finite element methods, the development of a general framework for finite element error estimation, and $p$ and $h$-$p$ finite element methods. In the area of reliability, Babuška's papers initiated research into *a posteriori* error estimates and adaptivity. These papers have spawned a large effort. The importance of this work is that it validates finite element computations and ensures their reliability. The basic stability condition for finite element methods, now known as the Babuška-Brezzi condition, was obtained independently by Babuška and F. Brezzi. It is fundamental in the development and assessment of finite element methods. Babuška recognized the potential of the $p$ method, first used by engineers (in particular by B. Szabo). He analyzed this method and greatly expanded its range of applicability and has gone on to develop and analyze the $h$-$p$ method. These methods have great accuracy, and they have been effectively implemented in many industrial computer codes.

Babuška has trained over twenty-five students, many of whom have gone on to have successful scientific careers. In

Ivo Babuška

addition, he has attracted and worked with many postdoctoral visitors and has collaborated widely with mathematicians and engineers. He is also the founder and leader of the "Finite Element Circus", a twice-yearly meeting of the finite element community that has continued for twenty years.

In summary, Babuška has had an enormous influence on numerical analysis and engineering computation.

**Response from Ivo Babuška**

I am very grateful and proud to be awarded the very prestigious Birkhoff Prize by the American Mathematical Society and the Society for Industrial and Applied Mathematics. I accept this award as a representative of those working in numerical mathematics, in general, and the finite element method, in particular—fields that have a direct relation to engineering computations. I appreciate very much the generous citation of my achievements. I have always believed that, on the one hand, the best mathematics takes its stimuli from applications, such as engineering, and, on the other hand, influences applications. On this occasion, I would also like to thank the large group of my scientific friends in mathematics and engineering whose discussions and collaborations have influenced significantly my work, its direction, and concrete results.

**Biographical Sketch**

Ivo Babuška was born March 22, 1926, in Prague, Czechoslovakia. After World War II he studied civil engineering at the Technical University in Prague and received the Ing. degree in 1949 and a Ph.D. degree in technical science in 1951. In the period 1949–1952 he studied mathematics as an "aspirant" (the analogue of a graduate fellowship in the U.S.) in the Mathematical Institute (later the Mathematical Institute of the Czechoslovak Academy of Sciences). In 1955 he received the C.Sc. degree in mathematical sciences. (The C.Sc. degree is equivalent to the Ph.D. degree in the U.S. and was introduced by a law passed in 1953, which accepted the USSR system.) In 1960 he received the D.Sc. degree of mathematical and physical sciences, awarded for highest scientific achievements. From 1952 until 1968 he was head of the section of constructive methods and differential equations in the Mathematical Institute of the Czechoslovak Academy of Sciences.

The main emphasis of Professor Babuška's group was on the theory of partial differential equations, with applications in mechanics and numerical mathematics. In the mid-1950s he was the leader of the computational analysis group for ORLIK, a gravitational dam about 120 meters high, which was built on the Moldau (Vltava) River. This collective work, which involved engineers and material scientists, concentrated on the technology of building a dam without artificial cooling. (The big dams in the U.S., such as Boulder Dam, were built with cooling, which removes the heat created during the hardening of the concrete.) The computations for ORLIK were performed on mechanical desk calculators.

Professor Babuška was the founder of the journal *Applications of Mathematics*. He organized a series of international conferences in differential equations, such as, for example, the conference EQUADIFF, which still takes place every four years, and a series of international workshops on numerical mathematics with emphasis on its optimality. In addition to publishing scientific articles, he has published books on elasticity and the numerical treatment of differential equations.

In 1968 Professor Babuška arrived in the U.S. and was a visiting professor at the Institute for Fluid Dynamics and Applied Mathematics at the University of Maryland at College Park. In 1969 he became a research professor at that institute (which is now called the Institute for Physical Science and Technology) and later in the Department of Mathematics at Maryland. The finite element method—its reliability, *a priori* and *a posteriori* error estimations, and adaptive approaches—became his main interest.

Professor Babuška's work is mathematically oriented and is heavily influenced by the needs of engineering computations. His results are now directly and indirectly used in engineering computational practice. He has published numerous articles on the finite element method in mathematical and engineering journals and has written two books on the subject. He has been involved with the education of numerous Ph.D. students, along with other scientific activities. With his colleagues, he is a founder and leader of the "Finite Element Circus", an informal meeting which, for more than twenty-three years, has taken place twice a year. He is also on the editorial board of many mathematical and engineering journals.

Professor Babuška has received recognition and various awards for his scientific work, including the Czechoslovak State Prize for Mathematics (1968), the Humboldt Senior U.S. Scientist Award of the Federal Republic of Germany (1976), and the Medal of Charles University in Prague (1992).

## S. R. S. Varadhan

**Citation**

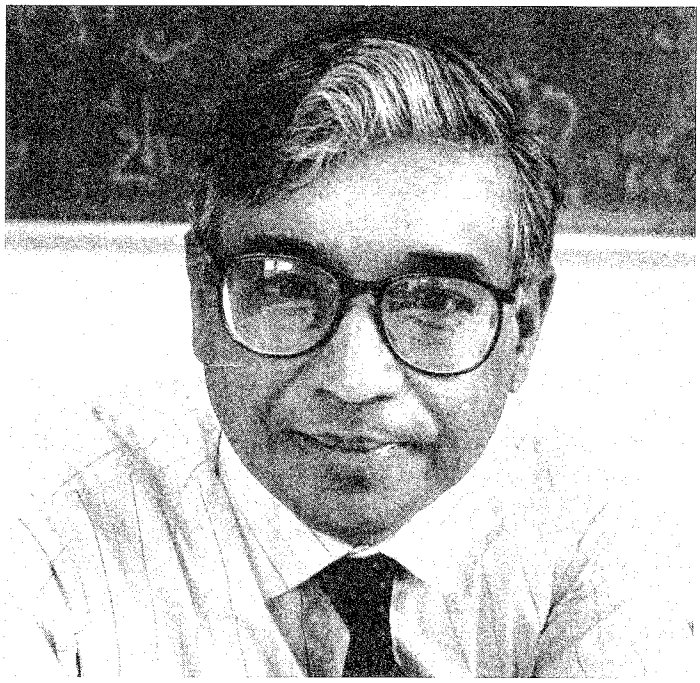
S. R. S. Varadhan is one of the leading probabilists of our time. Throughout his thirty-year career, he has contributed ideas and results that have had revolutionary impact on many fields.

Varadhan's work with Stroock on the martingale characterization of diffusion processes has changed the way Markov processes are studied, and their book on diffusion processes has become a classic.

The Donsker-Varadhan theory of large deviations for functionals of occupation times of Markov processes (with applications to spectral theory of second-order elliptic PDE) defined a new set of problems in the study of large deviations, and his formulation of the "large deviation principle" has served to define the field. This principle, presented in a series of basic works that are very original and full of technical innovations, has erected a recognized subject which is both of considerable interest on its own (as is evident from the significant number of international meetings devoted to it) and a powerful tool for theoretical problems based on applications (e.g., the polaron problem).

Varadhan's contributions with Papanicolaou to the study of random media and his introduction of large deviation and entropy methods into the study of hydrodynamic limits for the time evolution of interacting particle systems have also had major influence in these broad fields.

In summary, Varadhan has made highly visible and long-lasting contributions to probability theory and its applications, in a style which has been noted for its naturalness, effectiveness, and lucidity.



S.R.S. Varadhan

**Response**

I am indeed very happy that I am receiving the George David Birkhoff Prize from the American Mathematical Society and the Society for Industrial and Applied Mathematics. It is particularly gratifying to learn that my work is included in the broad category of applied mathematics. My mathematical interests and attitudes were influenced considerably by my colleagues at the Courant Institute, and over time I have learnt to view mathematics as a whole, rather than divided into pure and applied areas. I wish to thank my many collaborators over the years who have made my research experience all the more enjoyable.

**Biographical Sketch**

S. R. Srinivasa Varadhan was born in Madras, India, on January 2, 1940. He received his undergraduate education at the Presidency College of Madras University, where he earned a B.Sc. (Hons) degree in statistics in 1959. He then went to graduate school at the Indian Statistical Institute in Calcutta, receiving a Ph.D. in statistics in 1963. This was followed by three years of postdoctoral work at the Courant Institute of Mathematical Sciences at New York University.

He joined the faculty of Courant in 1966 as an assistant professor of mathematics, becoming an associate professor in 1968 and a professor in 1972. He was an Alfred P. Sloan Fellow (1969–1971) and a Guggenheim Fellow (1984–1985). Professor Varadhan was a visiting professor at the Mittag-Leffler Institute in Sweden (1972) and at Stanford University (1976–1977). He served as director of the Courant Institute during 1980–1984 and again during 1992–1994.

Professor Varadhan is a member of the AMS and the International Assocation of Mathematical Physics, as well as the Institute of Mathematical Statistics, of which he is an elected Fellow. He has also been elected to the Third World Academy of Sciences and the American Academy of Arts and Sciences.

Professor Varadhan serves on the editorial boards of several scholarly journals. His research interests include probability theory, partial differential equations, and statistical mechanics.