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The Fourth Bellman Prize

The Bellman Prize is awarded for the best paper published in *Mathematical Biosciences* over a two-year period. The establishment of the Bellman Prize was announced in the Bellman Memorial Volume, Volume 77 of *Mathematical Biosciences*. Up to and including the current award, the prize has been $500 and announcement of the award in *Mathematical Biosciences*. Starting with the next award, the prize will be $1000.

The fourth Bellman Prize is for the best paper published in 1990–1991, i.e., in Volumes 98–107. The selection committee for the fourth Bellman Prize consisted of Jim Keener, Claude Lefèvre, Catherine Macken, John Milton, John Tyson, and Stanley Zietz.

The members of the selection committee, members of the Editorial Board, and readers were asked to submit nominations for the prize. Papers of which Editors or members of the Editorial Board were authors are not eligible for the prize. After elimination of such papers, there were 14 nominations.

After a two-stage ranking, the paper that has won the fourth Bellman Prize is

G. Horváth and D. Varjú, Geometric optical investigation of the underwater visual field of aerial animals, *Math. Biosci.* 102:1–19, 1990.

Honorable mention goes to the runner-up:

P. Colli Franzone, L. Guerri, and S. Tentoni, Mathematical modeling of the excitation process in myocardial tissue: influence of fiber rotation on wave front propagation and potential field, *Math. Biosci.* 101: 155–235, 1990.

BIOGRAPHICAL SKETCHES OF THE AUTHORS OF THE FOURTH BELLMAN PRIZE PAPER

Gábor Horváth was born in 1963 in Kiskunhalas, Hungary. After receiving his diploma in physics from the Loránd Eötvös University (Budapest) in 1987 he was a research assistant for two years in the Department of Low Temperature Physics of the same university, where he studied electrical percolation processes in granular superconductors.

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In 1989 he received a doctoral fellowship in the Biophysics Group of the Central Research Institute for Physics of the Hungarian Academy of Sciences (Budapest), where he developed a mathematical description and computer simulation of retinal cometlike afterimages. He obtained his doctoral degree in biophysics from the Eötvös University in 1991. His thesis on physiological optics is a theoretical study of the visual system and optical environment of certain animals. At the Institute for Zoology of the University of Regensburg (Germany) in 1991–1992, he and Rudolf Schwind began a study of the reflection-polarization patterns of skylight reflected on water surfaces. Currently Dr. Horváth is a postdoctoral fellow at the Department for Biological Cybernetics of the University of Tübingen (Germany), where he is investigating the polarization vision of water insects and the physical optics of reflection- and refraction-polarization patterns of skylight at water surfaces in nature. In 1993 he obtained the degree Candidate for Biophysical Sciences from the Hungarian Academy of Sciences with a dissertation on computational visual optics. For this treatise he won the first International Dennis Gabor Award.

Dezső Varjú was born in 1932 in Hungary. In 1956, after receiving a diploma in physics from the Loránd Eötvös University in Budapest, he joined a small group of biophysicists at a research institute of the Max-Planck Society in Göttingen headed by the later Werner Reichardt. There he was involved in investigating movement perception in insects and the phototropic and light growth responses of a slime mold (Phycomyces), on both the experimental and theoretical levels. He received his doctoral degree from the Georg-August University in Göttingen in 1958. In the same year the group moved to the Research Institute for Biology of the Max-Planck Society in Tübingen. In 1959 he was given a one-year postdoctoral position at Caltech in Pasadena, where he continued his investigations into the light responses and geotropism in Phycomyces. Returning to Tübingen he began to investigate nonlinear signal transformation and binocular interactions in the human pupillomotor pathway. Afterward he studied the properties of retinal ganglion cells in the frog. In 1968 the University of Tübingen offered him a Chair in Zoology, since renamed the Lehrstuhl für Biokybernetik. Dr. Varjú's general field of research interest has for the last twenty years been invertebrate behavioral neurobiology. His activities include both experimental investigations and mathematical modeling. He spends his subbaticals in the laboratories of friends in Canberra and Sydney, Australia.

This prize-winning collaboration goes back to 1988, when in Tübingen, in the Laboratory for Biological Cybernetics, the authors started to study the geometrical optics of the visual field of animals

living near the air–water interface. This study was inspired by the earlier experimental work of L. M. Dill (1977) and G. Katzir and N. Intrator (1987) on correction for refraction of light during prey capture in archer fish and herons. Their aim was (i) to describe mathematically the animals' binocular visual field as distorted by refraction as a function of the position of their eyes with respect to the water surface, and (ii) to correct the frequent erroneous interpretations of this visual field.

The Bellman Prize

In memory of Richard Bellman, *Mathematical Biosciences* is pleased to announce the establishment of the Bellman Prize, to be awarded every two years for the best paper published in *Mathematical Biosciences* over the preceding two years. The Bellman Prize will consist of a $500 cash prize and the announcement of the name(s) of the author(s), plus brief vitae, in *Mathematical Biosciences*. The prize will be awarded by a committee chosen by the editor and associate editors. The first Bellman Prize will be awarded in 1986 for papers published in 1984 and 1985.

Richard Bellman

I. *PERSONAL HISTORY*

Richard Bellman was born in New York City on August 26, 1920. He attended public schools including Abraham Lincoln High, graduating in 1937. After a year at CCNY, he transferred to Brooklyn College. At first interested in theoretical physics, he soon transferred to mathematics and graduated in June 1941. In September 1941 he started graduate work in mathematics at Johns Hopkins. In November he married Betty Jo Kates, his steady from college. He joined the civil service and was sent to teach electronics to army personnel at Truax Field at Madison, Wisconsin. He and Betty Jo both enrolled at the University of Wisconsin, Betty Jo in history, Dick in mathematics. At the end of the year Dick got his masters in mathematics. Lefschetz invited him to Princeton to do his Ph.D. work. Dick started in September 1943, working for his Ph.D. and teaching in the ASTP. In March 1944 the ASTP was dissolved and Dick went to San Diego for a brief period to work on sonar at the Naval Radio and Sound Laboratory at Point Loma. He was inducted into the army in December 1944 and was sent to Los Alamos, where he was assigned to the Theoretical division, with the rank of staff sergeant.

After the end of the war Dick was discharged, in March 1946, and he returned to Princeton. He completed his Ph.D. that year and was appointed assistant professor, a position he held until 1948. Eric, the Bellman's first child was born at Princeton in 1947. In the summer of 1948 Dick had his first experience working at RAND. In the fall he started at Stanford as associate professor, staying there until 1951. Kirstie, the Bellman's second child was born at Stanford. During his Stanford years, Dick continued his association with RAND and after a brief stint at Princeton, working on Project Matterhorn, he joined RAND in 1952. His years at RAND, 1952–65, were golden years of productivity (more on that later). In 1965 Dick moved to USC as professor in mathematics, engineering, and medicine and worked on developing a wide-ranging program in applied mathematics.

In 1962 Dick and Betty Jo separated and when the divorce became final, Dick married Nina Day. Nina was 17 years younger than Dick but the two seemed to adjust easily to married life together. And, in the long years of Dick's disability after his operation, Nina was steadfast in providing both psychological support and nurturing care.

In the early 1970s, Dick began to have problems with balance and his tennis game deteriorated. Eventually, his difficulties were diagnosed as due to

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an 8th nerve neuroma, a benign tumor. It was operated on in 1974. Postoperative complications made the outcome worse than it might have been and Dick ended up with serious motor disabilities in speech and in movement. In spite of his handicaps, Dick continued his collaborations with many researchers and continued to publish research papers and books right up to his death. Dick Bellman died suddenly of a heart attack on March 19, 1984.

II. RICHARD BELLMAN'S WORK

Dick's first paper was entitled "On Symmetric Means" and appeared in the Brooklyn College Mathematical Mirror in 1940. His thesis at Princeton was on stability theory of differential equations, and this remained one of his major interests. His first book, which appeared in 1953, was *Stability Theory of Differential Equations*. Dick was always prolific but his move to RAND propelled him into a torrent of activity. His interests in multistage decision processes and control theory were fed by the many applications and problems he worked on at RAND and led him to the work for which he is probably best known—dynamic programming. His second book, *Dynamic Programming* appeared in 1957 and has continued to exert an important influence. Over the years Dick applied and encouraged others to apply dynamic programming to a remarkable variety of problems.

All told, Dick published over 600 papers and over 30 books and many of his books were translated into Russian, Japanese, and other languages. This productivity was sustained by Dick's inherent abilities, his wide-ranging interests, and his ability to collaborate easily and effectively with many researchers at the same time. In collaboration he quickly focused on the aspects of the problem he did best and left the rest to his collaborators. Dick did not seek long quiet periods to work, he actively sought the stimulation of interaction with many people, on many problems. To top that off, he was able to think about mathematics under almost any circumstances. With his large output, it is hard to see the forest for the trees. It may help to list some of the major areas where Dick played and where those of us who played with him briefly shared with him the joys of the game: optimization and control theory, differential and differential–difference equations, invariant imbedding and quasilinearization, radiative transfer, system identification, stochastic and adaptive control, plus applications in many areas including the biomedical area. In all of his work, he was concerned with basic theory, applications, and computational approaches.

My collaboration with Dick was in modeling in the biomedical area. A number of his friends and some members of his family had died of cancer and by the mid-1950s Dick began to look for opportunities to apply mathematical modeling in cancer therapy. It so happened that Dick's interest fit in with RAND management's concern to broaden their funding base. Most of the RAND's support at that time was from the Air Force and from

AEC. Dick visited the Sloan–Kettering Institute in New York City in 1958, looking for collaborators. We met during that visit, took to each other, found a common interest in modeling, and started our collaboration. We chose as our first problem modeling the kinetics of distribution of chemotherapeutic agents. The group involved in the early work consisted of Dick, Bob Kalaba, Bella Kotkin, and myself; later a number of others at RAND became involved. The initial work was supported by a special fund RAND had set aside for exploratory work that could not be charged to the Air Force. That work led to Dick's first papers in the biomedical area and to RAND's first NIH grant. Within a few years, Dick had expanded his involvement in biomedical applications to radiation dosimetry, pharmacokinetics in general, the inverse problem in electrocardiography, and the identification problem and identifiability in biological modeling.

By the early 1970s the cumulative effect of his contributions invited recognition and the awards started coming in. His major awards were: The first Norbert Weiner Prize in Applied Mathematics, 1970; the first Dickson Prize from Carnegie–Mellon, 1970; the ALZA Distinguished Lectureship, 1972; the John von Neumann Theory Award from the Institute of Management Sciences and the Operations Research Society of America, 1976; the Gold Medal from the IEEE for his work on dynamic programming, 1978; The Heritage Medal from the American Council for Control, 1983.

He was elected to the National Academy of Engineering in 1977 and to the National Academy of Sciences in 1983.

III. TEACHING, LECTURING

At USC Dick established a program in which graduate students were stimulated not only by Dick's example and his teaching but also by a stream of collaborators who visited and lectured to his group. Many of us spent one to two weeks every summer visiting USC to work with Dick and to lecture to and talk with his graduate students.

Dick was constantly on the go, lecturing at other universities, talking at meetings. An interesting sidelight is that Dick often commented that he had been very shy as a child and that giving an oral report in school had been an ordeal for him. It should be reassuring to all that with that background Dick became a good speaker, often appearing on talk shows, and that he was able to lecture to many types of audiences.

In addition to all of these activities, Dick started a number of journals, including *Mathematical Biosciences*, and founded a number of book series in applied mathematics, all part of his way of "spreading the gospel."

IV. SUMMATION AND APPRECIATION

Dick had his faults and came in for his share of criticism. Some mathematicians faulted him for his concern with application; he was not pure enough

for them. A more serious charge was that of dilettantism, which stemmed from his hopping from problem to problem, and there was some substance to that. His output was so great it could not be expected that all of it would be significant; some was ordinary and some was superficial. But in the last analysis all have to be judged by how good their good work is and by the balance between the effects of their good and bad work. In the balance, Dick's contributions easily tip the scales in his favor; his best work was outstanding.

Dick's enthusiasm was infectious and those of us who had the good fortune to work with him learned the joy of the game of modeling. There was a time when we were all Tom Sawyers together and the world was full of caves to explore.

I remember Dick with affection and admiration.

JOHN A. JACQUEZ

THE RICHARD BELLMAN MEMORIAL VOLUME

This issue honors the life and accomplishments of Richard Bellman, mathematician, who believed mathematics could be and should be used in solving the problems of this world.