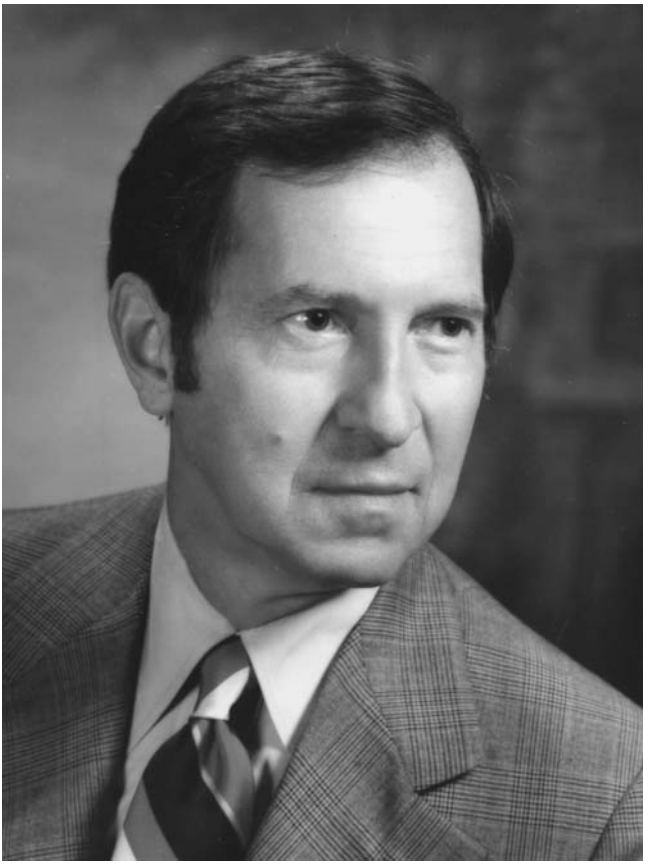

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ALAN S. MICHAELS

1922–2000

Elected in 1979

"For pioneering developments in the fields of surface, colloid and polymer chemistry, membrane science and technology, and advanced systems for drug delivery to the human body."

BY ANDREAS ACRIVOS

ALAN S. MICHAELS, a talented, creative, and influential educator, inventor, and entrepreneur in the field of chemical engineering, and one of the pioneers in biomedical engineering and biotechnology, died on January 16, 2000, in his winter home in Pasadena, California, after a prolonged illness. He was 77 years old.

Alan was born in Boston, Massachusetts, on October 29, 1922, the elder of two sons of Harry (who was a lawyer) and Edith Michaels. He grew up in Boston and Newton, Massachusetts, and attended Newton High School, graduating in 1941 prior to entering MIT to study chemical engineering. Like many of his contemporaries who chose to study chemical engineering, he decided on the subject because he liked chemistry but wanted to do practical work. His studies were interrupted in 1942 for military service with the U.S. Army Chemical Warfare Service. He saw combat in Germany as a mortar platoon officer (first lieutenant) and was awarded a Bronze Star. One of the few WWII memories he shared with his two sons was of drinking vodka with the Russians on the Elbe on VE day. Alan returned to MIT in 1945 to complete his B.S. (technically class of '44), S.M. in chemical engineering practice (1947), and Sc.D. (1948). His doctoral thesis, "The Measurement of Interfacial Tension at Elevated Temperatures and Pressures," was directed by Ernst Hauser.

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After receiving his Sc.D., Alan joined the MIT chemical engineering faculty for the following two years as an assistant professor and worked closely with his senior colleagues W. K. Lewis and E.A. Hauser in the teaching of colloid chemistry. Following a year in industry where he joined a colleague trying to commercialize a new leather tanning process, he was invited to return to MIT as a co-director of the newly organized Soil Stabilization Laboratory (a collaborative activity of the civil and chemical engineering departments). He was promoted to associate professor of chemical engineering in 1956 and to professor in 1961. In 1962, Alan founded Amicon Corporation and went on part-time leave of absence from MIT to organize and build the new company and serve as its president. In 1966, he resigned from the MIT faculty to devote full time to managing the company.

During his 18 years at MIT, Alan played a major role in the development of an intensive teaching and research program in the synthesis, properties, and applications of colloids and polymers. By 1966, this program encompassed six graduate courses and a research team comprising more than 20 predoctoral and postdoctoral students and postdoctoral fellows, whose studies were supported by industrial and government grants. Between 1960 and 1966, the faculty teaching staff associated with this activity increased from two to six. This program brought the MIT chemical engineering department the distinction of being one of the nation's premier centers of graduate study in polymer science and in the engineering applications of surface and colloidal phenomena.

Alan's research activities in the course of his tenure at MIT were extensive and diversified and brought him international recognition in a variety of fields. Specifically, his early work on chemical methods of solidifying solids for military highways and airstrips attracted broad interest in the civil and chemical engineering communities. His use of phosphoric acid, chemically modified asphalt and cement, and synthetic resins as soil stabilizers was considered useful and economical in both military and civilian applications. This work also stimulated his interest in the surface and colloidal properties of clays

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and clay-water systems and in the development of techniques for modifying mineral surfaces to make them better fillers and reinforcing agents in plastics. Furthermore, his interest in the problems of wetting and adhesion led him into basic research on the spreading of liquids on solids and, later, into the development of a novel method for improving the efficiency of oil recovery from petroleum reservoirs using a previously unrecognized wetting phenomenon.

In 1958, Alan became interested in the factors influencing the transmission of gases and vapors through polymers. He rapidly expanded his research program on polymer permeability and its dependence on polymer structure. The results of this research, which were described in about a dozen published papers, are regarded as the most significant contributions in the literature of polymer physics and are widely referenced both in the United States and abroad. An important concurrent research program involved the development of techniques for preparing "permselective" polymeric membranes, useful for the separation and purification of gaseous and liquid mixtures, which Alan and his MIT research staff subsequently applied, under the auspices of the U.S. Office of Saline Water, to the important problem of desalting seawater. Out of this research evolved the current great interest of the chemical-process industries in membrane separation as a new unit operation.

Amicon was established by Alan as a unique research and development organization devoted to providing innovative product and process development capabilities to private industry and government in the fields of applied surface, colloid, and polymer chemistry and novel chemical separation technology. It also pioneered the concept of "joint venture" research and development projects, wherein the company and its industrial clients or partners shared the cost of the initial research, subject to retention by Amicon of ownership rights to the developed technology, and the grant of royalty-bearing license rights in limited fields to the partners. These arrangements made it possible for Amicon to develop and exploit commercially its most significant technical developments; thus, in 1965, Amicon entered the important

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new field of membrane ultrafiltration and, in 1968, the field of high-performance epoxy resin adhesives. Amicon's most outstanding technical accomplishments were the development of a unique family of high-flow, low-pressure, semipermeable ultrafilteration membranes and the associated membrane process equipment for laboratory and industrial uses, as well as the development of a novel class of plastics and polymeric composites as engineering materials, packaging materials, and the like. Before its twentieth birthday, the company had become a well-established and respected producer of membranes and related laboratory products, including industrial-scale membrane process equipment and systems, for the pharmaceutical and biotechnology industries and of high-performance adhesives, encapsulants, and specialty polymeric materials for the automotive, electrical equipment, electronics, and computer industries. Amicon was acquired by W. R. Grace and Company in 1983 and merged with Millipore Corporation in 1997.

In 1970, Alan resigned from the presidency of Amicon in order to found and serve as president of Pharmetrics, Inc. (Palo Alto, California), a venture dedicated to research and development in the field of advanced drug delivery systems and devices. (He continued to serve as one of Amicon's directors until its acquisition by Grace.) In 1972, Pharmetrics was acquired by ALZA Corporation of Palo Alto, and, following this acquisition and until 1977, Alan served as president of Alza Research and senior vice president and technical director of ALZA Corporation, as well as a director of ALZA. During his tenure at ALZA, he also served as visiting scholar and consulting professor of chemical engineering at Stanford University, and as visiting professor of chemical engineering at University of California, Berkeley, where he taught courses in surface and colloid chemistry, polymer science, and chemical thermodynamics.

Under Alan's direction, Alza Research became identified as the first research and development organization in the pharmaceutical industry to involve close collaboration between physical and life scientists and engineers engaged in the

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development of novel pharmaceutical dosage forms. Between 1970 and 1975, the company perfected and introduced into commerce: (1) an ocular therapeutic system (OCUSERT®) which provided seven days' continuous administration of pilocarpine to the eye for the control of glaucoma; (2) an intrauterine system (PROGESTASERT®) which, for effective contraception, continuously delivers progesterone at low rate to the uterine lumen for one year; (3) a small, topically applied transdermal therapeutic system (TRANSDERM SCOP®) that provided 72 hours of continuous administration of scopolamine for the control of motion-induced nausea; (4) an osmotically driven oral therapeutic system (OROS®) permitting the essentially constant delivery of a variety of drugs to the gastrointestinal tract for periods of 6-24 hours; and (5) a self-contained, self-energized, patient-wearable, disposable, liquid-infusion system providing constant-rate intravenous medication for periods of days or weeks. Today, ALZA's TRANSDERM® and OROS® delivery systems are in widespread use around the world and have provided, for many years, a major share of the company's revenues and profits. Alan played an important technical and managerial role in these developments, widely espoused the contributions of the engineering disciplines to the medical community, and stimulated the awareness by the engineering profession of opportunities for engineers in the field of therapeutics. In 2001, ALZA was acquired by Johnson & Johnson Corporation.

Early in 1977, Alan resigned from ALZA to accept an appointment on the faculty of Stanford University as adjunct professor of chemical engineering and medicine, under a grant from the National Kidney Foundation, for the purpose of conducting a research and instructional program on the artificial kidney, other extracorporeal artificial organs, bioengineering, and biomedicine. During his tenure at Stanford, he established an active graduate research program in membrane transport fundamentals; played an instrumental role in initiating an interdisciplinary research program in bioreactor development and genetic engineering; collaborated with the Division of Nephrology of Stanford University's

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Medical School in the development of novel diagnostic techniques for studying kidney disease; and co-directed a program devoted to the study of piezoelectric polymers in the Center of Material Research. During this period, Alan was also a visiting professor of chemical engineering at the University of California, Berkeley. His tenure at Stanford also permitted him to reestablish an extensive industrial consulting practice.

In 1982, Alan resigned from Stanford to devote the majority of his time to industrial consulting. Between 1982 and 1984, he also served as adjunct professor of chemical engineering at both MIT and Lehigh University, in the capacity of faculty and student advisor, research co-supervisor, and lecturer. In 1986, however, Alan accepted an appointment as distinguished university professor in the Department of Chemical Engineering at North Carolina State University, Raleigh, where he resumed his teaching and research activities in membrane and separation technology, surface and colloid chemistry, and biochemical/biomedical engineering. In September of 1989, he retired from his faculty position to return to Boston and devote full time to his industrial consulting practice as president of Alan Sherman Michaels, Sc.D., Inc.

In addition to his consulting service to the food, drug, and chemical industries, he served as scientific advisor to the Bioproducts Group (Pharmaceutical and Biosciences Division) and the Food Processing Systems Division of FMC Corporation; as director and scientific advisor to Membrex, Inc. (Fairfield, New Jersey); as scientific advisor to Reprogenesis, Inc., of Cambridge, Massachusetts; and as scientific advisor to Cyotherpeutics, Inc., of Providence, Rhode Island; and from 1996 until his death, as visiting scholar in chemical engineering at the California Institute of Technology, where he collaborated in the planning and the graduate research activities of the expanding program of bioengineering research.

Alan's advisory service to industry, government, and the scientific and academic communities has been extensive and varied; as a consequence of his visit to West Pakistan in 1959 to survey the irrigation problems of the Indus River basin, he was requested to serve as consultant to the President's Science

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Advisory Committee and as a member of the Revelle Committee appointed by President Kennedy to study agricultural problems in Pakistan. Also, in 1959, he served as visiting professor of chemical engineering at University College (London). In 1965, he chaired an advisory committee to the director of the Office of Saline Water (U.S. Department of the Interior) on reverse osmosis desalination and, in 1972, he chaired a similar committee for that agency to review piezodialysis. He also served as a member of an advisory committee to the National Institutes of Health on hemodialysis.

Alan organized and chaired numerous symposia and conferences, including the ACS Symposium on Nucleation Phenomena (1965), the Gordon Research Conference on Separation and Purification (1976), and the Engineering Foundation Conference on Advances in Fermentation Recovery Process Technology (1981). He was chairman of the 1986 Gordon Research Conference on Synthetic Membranes.

Alan was elected to the National Academy of Engineering in 1979. After his election, he was actively involved with academy affairs, where he served on the Research Briefing Panel on Chemical and Process Engineering for Biotechnology, as a member and subcommittee chairman of the Committee on Chemical Engineering Frontiers: Research Needs and Opportunities (the Amundson Committee), and of the Committee for Bioprocessing for the Energy-Efficient Production of Chemicals. In 1988, he served as chairman of a National Research Council Workshop on Manufacturing Issues in the Biotechnology Industry. In 1991–1992, he served as a member and subcommittee chairman of the Committee on Bioprocess Engineering for the Board on Biology of the National Research Council.

He served as advisory editor of *Separation Science and Technology* (Dekker), *Desalination* (Elsevier), the *Journal of Preparative Chromatography*, and the *Journal of Membrane Science* (Elsevier). During his professional career spanning more than 50 years, Alan authored and coauthored more than 140 technical papers and 58 patents and was a contributing author to eight textbooks.

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Alan was a member of Tau Beta Pi, Sigma Xi, the American Institute of Chemical Engineers (fellow), the American Chemical Society, the New York Academy of Sciences (fellow) and AAAS. He received the McGraw-Hill Outstanding Personal Achievement Award in Chemical Engineering in 1974; was designated the 37th Institute Lecturer of AIChE in 1975; received the Food, Pharmaceutical, and Bioengineering Award of the A.I.Ch.E. in 1977; and received the ACS Award in Separation Science and Technology in 1985. In June of 1988, he was honored as one of four Ninth Centennial Lecturers in Chemical Engineering at the 900th Anniversary of the Founding of the University of Bologna (Italy). In 1991, he was elected a founding fellow of the American Institute of Medical and Biological Engineering. In 1992, he was a lecturer at a workshop on "The Biotechnological Production Process" sponsored by the Fondazione per le Biotechnologie, held in Turin, Italy. In 1993, he was plenary lecturer at the Gordon Research Conference on Membranes, Materials, and Processes; an invited lecturer at the International Congress on Membrane and Membrane Processes in Heidelberg, Germany; and an invited lecturer at the 21st Katzir-Katchalsky Conference Workshop on Applications of Membranes in Industry at the Weizmann Institute of Science, Israel. In May 1994, a symposium in his name was organized at the annual meeting of the North American Membrane Society held in Breckenridge, Colorado. He was a director of the North American Membrane Society and was also elected an honorary member of the European Membrane Society.

In 1996, MIT established the Alan Sherman Michaels Endowment Fund in Medical and Biological Engineering in recognition of Alan's contributions to the MIT Department of Chemical Engineering during his tenure as professor in that department and his success in advancing this technology to society's benefit through his service to the medical and pharmaceutical communities. The fund is currently being used to support the Alan S. Michaels Distinguished Lectureship in Medical and Biological Engineering, administered by the Department of Chemical Engineering, whose objective is to bring pioneering contributors in the basic and applied life

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sciences and bioengineering into constructive interaction with students in engineering and to stimulate cross-disciplinary collaboration in this exciting new area of technology.

Alan is survived by his wife Janet Glotzer Michaels of Pasadena, California, whom he married in 1951; two sons (both chemical engineers), Stephen of Cambridge, Massachusetts; and James of Bedminster, Pennsylvania; and two grandchildren, Aaron and Andrew. A more active, fascinating, and fulfilling life would be difficult to imagine.

*This memorial tribute is a slightly revised version (with help from James Michaels and Allan Hoffman) of a manuscript that Alan Michaels left with his family six months before he passed away.

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