The
Selected Works
of
John W. Cahn

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Edited by

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and

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Forward:

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The *Selected Works of John W. Cahn* is meant to serve two purposes. First and foremost, it is intended to honor John Cahn by creating a document which, at least partially, reflects his remarkable achievements and contributions to materials science. Second, we feel that the breadth of topics included in the selected works, the rigor with which they are introduced, and their importance to materials science suffice to create a useful reference for any materials scientist. Furthermore, a small portion of the contents of this book might well provide a syllabus for a graduate course in theoretical materials science, and we hope the *Selected Works* would serve as a suitable text. The entire *Selected Works* will provide a lifetime of study for most of us.

The publications appearing in the *Selected Works* represent about one-eighth of John's total publications; those of us who know John Cahn well, know that his contributions to the field of theoretical materials science far exceed his formidable set of publications. His liberality of ideas has nucleated entire careers, his shrewd criticism has made our field significantly more rigorous, and those who have learned from John (and those that have learned from them) have a deep foundation in the fundamentals of materials science. A complete list of John's publications (to-date!) is included in this volume.

Collecting all of John's publications together into one volume would have been very useful, but would also have produced an unwieldy book. It was no easy task to select a fraction of his works to appear in this volume. Initially, we had intended to limit the *Selected Works* to fifteen papers; however, the extent of John's contribution made this impossible and we finally iterated to thirty papers. We are fairly certain that any thoughtful list of thirty of his publications would have many in common with those that appear herein, but we are also fairly certain that no two lists would be identical. John helped us out considerably by making the selections himself, and we know that it was very difficult for him to exclude some of his best work from the list.

Each paper is introduced and put in perspective by an author whom we considered to be well-qualified in the subject area of the paper and who had been a student or colleague of John's. This also was no easy task as there are many scientists who have been influenced by John and whose contributions would have been appreciated had space allowed. We placed few restrictions on the introductions other than that a coauthor of one of the papers could not write an introduction for that paper and that each introduction be of limited length. We encouraged the rapporteurs to identify why each paper was important to the field, to put the paper in historical perspective, and to provide a list of additional references when appropriate. We are very pleased with the results and feel that the introductions will be most useful to students, professors, and other scholars. We are extremely grateful for the efforts of the rapporteurs, a list of whom appears in this volume.

One of John's most important contributions to materials science has been in the development of diffuse interface theory. It is certainly of historical interest, as well as of personal interest to many, and John is asked frequently to recount its development. Recently, John was asked once again to describe the development of the diffuse interface concept and it was decided that the *Selected Works* would provide an excellent venue for its telling. John's history of this development appears at the beginning of the *Selected Works*.

John's technical accomplishments speak for themselves and are reflected in his complete list of publications and the *Selected Works* presented herein. John's scientific contributions range across the entire spectrum of materials science. Metallurgists, who claim him as one of their own, know him for his pioneering work on the thermodynamics and kinetics of phase transformations, stereology, spinodal decomposition, coherency stresses, and solidification. Ceramists know him for his work on boundary faceting transitions, capillary forces, and impurity drag. Crystallographers know him for quasicrystals and descriptions of grain boundary symmetry. Mathematicians know him from the Cahn-Hilliard and Allen-Cahn equations and variational formulations of kinetics. Polymer scientists are using Cahn-Hilliard analyses in the process design of novel microstructures. Physicists know him for developments in critical wetting, diffuse interfaces, surface thermodynamics, and general applicability of the concepts arising from spinodal decomposition. As impressive as this list is, it is far from complete.

During the last ten years, despite a nearly fatal illness, John has continued to reach ever higher intellectual levels through mutually beneficial collaborations with mathematicians. These efforts, in pursuit of objectives driven primarily by his desire for rigor in the science of interfaces and their energetics, have yet again changed the direction of a subdiscipline of materials science. The success of these efforts have accelerated the use of mathematics in the now rapidly developing and growing areas of theoretical and computational materials science.

It is painful to imagine what our field would be like today, had John and his parents suffered the same tragedies as those of countless other European Jews earlier this century. Yet, the transformation of Hans Werner to John W. Cahn depended on the foresight of John's father and several twists of fate. A brief overview of the exodus of John, his sister, and parents from pre-World War II Germany in 1933 to America in 1939 is given in the accompanying biographical sketch. We are most grateful to Gary Shiflet and Hub Aaronson for their many contributions to this biographical sketch, and especially to Anne and John Cahn for sharing this history with us and making available some family photographs.

Finally, both of us have benefited enormously from John's tutelage, patience, wisdom, and support. We sincerely hope that our efforts in putting together this volume reflect our profound admiration and respect for John Cahn.

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Facing Page: Cahn Family circa 1962, taken in Schenectady, New York, Anne and John are standing behind their children, (from left to right) Lorie, Andrew, and Martin
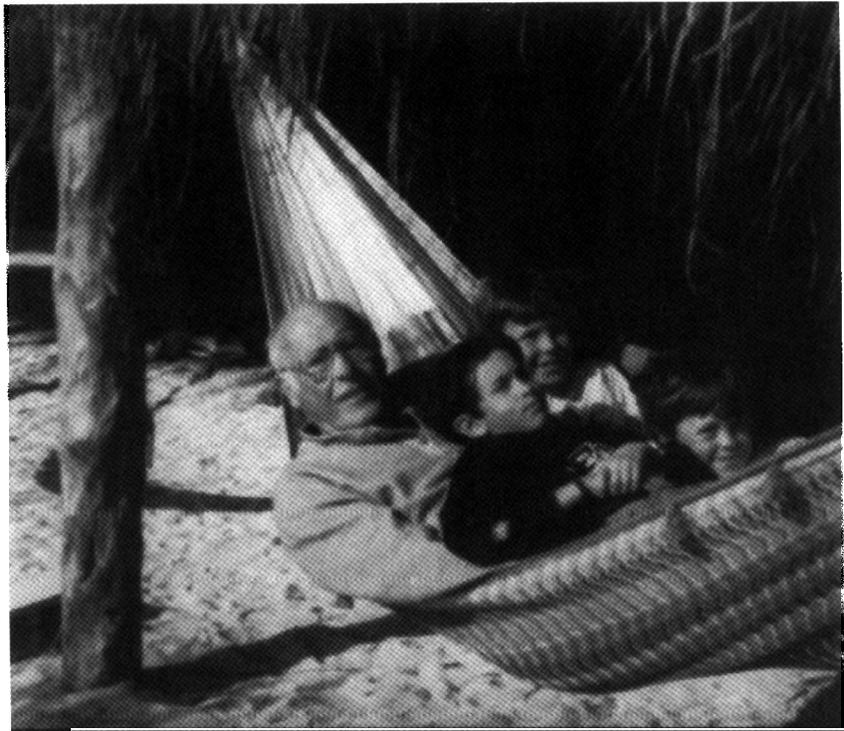
John with three of his six grandchildren (from left to right) Devin Cahn, Kyler and Tobin Brown

John's favorite part of a hike, lunch!

John and Mats Hillert relaxing after chopping wood in the back of Anne and John's house in Bethesda, Maryland in late 1997

John Werner Cahn

This biographical sketch of John Werner Cahn highlights a few important events in an extraordinary life and a truly remarkable career of one of the world's most influential materials scientists. The thirty scientific papers contained in this volume (of more than 230) comprise one of the most significant contributions to the understanding of materials science of this century. The range and depth of thought embodied in these pages, and their subsequent impact on the development of materials science, justifies Professor David Turnbull's statement that: "The research, instruction, and critiques of John Cahn have constituted a powerful driving force .... They have vitally affected every area of the field and have strongly influenced statistical physics as well. It seems safe to say that without them, our knowledge and understanding of materials science would have been, today, in a far more primitive and disjointed state."

John Cahn's early years were inextricably entwined with, and influenced by, the turmoil of pre-World War II Germany. His parents, Lucie P. Schwarz, a medical X-ray technician, and Felix H. Cahn, a lawyer with a Dr. Jur. degree, were married in Cologne, Germany, on August 16, 1925. Almost three years later, on January 9, 1928, their first child, John Werner Cahn was born in Cologne. His younger sister, Anne, was born on April 1, 1930.

In the early 1930's, Felix Cahn was active in the local Bar Association, and had been elected to their Board. Before the National Socialists came to power in 1933, he had assumed several civil cases against the Nazis. In addition, he had opposed Nazi efforts to bring down the Weimar Republic. This activity attracted the attention of the German SS and he was targeted for arrest during a mass roundup.

On the way to his office in early 1933, Felix Cahn was intercepted on the street by a lawyer from a neighboring office who warned him that the SS had arrived earlier that morning to arrest him. Felix Cahn returned home immediately, gathered his family, and fled to the Black Forest region in southwest Germany. After about a week, it was decided that they would be safer if they were to leave Germany. The Cahns eventually rented an unheated summer cottage at a beach resort in LeCoq, Belgium, remaining until November, 1933. They then moved on to Amsterdam, Holland. Throughout this period, Felix Cahn was confident that the German court system would restore lawful government, and that they would be able to return to Germany.

John received his elementary schooling in Amsterdam. Although his parents were quite happy in Holland, they had applied for permission to emigrate to the United States soon after their flight from Germany. Their quota number came up in 1937 and, later that summer, Felix and Lucie Cahn emigrated officially to the United States, leaving John and his sister Anne behind in Holland. Felix Cahn had accumulated some capital and was seeking a place with opportunities in the United States before sending for the children. Instead of settling in the United States, however, Felix and Lucie Cahn returned to Holland in early October 1937 with a franchise to import American electric welding equipment. In order to retain their immigrant status in the US, they asked for and were issued an immigrant's *reenter permit* valid for two years. This forced the Cahns to reserve round-trip passage long before the outbreak of WWII; they had return tickets to the United States booked for September 17, 1939 on the Holland-America Line.

Events in 1938 and 1939, the German *Anschluß* of Austria and later of Czechoslovakia, the *Kristallnacht* of November 1938, and the outbreak of World War II on September 1, 1939 with the invasion of Poland, gave special importance to the question of a permanent return to the United States. Felix Cahn was alone in arguing for a permanent return to the United States. Lucie Cahn, their friends, and the partner in the welding business were all confident that Holland's neutrality would again be honored by the Germans as it had been in World War I. Even John's elementary school teacher visited his parents and urged them to remain in Amsterdam, as he felt John's education would suffer were he to leave. Eventually, Felix Cahn prevailed and the entire family embarked for the United States. Most of John's extended family remaining in Germany perished in German concentration camps. Of those relatives who had managed to flee to Holland, almost all were killed in concentration camps. For many, their emigration to other countries had been denied.

The Cahn family settled in New York and John attended Brooklyn Technical High School from 1941 to 1945. John became an American citizen in 1945. His undergraduate studies at the University of Michigan (1945-9) were interrupted for three semesters for service (1946-7) in the US Army during the occupation of Japan. After receiving his B.S. in Chemistry in 1949 from the University of Michigan, he began graduate studies at the University of California at Berkeley, studying the oxidation of isotopically labeled hydrazine under the direction of Richard E. Powell. He obtained his Ph.D. in Physical Chemistry in 1953. In 1950, John married Anne Hessing. They have three children; Martin, Andrew, and Lorie, and six grandchildren.

John worked as an instructor at the University of Chicago from 1952 to 1954. He was associated with the Institute for the Study of Metals which, at the time, was directed by Cyril Stanley Smith and included such senior scientists as Charles Barrett. He was subsequently hired by David Turnbull of the Chemical Metallurgy Group (a branch of the Metallurgy and Ceramics Division) of the General Electric Research Laboratory in Schenectady, New York to work on tracer diffusion in metals. At that time, the Metallurgy and Ceramics Group was under the direction of J. Herbert Holloman, and was considered one of the most productive and stimulating materials research laboratories in the world. (The intense basic research activity at GE during this period is conveyed in John's accompanying historical reflections on diffuse interfaces.) He left GE in 1964 to become Professor of Metallurgy (later of Materials Science) at the Massachusetts Institute of Technology. In early 1977 John took a two-year leave of absence from MIT and followed his wife to Washington D.C. where she assumed a position in the Carter Administration. Initially hired as a Visiting Scientist at the National Bureau of Standards, John became Center Scientist in the Center for Materials Science after his resignation from MIT later that year. Following the reorganization of NBS in 1984, John assumed his current position as Senior Fellow at the National Institute for Standards and Technology.

John's many awards include a Guggenheim Fellowship at the University of Cambridge in 1960-61, the Dickson Prize of Carnegie-Mellon University, the Michelson and Morley Prize of Case-Western University, the ASM Sauveur Award, the National Bureau of Standard's Stratton Award, the Rockwell Medal, the Harvey Prize from the Israel Institute of Technology, and Gold Medals from Acta Metallurgica, the US Department of Commerce, and the Japan Institute of Metals. He is a Fellow of both ASM and The Metallurgical Society (TMS) and is a member of the National Academy of Sciences, the National Academy of Engineering, and the American Academy of Arts and Sciences. John has given The Metallurgical Society's Institute of Metals Lecture and the Material Research Society's Von Hippel Lecture. He has received an honorary Sc.D. from Northwestern University, Doctor Honoris Causis from Universite d'Evry in France, and has been a Visiting Professor at universities in Israel, China, Taiwan, Iran, and Sweden. Since 1984 he has been an Affiliate Professor both in Physics and in Materials Engineering at the University of Washington in Seattle.

John's awards, degrees and academic positions are most impressive. However, it is John's technical papers, his incredibly deep and broad scientific contributions, personal interactions and countless suggestions, support of young people, and standards of excellence that will endure and continue to influence the development of materials science. John takes pride in his association and collaboration with other scientists and especially in his support of women in science. John's frequently proffered advice to scientists of all ages, "READ GIBBS," is as timely as it has always been. However, there is another refrain between materials scientists that seems to be heard just as frequently these days: "READ CAHN!" The small sampling of John's publications contained within this volume, and the historical perspective of his work contained within the accompanying introductions, clearly attest to the merit of such advice.

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