Elliott Hershel Lieb

Elliott Lieb was born in Boston in 1932, and at the age of five moved to the Bronx where he was educated in the New York City school system, graduating from the Bronx High School of Science. At the age of 17 he moved with his parents back to Boston, where he was able to attend the Massachusetts Institute of Technology, thanks partially to a scholarship.

While in high school, Elliott was interested in electronics (vacuum tubes then) and amateur radio; one of his proudest achievements was being able to master Morse code sufficiently to obtain a broadcasting license, W2ZHS. Upon entering MIT in 1949 his intention was to acquire an electrical engineering degree, but thanks to the superb teaching of his first-semester physics professor Matthew Sands (who collaborated with Richard Feynman and Robert Leighton on the famous "Lectures"), Elliott switched to the physics department.

The years at MIT were fraught with political turmoil. There was McCarthyism, which devastated the academic community in several ways. One famous case was the MIT mathematics professor, Dirk Struik, who was suspended from teaching. His defense sparked much activity within some of the student body, including Elliott. Also of major concern was the Korean War. Students were told by the ROTC officers that they could either graduate and become officers in Korea or do nothing and probably go directly to Korea as privates. Elliott took his chances with the latter and was lucky to continue through to a bachelor of science degree.

Elliott recalls that he was powerfully impacted at MIT by Professors Victor Weisskopf, Jerrold Zaccharias, Francis Friedman, Peter Demos, Isaac Halpern, Norbert Wiener, and Isadore Singer.

In 1953 Elliott took off on a National Science Foundation fellowship for Birmingham University in England, for Ph.D. studies in the department of mathematical physics under Rudolf Peierls, Samuel Edwards, and Gerald Brown. Birmingham was one of the main centers of theoretical physics in Europe in those days. Like many young people then and now he steered towards the most advanced subject offered, quantum field theory. But after graduation in 1956 he tacked towards other directions in physics.

Throughout the rich scientific career that followed, Elliott has been guided by his drive to understand challenging physics phenomena in lucid mathematical terms. In the process, he would repeatedly break new ground in physics and in mathematics. A number of active fields of research were started or invigorated that way, and some now enjoy renewed attention. His early work withstands the test of time in its clarity and reach.

Elliott is an avid traveler. As a student he expanded his horizon by extensive road trips throughout Europe. He received a Fulbright Scholarship for a postdoctoral stay in Kyoto and spent 1956-57 at the Yukawa Institute for Theoretical Physics. In those days, 11 years after the war, a foreign postdoctoral position was almost unheard of. Elliott remembers witnessing the old Japan as an astounding cultural experience. A few years later he spent a paid leave from IBM teaching applied mathematics at Fourah Bay College in Freetown, Sierra Leone. A Peace Corps project arrived in the same year. A noteworthy volunteer was Shirley M. Tilghman, president of the University, emeritus, and professor of molecular biology and public affairs, though Elliott and Shirley did not cross paths there.

After postdoctoral appointments at Illinois and Cornell, Elliott was offered a permanent position in the new IBM laboratory in Yorktown Heights, New York, in 1960. He joined a pure theory group, which was started by Elliott Montroll. This was a new concept at IBM, as it was in several major industrial labs. The decades of the 1960s and 1970s were golden years for non-directed research.

At IBM, Elliott and his co-workers, Theodore Schultz and Daniel Mattis, published several influential papers in condensed matter physics. Among the themes developed in these papers is the emergence of fermionic structures in classical models of statistical mechanics. Other fundamental results concern correlations in quantum statistical mechanics and the roots of ferromagnetism.

A collection of these and other papers on one-dimensional physics were gathered together in the 1968 book by Lieb and Mattis, *Mathematical Physics in One Dimension: Exactly Soluble Models of Interacting Particles*. The book appeared well ahead of its time, for the physics of one-dimensional spin chains is now regarded as very important.

Invited by Joel Lebowitz, Elliott briefly held a position at the newly created Belfer Graduate School of Yeshiva University, in New York. Elliott and Lebowitz became lifelong friends and collaborators, but in 1966 Elliott moved to Northeastern University in Boston. It was there that he and Fa Yueh Wu wrote one of the most cited papers in condensed matter physics on the one-dimensional Hubbard model. Elliott also solved the “square ice problem” and computed the entropy per atom to be (3/2)log (4/3), since known as “Lieb’s ice constant.” Building on the work of Hans Bethe and Chen-Ning Yang, and triggering subsequent papers by Rodney Baxter and others, this work played an important role by opening up a new area of soluble models, beyond Lars Onsager’s solution of the Ising model.

In 1968 Elliott returned to MIT, this time as a faculty member. Important scientific results from that period include the foundations of Thomas-Fermi theory and Hartree-Fock theories (with Barry Simon), the Lieb-Robinson bound in condensed matter, the Hepp-Lieb maser-model, and the thermodynamic limit for Coulomb systems (with Joel Lebowitz).

The Lieb-Robinson bound plays a significant role in current work on the topological phases of extensive quantum systems. Another seminal work was the “Strong subadditivity of quantum entropy,” with Mary Beth Ruskai. Together with the methods developed for its proof, it now forms part of the basis of modern quantum information theory. The first “Brascamp-Lieb inequalities” date from this period, while the final version was constructed by Elliott at Princeton in 1990. An important work was the “Theory of monomer-dimer systems” with Ole Heilmann.

Yet another major development was “The proof of stability of matter” with Walter Thirring. Addressing the fundamental physics question through the newly conceived Lieb-Thirring inequalities, they opened a new chapter in functional analysis. Over the years it has continued to inspire new mathematical results, playing a significant role in partial differential equations.

The MIT period lasted until 1974 when Elliott moved to Princeton on leave of absence. He officially came on board in 1975.

At Princeton, Elliott addressed important problems including stability of matter in magnetic fields, with Jan Philip Solovej and Jakob Yngvason; conditions for the emergence of ferromagnetism, some with Michael Aizenman; and an axiomatic presentation of thermodynamics based on the concept of entropy, developed with Jakob Yngvason.

Much of the research was directed toward understanding the quantum mechanics of atoms and the lowest energy state of the

Bose gas. Colleagues involved with this effort have included Michael Aizenman, Michael Loss, Robert Seiringer, Jan Philip Solovej, and Jakob Yngvason. A significant 1987 work with Ian Affleck, Tom Kennedy, and Hal Tasaki, carried out at Princeton, was the invention and solution of the AKLT quantum spin system. This provides an early example of a system exhibiting what is nowadays referred to as a topological state of matter, which is a subject of great current interest.

Elliott also wrote pedagogical texts, such as the mathematics book with Michael Loss called simply *Analysis*.With Robert Seiringer he co-authored *The Stability of Matter in Quantum Mechanics*, which brought together the work on the relativistic and non-relativistic many-body theory developed over the years by Elliott and others.

Elliott's contributions were recognized by many prizes and honors. He is a member of five national academies, including the National Academy of Sciences, a foreign member of the Royal Society in the United Kingdom, and holds four honorary doctorates. He was twice president of the International Association of Mathematical Physics. For his work in physics he was awarded the Boltzmann Medal, the Max Planck Medal, the Norwegian Onsager Prize and the Heineman Prize. The American Mathematical Society recognized him with the Birkhoff and Conant Prizes, and the Swedish Royal Academy awarded the Shock Prize. The Austrian government awarded him the lifetime Austrian Medal of Honor for Science and Art, which can be held by no more than 18 foreign scientists at any time.

While Elliott has retired from active professorial duties he continues to do research in mathematics and physics. We wish him many years of joy in this endeavor.