THE LEGACY OF EUGENE FEENBERG AT THE CENTENARY OF HIS BIRTH

JOHN W. CLARK

Department of Physics, Washington University,
St. Louis, Missouri 63130, USA
**E-mail: jwc@wuphys.wustl.edu*

Eugene Feenberg's brilliant career in theoretical physics is reviewed, commemorating his vital role in the development of microscopic quantum many-body theory. The examples of his life and work continue to exert a profound influence on the character of the field, as reflected in the International Conferences on Recent Progress in Many-Body Theories.

Keywords: Eugene Feenberg; history of physics; many-body theory.

1. A Guiding Theme

Eugene Feenberg (1906-1977) emerges in the historical records of twentieth-century science as a leading pioneer in the application of quantum mechanics to nuclei and superfluid helium. In seeking an understanding of the behavior of these systems, he was not content with phenomenological descriptions or oversimplified models made popular by their tractability. Rather, his major contributions stemmed from a continuing quest (almost in his own words) for —

> Quantitative microscopic prediction of the observable properties of strongly interacting quantum many-body systems under realistic conditions of interaction, density, and temperature.

This is often referred to as *ab-initio* theory (although the term has seen much abuse in recent years).

Before the mid-1950's, the most prominent theorists shared the attitude that such a goal was unattainable, either in principle or due to insufficient computational resources. It is a tribute to Feenberg's vision that the guiding theme of his life work, expressed so visibly in this conference series on Recent Progress in Many-Body Theories (RPMBT), steadily gained ascendancy and now pervades condensed matter and nuclear physics as well as quantum chemistry.

The Fourteenth RPMBT conference takes place within the centennial year of Eugene Feenberg's birth. This gives us an excellent opportunity for remembrance of the man and celebration of his legacy for theoretical physics. The imprint of his intellect endures both in his foundational research in quantum many-body theory,

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

beginning with his studies of nuclear forces and nuclei in the early days of nuclear physics and culminating in the Method of Correlated Basis Functions (CBF), and in the standards he set for microscopic ("*ab-initio*") theory . There is also Feenberg the wise teacher, mentor, and exemplary role model, whose influence continues to be spread by his former students and colleagues, and by their own scientific progeny.

2. Birth and Youth

Eugene Feenberg was born on October 6, 1906 in Fort Smith, Arkansas, to Polish immigrant parents. His father Louis, starting out as a peddler in his youth, traveled widely in the central states west of the Mississippi, settling for a while with his young wife Esther in Deadwood, South Dakota. He later achieved moderate financial success as a junk dealer in Fort Smith. At the time, this profession was not high on the social ladder, but — as Eugene himself has pointed out — its standing has risen with the increase of environmental concerns and the growing emphasis on recycling.

Feenberg grew up in Fort Smith and attended the public high school, where he excelled in math and science, occupying himself with electrical gadgets, motors, and radios in his spare time. College was simply not part of his world, so after high school he worked for three years in a number of odd jobs (*e.g.* with his uncle's fur business in Illinois). This rather dreary experience convinced him that he was not cut out for making a living in ordinary business jobs; he finally and firmly decided to pursue his true interests in science. His family had moved to Dallas, so he entered the University of Texas (UT) at Austin in 1926 (where the tuition was $25/semester), studying physics and math and making up for lost time by finishing first in his class with both B.S. and M.A. degrees in three years. He was the first graduate of his high school to attend college.

3. From Austin to Cambridge

Feenberg's brilliance attracted the attention of his professors at UT, including C. P. Boner and Arnold Romberg in Physics and Hyman Ettlinger and R. L. Moore in Math. With Boner's support, he applied to Harvard, where he undertook doctoral studies during 1929-33. Early on, the Stock Market crash curtailed financial help from Eugene's father, but Harvard physics faculty arranged part-time employment for him with Raytheon to fill the gap. Feenberg's thesis research was directed by Edwin C. Kemble, who had established one of the early schools of theoretical physics in the U.S. The thesis, resulting in Feenberg's first publication (1932), developed the quantum theory of scattering and contained the first statement and proof of the quantum optical theorem. During his years at Harvard, Eugene was also mentored by John Van Vleck, and he took courses from Kemble, John C. Slater, Percy Bridgman, and George Washington Peirce.

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

4. European Hejira

Harvard awarded Feenberg a Parker Traveling Fellowship in 1931, which allowed him to study in Europe for a year and a half. This was a time and place of turbulent developments both in physics and politics, as the ramifications of quantum mechanics were being explored and Nazism and Fascism emerged as horrific threats to world order and basic human rights. Eugene spent varying periods in Munich (Sommerfeld), Zurich (Pauli), Rome (Fermi), Berlin (Wigner), and Leipzig (Heisenberg). In hindsight, he remarked that he was not really mature enough to be sent over that way (on his own, without a definite study plan), but the experience at these magnificent sites of quantum ferment had to be inspiring. One highlight was the instant rapport he established with Ettore Majorana, a young Italian genius of Eugene's age who disappeared inexplicably in 1938.

By contrast, Feenberg reacted with shock and outrage to the political turmoil and violent anti-Semitism generated by the Nazi seizure of power in 1933. He could hardly restrain himself as he walked the crowded streets of Leipzig and saw roving gangs of Brown-Shirt thugs attack Jewish shops and their owners — passersby warned him to keep calm. Upon receiving a letter from Eugene describing this experience, Kemble immediately sent a plea for him to return to the U.S., fearing for his safety.

5. Precocious Nuclear Shells and the First Internal Symmetry

After his return, Feenberg spent two years (1933-35) at Harvard as an instructor, in a holding pattern until a regular faculty appointment could be found for him. With the Great Depression in full effect, faculty jobs were scarce, and in addition there was a pernicious anti-Semitism within academic administrations. (Presumably to dispel the stereotype, Kemble is known to have described Feenberg as a "tall, rangy Texan.") It was in this period that Eugene carried out the first calculations of the structure of the lightest nuclei (d, t, ^{3}He, α) with postulated nuclear forces — variational calculations based on trial functions built from Gaussians. Van Vleck came to him one day with the suggestion that such calculations should be carried out. Gene pulled open his desk drawer and handed Van Vleck the results.

A one-year faculty slot at Wisconsin opened up for Feenberg in 1935-36 when Gregory Breit, already a prominent nuclear theorist, left for a visit to Princeton. At Wisconsin, Feenberg shared an office with Eugene Wigner, and there they began laying the foundation for the nuclear shell model with calculations on p-shell nuclei that led ultimately to supermultiplet theory, a precursor of supersymmetry. In 1936, experimental results for proton-proton scattering broke open the controversial puzzle of the like-nucleon interactions, supporting the charge independence of nuclear forces and giving the first solid evidence of an internal symmetry: isospin. Breit and Feenberg, through correspondence, published one landmark *Physical Review* paper on the subject, back-to-back with another by Cassen and Condon. Steven Weinberg has called attention to the historical importance of these papers.

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

Wigner next arranged a two-year staff appointment for Feenberg at the Institute for Advanced Study (1936-38). There Eugene moved the p-shell calculations forward based on the new symmetry principles, working with Wigner and supervising the research of Melba Phillips. Phillips, one of Oppenheimer's first students, was among the very few women theorists on the scene in the 1930's; she was later to gain international prominence in science education. While at the Princeton Institute, Feenberg also collaborated with John Bardeen (then a Harvard Junior Fellow) on symmetry effects in nuclear level spacings. With the recommendations of Kemble, Wigner, and Isidor Rabi, in 1938 Feenberg was recruited to the faculty of New York University, where he began a long association with Henry Primakoff. And one day a vivacious young student named Hilda Rosenberg appeared at Gene's office door, seeking support for a liberal political cause — and sparking a relationship that led to marriage. Two sons, Andrew and Daniel, were born to Hilda and Eugene; both have enjoyed successful intellectual careers, Andrew in philosophy and Daniel in economics. There are two grandchildren. Hilda Feenberg passed away in 1997.

6. Selective War Work

During World War II, Feenberg took a leave of absence from NYU to join the Allied war effort, engaging in radar research at the Sperry Gyroscope Laboratories on Long Island. There he applied electromagnetic theory to microwaves and the development of Klystron tubes and is credited with an important technical innovation. Gene was invited to join the fission bomb project at Los Alamos but declined; this is fully consistent with his expressed views on the responsibility of scientists to make morally correct choices in applying their knowledge. It is worth noting here that, quite independently of Meitner, Eugene worked out and published (in a 1939 letter to *Phys. Rev.*) the standard analysis showing how the competition between Coulomb and surface energies governs the possibility of nuclear fission.

7. At Home in St. Louis with Mature Nuclear Shells

When Arthur H. Compton — who directed the Metallurgical Project in the development of the fission weapon — returned to Washington University (WU) as Chancellor in 1945, he spearheaded a significant expansion of the science departments. Both Feenberg and Primakoff moved from NYU to join the physics faculty as associate professors in 1949. With the war years behind them, physicists resumed a vigorous engagement with fundamental scientific issues, armed with fresh ideas and technological advances in instrumentation. Nuclear facilities developed in connection with the war effort produced copious data that cried out for explanation in terms of nuclear models. Feenberg seized the opportunity to gain leadership in reviving the shell model as a viable alternative to the collective (or compound-nucleus) model of Bohr, which had dominated thinking after the discovery of fission and measurements of neutron cross sections at low energy.

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

It is telling that in Blatt & Weisskopf's monumental 1952 text *Theoretical Nuclear Physics*, it was Bethe, Breit, Feenberg, and Wigner who were the winners of the citation contest. Analyzing the new data on isomerism, beta decay, spins, and magnetic moments in the late 40's, Feenberg provided compelling evidence for the validity of the shell model, summarized in his 1955 monograph *Shell Theory of the Nucleus* (written while on leave as Higgins Visiting Professor at Princeton (1953-54)). But he missed one vital point: the existence of a spin-orbit component in the nuclear potential well, which leads naturally to the observed magic numbers for shell closure. Both J. Hans D. Jensen and Maria Goeppert-Mayer got this part right (the idea was actually suggested to Goeppert-Mayer by Fermi). They shared half of the 1963 Nobel Prize in Physics for the nuclear shell model, with Wigner receiving the other half for his work on fundamental work on symmetries in quantum mechanics.

In retrospect, the magnitude of Wigner's multifaceted achievements warranted an *unshared* prize, and Feenberg, for his pioneering work both before and after WWII, deserved a share of the shell-model award. This circumstance may be the origin of Gene's incisive observation, "Any physicist who misses a chance to be magnanimous is a fool." This statement, which we should all take to heart, is a poignant reflection of Eugene Feenberg's stoicism, dignity, and generosity.

8. A Man of Few Words — But Many Ideas

Feenberg and Primakoff shared an office at Washington University, face-to-face with their desks pushed together in the middle of the room. This proximity led to some highly original and imaginative science. With Compton a Washington University "franchise player" (the original Compton experiment was performed on the WU campus in 1922), and with Arthur Holly physically present either as Chancellor — and later as Professor-at-Large — it was natural for Gene and Henry to propose and analyze the *inverse* Compton effect (protons and electrons scattering off photons). The result was a truly classic 1948 paper in *The Physical Review*. Inverse Compton scattering is now a staple of high-energy astrophysics. Another idea they put forward in 1946 (pre-Bodmer, very pre-Witten) is that nuclei are metastable and can collapse into abnormal, superdense matter.

Modest and thoughtful, Eugene Feenberg was a quiet man of few but well-chosen words, which could be filled either with wisdom or humor (or both). Conversation with him could be somewhat halting, as he tended to ponder deeply and at length, especially when a scientific matter was under discussion. Accustomed to this trait, I took some malicious pleasure in watching the obvious discomfort of visitors, when Gene lapsed into silence extending to minutes, before speaking directly to the point.

Many of us have had the experience of being interviewed by an FBI agent (or other government official) in the process of security clearance of a scientist known to us. It came to pass that such an agent interviewed Eugene to determine the loyalty and sobriety of Henry Primakoff. Eugene gave brief but reassuring answers to the lengthy series of questions, and, at the end, told the agent, "Dr. Primakoff is really

© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

a very fine man. Would you like to meet him? He's sitting right across from us."

In 1950 Robert Hofstadter drove with his family from Princeton to Stanford, where he had accepted a faculty position. Passing through St. Louis, they visited Eugene and Hilda. During a extended account by Bob of his plans for experiments using his new NaI(Tl) crystals, Gene suggested, "Why not do electron diffraction [on nuclei] like the earlier work on atoms?" This question was the catalyst for Hofstadter's research at Stanford leading to measurements of charge and magnetic moment distributions in nuclei and nucleons, recognized in a 1961 Nobel award.

9. Birth and Youth of CBF Theory

From the early 50's into the middle of that eventful decade, Feenberg's interests were evolving from nuclear structure theory toward something recognizable as modern microscopic many-body theory. The pattern is evident in his elegant papers of this period analyzing different formulations of perturbation theory (with significant precursors in 1948). It was toward the end of this transitional period, in Fall 1956, that I entered the physics graduate program at Washington University, having been attracted by the opportunity of research in nuclear theory under Feenberg's direction.

At that time, Feenberg and Primakoff formed the department's graduate admissions committee. Looking back, I realize that on seeing my application, coming as it did from the University of Texas (UT), Feenberg must have had a sense of *déjà vu*. As Eugene had been, I was a student on a fast track to the B.S. and M.A., and although nearly thirty years had elapsed, I had been taught by some of same professors, most notably Ettlinger and Moore. (Also, the tuition was still $25/semester! The legendary mathematician R. L. Moore continued to teach for another 13 years in his famously crusty Socratic style, until he was forced to retire in 1969 at age 86+. Another curiosity: Feenberg was at UT at the same time my mother studied there, and they probably had the same professor — Romberg — for the general physics course.)

Together, Feenberg and I studied the advances being made in microscopic theories of quantum many-body systems based on methods, diagrammatic and otherwise, borrowed from quantum field theory (Goldstone, Hugenholtz, Hubbard, Bloch & De Dominicis, Pines, the Russian School, ...). We also followed the development of Brueckner's more rough-and-ready reaction-matrix theory, based on resumming ladder diagrams of perturbation theory including medium dispersion in the propagators. (Brueckner visited St. Louis for a week in 1957, giving a series of lectures on his work; the notes were made available in Brueckner's chapter of the 1959 Les Houches Summer School volume on *The Many-Body Problem*.) However attractive these approaches might be, we chose another direction. In view of Feenberg's earlier work, our approach was quite naturally based on a wave-function description in which the most important geometric correlations are included at the outset — arguably a superior strategy when dealing with interactions that feature a strong inner repulsive core. The first paper on what was to become the Method of Corre-

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

Fig. 1. Eugene Feenberg (center) conversing with Joseph Hirschfelder (left) and Richard Norberg (right) in the Pfeiffer Physics Library during the 1974 Washington University symposium celebrating Feenberg's career.

lated Basis Functions (CBF) was published in *The Physical Review* in 1959 — this was in fact the only paper we coauthored.

10. CBF Theory — Halcyon Days

In 1964, Eugene Feenberg succeeded Edward Uhler Condon as the fifth Wayman Crow Professor of Physics. Dating from the 1860's, this is the oldest endowed chair at Washington University, held previously by Compton.

The last two decades of Feenberg's professional life were devoted to the development and application of CBF as a practical and comprehensive scheme for quantitative description of strongly interacting quantum many-body systems. While the main focus of Eugene and his students was on the helium quantum fluids, advances were also made for Coulomb systems. In 1963 I returned to Washington University as a faculty member after postdoctoral study at Princeton and in Europe, and undertook the application of CBF to nuclear problems.

The majority of Ph.D. students supervised by Feenberg during his long and productive career worked on projects in CBF theory. In another case of *déjà vu*, two more Texans followed me from Austin to St. Louis to work with Feenberg: Tollie Davison and H. Woodrow (Woody) Jackson. (This repeated a pattern observed thirty-some years before, with three Texas students following Feenberg's path from Austin to Harvard — Noyes Smith, Charles Fay, and Arnold Romberg's son.) Indeed, quite a collection of talented students were to benefit from Feenberg's guidance and

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html

care as research mentor, including Clayton Williams (from Tulsa; almost a Texan), Fa Yueh (Fred) Wu, William Mullin, Walter Massey, Chia-Wei Woo, Deok Kyo Lee, Hing-Tat Tan, Charles Campbell, David Hall, and Kai-Yaun Chung. (Precursors in the transitional period were Mark Bolsterli and Paul Goldhammer.) After these there are flocks of scientific grandchildren and great-grandchildren, too numerous to list. If postdoc mentoring links are counted, we can include Manfred Ristig, Eckhard Krotscheck, Stefano Fantoni, Klaus Gernoth, and Arturo Polls, among other active figures on the many-body scene. We can all be proud of our heritage, while continuing to honor and preserve Feenberg's legacy in our work.

Feenberg retired in 1975 at the age mandated at that time. In the same year, he was elected to the U.S. National Academy of Sciences. On November 7, 1977, he died of a heart attack suffered while walking home from his office. In his lifetime, he had been to Europe only three times. He was looking forward to attending the *First* International Workshop on Recent Progress in Many-Body Theories, scheduled for Trieste in 1978. The meeting was dedicated to his memory, and the Feenberg Medal for Many-Body Physics was established at RPMBT3 in 1983.

11. Conclusion

If Eugene were able to read the above narrative of his life course, he would be embarrassed by the praise, but show his appreciation by variously telling us to "Tend to your knitting!," and, in Texan vernacular, "Come back full of beans!"

I close with a short message to the 2007 Feenberg Medalists, Stefano Fantoni and Eckhard Krotscheck:

> At the Centenary of Feenberg's birth, no two theorists could better represent his legacy and realize his aspirations.

Acknowledgments and Bibliographical Notes

I am grateful to the Niels Bohr Library of the American Physical Society's Center for the History Physics, for making available an electronic copy of the Eugene Feenberg Oral History Interview of April 13, 1973, carried out by Charles Weiner. Other valuable resources include the entries for Feenberg and for Robert Hofstadter prepared for the *Biographical Memoirs* of the National Academy of Sciences by the late George Pake and by J. I. Friedman and W. A. Little (www.nap.edu/readingroom/books/biomems/efeenberg and /rhofstadter), respectively. The "tall, rangy Texan" quote is from Daniel J. Kevles' *The Physicists: The History of a Scientific Community in Modern America* (A. A. Knopf, New York, 1978). The obituary by K. A. Brueckner, J. W. Clark, and H. Primakoff in *Nuclear Physics A* **328**, 1 (1979) includes an (almost) complete listing of Feenberg's publications.

RECENT PROGRESS IN MANY-BODY THEORIES - Proceedings of the 14th International Conference
© World Scientific Publishing Co. Pte. Ltd.
http://www.worldscibooks.com/physics/6690.html