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Chaim Leib Pekeris

June 15, 1908–February 24, 1993

By Freeman Gilbert Haim

CHAIM LEIB PEKERIS WAS born in Alytus A, Lithuania, on June 15, 1908. His father, Samuel, owned and operated a bakery. His mother, Haaya (née Rievel), was an intellectual and propelled Pekeris to excel. The family home was located at 4 Murkiness Street, near the corner with Ozapavitz Street. His older brother died at birth, a very sad event that led his parents to select the name Chaim, meaning life in Hebrew, for their second son. They added Leib, meaning life in Yiddish, for good measure. He was followed by four siblings, Rashka (Rachael), Jacob, Zavkeh (Arthur), and Typkeh (Tovah). The family name, Pekeris, is derived from the earlier name, Peker. Lithuanian authorities required the suffix, -as or -is, be added to the original name.

At a very early age Chaim exhibited his brilliance. By the age of 16 he was teaching mathematics at his high school and coaching 12-year-old boys how to prepare for the bar mitzvah. He was strongly encouraged to become a Talmudic scholar and a rabbi, but both he and his parents refused. By great good fortune one of Chaim's uncles, Max Baker, had emigrated from Lithuania to the United States and had settled in Springfield, Massachusetts. He was successful in the furniture business and was able to help Chaim and his two brothers to come to the United States for their continuing education. In addition, the prominent New England merchant and philanthropist, Edward Max Chase, came to the assistance of the Pekeris brothers. He, too, was an immigrant from Lithuania. He provided the young men with immigration affidavits, helped them find employment, and paid some of the tuition expenses.

The two brothers and Chaim, too, became U.S. citizens. Jacob, the older of the two younger brothers, became a teacher and spent the rest of his life in New England. He died at the young age of 31. Arthur became a specialist in agricultural products and settled in Denver, Colorado. Rachael, the older of the two sisters, became a Zionist and went to Israel (then Palestine) in 1935. Tovah, the younger of the two sisters was murdered by anti-Semitic townspeople in Alytus A, as were the parents, during the Holocaust. Furthermore, the family home was destroyed sometime during World War II.

Pekeris, as he was called by all but his most intimate friends, entered the Massachusetts Institute of Technology in 1925. At first he majored in mathematics but changed to meteorology and graduated with a B.Sc. degree in 1929. At that time meteorology was just being established at MIT, and it was a program administered in the Department of Aeronautical Engineering in the School of Engineering. Pekeris stayed at MIT for his graduate studies and became a student of Carl-Gustav Rossby. He graduated with his doctoral degree in 1933. It was the custom at MIT before World War II that doctoral graduates in the School of Science receive the Ph.D. degree and those in the School of Engineering receive the Sc.D. degree; thus, Pekeris received his Sc.D. The title of his Sc.D. thesis was "The Development and Present Status of the Theory of the Heat Balance in the Atmosphere." It was not published, but it was circulated in the form of informal class notes (MIT Meteorology Course No. 5, 1932).

During his time as a graduate student Pekeris won a Guggenheim Fellowship and studied in Oslo with some of the eminent meteorologists of the era. He was also an assistant meteorologist at MIT. Upon graduation he accepted an appointment as assistant geophysicist in the Department of Geology at MIT. In 1934 he published in meteorology but finished the year with a paper on the inverse boundary problem in seismology. For the rest of his career Pekeris seldom published on subjects in meteorology except classical fluid mechanics. Pekeris won a fellowship from the Rockefeller Foundation in 1934 and participated in academic travel and visits for the next two years. At this time Pekeris married Leah Kaplan. They had no children.

Louis B. Slichter joined the faculty at MIT just as Pekeris was completing his doctoral degree. Slichter had been a geophysical prospector in the 1920s but his company, Mason, Slichter and Gould, went bankrupt as prices for metals collapsed. Slichter had a Ph.D. in physics from the University of Wisconsin, but he returned to graduate school at the California Institute of Technology as a special student. After completing his studies in applied mathematics under the supervision of Harry Bateman, he joined the faculty of MIT to establish a program in geophysics. Pekeris was his first hire and was soon followed by Norman A. Haskell, a recent Ph.D. from Harvard. With these two appointments Slichter had established a strong program in geophysics at MIT.

For the second half of the decade of the 1930s Pekeris established his reputation in theoretical geophysics and made creative contributions to astrophysics and hydrodynamics. The debate about what was then called continental drift was in full bloom. R. A. Daly at Harvard opined that the mantle of Earth flowed at very long time scales. He persuaded N. A. Haskell to conduct a theoretical study of the uplift of Fennoscandia, a study that provided the first, and very accurate, estimate of the viscosity of the upper mantle. At the same time Pekeris published his study of thermal convection in the interior of Earth. Thus, well before World War II two young scientists had established part of the theoretical foundation of what would become the theory of plate tectonics.

In this period Pekeris published on oscillations of the atmosphere and of stars. This latter work was a precursor to his studies of the free oscillations of Earth some 20 years later. As the world entered World War II Pekeris began his work on the propagation of pulses and on the inverse problem of electrical resistivity. The former became important in the development of research in sonar and infrasound and the latter was, of course, commercially applicable as well as being intellectually stimulating. Pekeris's great productivity led to his promotion to associate geophysicist at MIT in 1936.

There is ample evidence that Pekeris was an avid reader of the literature on the propagation of pulses and waves; for example, he practically memorized the famous paper by Horace Lamb, "On the Propagation of Tremors over the Surface of an Elastic Solid" (Philosophical Transactions of the Royal Society A 203(1904):1-42). In 1939-1940 the signature card for that volume at the MIT Library was signed "C. L. Pekeris" every two weeks for several months. The paper led to Pekeris's work on synthetic seismograms in the 1950s and later. It is the key to his terse abstract in Transactions of the American Geophysical Union in 1941.

From 1941 to 1945 Pekeris was involved in military research, then unashamedly called war research. He worked as a member of the Division of War Research at the Hudson Laboratories of Columbia University, devoted to studies of acoustic pulse and wave propagation. In the years 1945-1950 he was the director of the Mathematical Physics Group. During that period he also had an appointment at the Institute for Advanced Study. Shortly after the war, Pekeris's wartime research was recognized by the U.S. Navy with the title of honorary admiral.

Following the war Pekeris's research productivity reverted to its former pace in both volume and quality. Yet science was not his only activity. In late 1945, after the end of the war and for a few years thereafter, there was a flood of surplus military equipment. In the United States and Canada supporters of the formation of a State of Israel, and Pekeris was one of them, formed a network of bankers, businessmen, farmers, shippers, engineers, and scientists. They would acquire the surplus equipment, move it to a "hachsharah" farm, recondition it, and ship it to a port near Palestine, such as Beirut, and deliver it to the Haganah units of the soon-to-be renamed Israel Defense Force. All of this completely clandestine work was done with seeming legality in every phase.

In the 1940s, as he reentered academic life following the war, Pekeris published several studies of microwave propagation and began his work on atomic physics. There are two publications that are preeminent. Both appeared in 1948. The first is the long paper on the propagation of explosive sound in shallow water. Pekeris considered the problem of a fluid layer overlying a fluid half-space of greater sound velocity. He provided a very thorough analysis of the normal modes of propagation, including a most penetrating study of dispersion. Later work on the propagation of dispersed seismic waves at both Columbia and at Caltech relied heavily on Pekeris's excellent memoir. That publication, Memoir 27 of the Geological Society of America, is one of the top two of his most cited papers.

The second paper, on the stability of flow in a circular pipe, was published in the Proceedings of the National Academy of Sciences. For decades it had been known from experimental studies that instability occurs at a Reynolds number of about 2000, but there was no quantitative explanation. Pekeris supplied the formal, quantitative derivation of the critical Reynolds number. This was a major contribution.

After the establishment of the State of Israel in 1948, the first President, Chaim Weizmann, asked Pekeris to come to the Weizmann Institute of Science and to be the founder of its Department of Applied Mathematics. Pekeris negotiated with the institute to build a digital computer for the new department. He then agreed to join the institute and moved to Rehovot in 1950. The computer was called WEIZAC (WEIZmann automatic computer).

The WEIZAC was built during 1954-1955. It is an early example of successful technology transfer, with the design of the von Neumann machine moving from the Institute for Advanced Study to the Weizmann Institute of Science (WIS) in Rehovot. WEIZAC's existence, its intense application to physical problems, and the cadres trained in digital hardware, software, and computational methods opened a market of concepts and practices outside the United States and Europe. The primary ostensible reason to build WEIZAC was to solve Laplace's tidal equations for Earth's oceans with realistic geographical boundaries. Pekeris insisted, however, that the entire scientific community of Israel, including the Defense Ministry, should have access to the WEIZAC.

One of Pekeris's first activities in Israel was the organization and management of Israel's first geophysical survey. This activity led to the discovery of oil near Heletz, northwest of the Negev. It also led to the establishment of the Institute of Petroleum Research and Geophysics.

Pekeris was constantly active in attracting graduate students to his department. He would visit other institutions of higher education in Israel, especially those having undergraduate studies, looking for bright students interested in higher degrees. He also toured centers for immigrants, bringing some of them to WIS to study for higher degrees, others to do alternative work such as becoming programmers. As a consequence of Pekeris's energetic activity, he and his department had a constant stream of excellent graduate students during his tenure as chairman.

Several of Pekeris's Ph.D. graduates became members of the faculties of Israeli universities, including WIS. Many stayed in geophysics or atomic physics and some entered other fields; for example, in the early 1960s Pekeris visited the Technion and met Amir Pnueli and persuaded him to do his Ph.D. at WIS on Earth's tides. Pnueli was more interested in compilers and other matters in computer science than tides and, with Pekeris approval and assistance, he went to Stanford as a postdoctoral fellow to work with Zohar Maneh. He is now a professor at WIS in the department that Pekeris founded. He received the Turing Award of the Association for Computing Machinery in 1996.

During his transition from the United States to Israel Pekeris published his first research note on the ground state of helium (1950). The foundation for this work was a series of papers in the late 1920s by E. A. Hylleraas who used a variational formulation for the energy levels. The wave functions are represented as a series of test functions or basis functions. The variational principal leads to a matrix of integrals of squares and cross-products of the basis functions and the eigenvalues of the matrix are upper bounds (by virtue of Rayleigh's principle) of the energy levels. The ground state is increasingly better approximated as the number of basis functions increases.

Pekeris was elected to the National Academy of Sciences in 1952. Shortly thereafter he visited the University of California, Los Angeles, where Louis Slichter had become director of the Institute of Geophysics. Just after World War II, Slichter and Rossby had tried to establish a geophysical institute at MIT, but administrative resistance led Rossby to go to the University of Chicago to found the Department of Geophysical Sciences. Slichter went to UCLA to become the first permanent director of the Institute of Geophysics. One of his first hires was Leon Knopoff, a recent Ph.D. in physics from Caltech, who had read Pekeris's 1941 extended abstract in the Transactions of the American Geophysical Union. Pekeris had claimed to have solved exactly the problem of the propagation of a seismic (SH) pulse near a boundary separating two media. Leon asked, "How did you do that?" Pekeris replied, " I don't remember." But he quickly refreshed his memory and published two pathway papers in 1955 on the propagation of seismic pulses. This work was to be the beginning of several papers and Ph.D. theses in theoretical seismology.

At the same time Pekeris returned to his early work on the nonradial oscillations of stars and began to extend that work to the free oscillations of Earth. Early work with Hans Jarosch and subsequent work with Zappora Alterman led to what has become the canonical formulation of the problem. After separation of variables, the ordinary differential equations are not combined into wave equations. Rather, they are left in first-order form. This is ideal for numerical calculations and allows the use of the matrix theory explicated by F. R. Gantmacher, in particular the theory of compound matrices. The great earthquake in Chile on May 22, 1960, soon gave Pekeris and his colleagues real data. No longer was the subject fit only for theoretical and computational seismology. It had become a major branch of observational seismology, too. Pekeris coined the term "terrestrial spectroscopy" for the new subject. The State of Israel issued a commemorative stamp.

As the 1950s drew to a close Pekeris and his students entered a new area of theoretical seismology, to compute synthetic seismograms for layered media by using generalized ray theory. There is some analogy with the "rainbow expansion" of B. Van der Pol and H. Bremmer. A formal expression of the wavefield can be done in the form of so-called generalized rays, each of which must be evaluated by methods stated in his 1941 abstract and more clearly developed in the Proceedings of the National Academy of Sciences papers (1955). Yet, in a fundamental way, it all goes back to H. Lamb in 1904. The use of generalized ray theory iscomputationally very intensive and the use of WEIZAC, and subsequently the more powerful GOLEM, was crucial to the success of the effort. WIS built GOLEM I in 1964 and GOLEM II in 1972. Golem is the Hebrew word for "shapeless man" and comes from a legend about Rabbi Loew in Prague in the sixteenth century, who is said to have made a golem from a lump of clay. In computer science the golem is a symbol for artificial intelligence.

In 1958 Pekeris published his fundamental paper on the ground state of two-electron atoms. That paper is the second of the top two of his most cited papers. The second major computational paper on the lower energy states of helium appeared in 1959. By using more than 1000 basis functions in the variational formulation Pekeris was able to obtain very accurate upper bounds for the lower energy states. Experiments at Brookhaven National Laboratory confirmed the computational results. This work would occupy his interests from time to time for the rest of his life.

In the Cold War years many Jews were still living behind the Iron Curtain. Many of Pekeris's distant relatives were in this category, as were those of his colleagues. Exit visas could be obtained, but the cost was prohibitive for most would-be émigrés. Pekeris and his wife were untiringly selfless in helping many of these people to leave Eastern Europe and to come to Israel.

In the decade of the 1960s there were more papers about the lower energy states of helium and lithium and the beginnings of a series of papers on Laplace's tidal equations. Pekeris was the first to solve, numerically, these equations for the world's oceans (1969). Prior work had used unrealistic boundaries, such as meridians and parallels, in order to achieve results analytically. Pekeris used the analytical results to verify his codes and then moved on to the realistic boundaries of the major ocean basins. There were initial problems with some of the amphidromes (they went the wrong way), but the use of observed boundary conditions led to a more successful result.

By the early 1960s Pekeris had a superb international reputation in theoretical and computational geophysics. He was a major participant in the first meeting of the Committee on Geophysical Theory and Computers (in 1964 in Moscow and Leningrad) and was the host for the second meeting the following year in Rehovot. In addition to his major contributions to the study of Earth's tides, Pekeris had renewed his interest in geophysical inverse problems, and this subject was one of the themes of the meeting. The Committee on Geophysical Theory and Computers was sponsored by the International Union of Geodesy and Geophysics.

Pekeris took mandatory retirement at age 65 in 1973. By that time the Weizmann Institute of Science had established a Faculty of Mathematics and Computer Science that included the Department of Mathematics and the Department of Computer Science and

Applied Mathematics. Pekeris was considered to be the founding father of that faculty.

As a widely respected senior scientist Pekeris began to receive formal recognition for his many contributions and accomplishments. He was elected a foreign member (socio straniero) of the Accademia Nazionale dei Lincei in 1972, and he received the Vetlesen Prize of Columbia University in 1974. Unfortunately, his wife, Leah, died in 1973, just as the awards and honors were beginning to occur. In 1980 the Royal Astronomical Society awarded him its Gold Medal and in 1981 the State of Israel granted him the Israel Prize.

By 1990 the Committee on Geophysical Theory and Computers had been renamed the Committee on Mathematical Geophysics, computers having become so ubiquitous. The meeting that year was held in Jerusalem to honor Pekeris for his many excellent contributions. At the closing banquet the speaker was Teddy Kollek, the mayor of Jerusalem. Kollek had been born in the Hungarian village of Nagyvaszony in 1911 and had visited Palestine in 1934. In the years just before the founding of the State of Israel he was active with the Haganah, just as Pekeris had been active in supplying that group. In his speech Kollek reviewed Pekeris's career, lauded him for his accomplishments both scientific and administrative, and closed with the remark, "I have told you a lot about Chaim Pekeris tonight and there is much more that I could tell, but you will understand that there are reasons that I can't. Let me simply say that Chaim Pekeris played a most significant role in the establishment of the State of Israel."

On February 25, 1993, Chaim Pekeris fell on the stairs of his home in Rehovot and died from the trauma of his injuries. He was hailed as a major figure in the physical sciences and in the history of the State of Israel. The following year the Faculty of Mathematics and Computer Science of the Weizmann Institute of Science established the Pekeris Memorial Lecture, which is presented annually.

THE MATERIAL in the memoir has come from many sources. The Web site (http://itzikowitz.20m.com/Index.html) maintained by Jacob Itzikowitz, a nephew of Pekeris's, has been informative. Discussions with Professor Walter Munk about C.-G. Rossby and about the stability of flow in pipes were helpful, as well. Samuel Itzikowitz, also a nephew, kindly provided the photograph. Professor Lee Segel of the Weizmann Institute of Science provided most of the bibliography. In particular, I am most grateful to Professor Flavian Abramovici of Tel Aviv University for assistance with family history, activity at WIS, and with the bibliography. My wife, Sarah, was very helpful with matters of grammar and style.

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