Biographical Notes

ALLISON, Samuel K. (1900–1965), a Harvard graduate student under Duane at the Jefferson Laboratories, was present at the time of Compton's unsuccessful demonstration. He subsequently had a long association with Compton and became his co-author in a widely used book on x rays. He became Compton's trusted man in the Metallurgical Laboratory and in other enterprises; he was Enrico Fermi's close friend. Allison was the responsible associate director (to Robert Oppenheimer) of the Los Alamos Laboratories and later became director of the Institute of Nuclear Studies of the University of Chicago.

ANDRADE, Edward Neville da Costa (1887–1971) was born in London to a Portuguese-English family; he was a graduate of the University of London, studied at Heidelberg under Phillip Lenard, worked at Cavendish under J. J. Thomson and with Rutherford at Manchester. He later became Senior Research Fellow, Imperial College of Science, London. He was a distinguished writer and poet; he authored a chapter of reminiscences of his Manchester years in a book edited by Birks[33] and published several books on atomic physics.[16]

ARMSTRONG, Alice Hall (1897–?), a graduate student under Duane, was subsequently a research worker of the Rockefeller Institute (Ph.D., 1930); taught physics at Wellesley College, Massachusetts. She did underwater sound research and joined the Los Alamos Laboratories in 1950 until her retirement in Santa Fe, New Mexico in 1964.

BARKLA, Charles Glover (1877–1944) was born in Widnes, Lancastershire, England; he received his Master of Science degree in Liverpool in 1899. Barkla did his first research work at the Cavendish Laboratories. He was elected to Fellowship in the Royal Society in 1912 and was appointed Professor of Natural Philosophy at the University of Edinburgh in 1913; he received the Royal Society's Hughes Medal and the Nobel Prize of Physics (1917) for his work on characteristic radiations. Barkla delivered the Bakerian Lecture in 1917 and spoke of his discovery of a new series of characteristic radiations of shorter wavelength that he called the *J series*; Duane was unable to verify their existence. Others referred to them as the *J phenomenon*. Barkla also had difficulty accepting Compton's findings. A religious man and a fine basso, Barkla contributed the wealth of his voice to the Methodist Church choir. He had four children, two of whom became physicians; the youngest of these died in the Second World War. In October 1944, aged 67, Barkla died suddenly.

BLAKE, Frederic Columbus (1877–1956), a Harvard graduate student under Duane. He became professor of physics at Ohio State University with tenure until 1946.

BORN, Max (1882–1970) was born in Breslau; he received his Ph.D. from the University of Göttingen in 1907. He taught theoretical physics at Göttingen from 1921 to 1936, at the height of the institution's influence. From 1936 to 1953, he taught at the University of Edinburgh; he retired to Göttingen in 1953. A guiding light and a consultant to innumerable outstanding physicists, Born was the author of several books and numerous articles, including a few on the responsibilities of scientists. He received the Nobel Prize in 1954 for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wave function. He died in 1970.

de BROGLIE, Duke Louis Victor Pierre (1892–1962) was born in Paris and received his Sc.D. degree at the Sorbonne (1912). In 1929 he received the Nobel Prize for his "discovery of the wave nature of the electrons." He was professor in the Faculty of Sciences of the University of Paris from 1932 to 1962. He also received the United Nations Kalinga Prize.

CALDWELL, Eugene Wilson (1870–1918), born in Savannah, Missouri, a graduate of the University of Kansas (1892), was one of the pioneers of radiology in the U. S. A physicist, he designed numerous tubes, including one for intracavitary radiotherapy; he also developed the first motorized tilting table for radiodiagnosis, an electrolytic interrupter, and numerous other gadgets for practical uses of x rays. With Pusey, he collaborated in an early book on *The Roentgen Rays in Therapeutics and Diagnosis* (1903). His medical inter-

est led him to obtain an M.D. degree from the Belleview Medical College of New York. He developed cancer of the skin of his hands. Caldwell is memorialized in an annual lecture of the American Roentgen Ray Society.

CLARK, George Lindenberg (1882–1968), a Ph.D. in chemistry from the University of Chicago, was a collaborator in numerous papers of Duane's; after his work at Harvard, he became professor of applied chemistry at the Massachusetts Institute of Technology. Clark authored a book on applied x rays[94] that went through four editions. In 1927 he joined the University of Illinois at Urbana; he became professor of analytical chemistry. He published a great number of papers and sponsored dozens of Ph.D. theses before he became professor emeritus in 1960.

COMPTON, Karl Taylor (1887–1954) was the oldest of the Compton brothers; he taught at Reed College in Portland, Oregon and then for 15 years at Princeton University. In 1913 he married Rowena Rayman (–1919). In 1921 he married Margaret Hutchinson. In 1930 he went to M.I.T. and became its president. In World War II, he worked on the National Defense Research Committee. In 1948 he was chairman of the Research and Development Board for National Security, succeeding Vannevar Bush.

COMPTON, Mary Elesa (1889–1961) made a better college record than any of her three brothers. She became engaged to Charles Herbert Rice and traveled to India to marry him (1913). Rice taught at Forman Christian College in Lahore and became principal of Ewing Christian College in Allabahad. The Rices spent 40 years as missionaries in India and lived the drama of the country's partition. Rice became vice-Chancellor of the University of Punjab.

COMPTON, Wilson Martindale (1890–1967) graduated as his brothers from Wooster; he considered a career in medicine but decided to study economics at Princeton. He taught economics at Dartmouth then went to work for the National Lumber Manufacturers Association; he had a hand in the development of a new technology in lumber engineering. He was a born diplomat and made a reputation in Washington as a spokesman for the lumber industry. He married Helen Harrington of Reedsburg, Ohio. In 1944 after many years away from academia, he became president of the Washington State University (1944–1951). He was president of the Council for Financial Aide to Education (1955) and spoke at Wooster College at the dedication of Otelia Compton Hall. The last survivor of his siblings, he spoke at Princeton upon the dedication of the Compton Court.

COOLIDGE, William David (1873–1975) was born in Hudson, Massachusetts, the son of a shoemaker. He graduated from Hudson High School and registered at Boston Tech (later M.I.T.) in electrical engineering and later took a position there as assistant in physics. He went on a scholarship to Leipzig, where he stayed two years and obtained his Ph.D. (1898). He returned to a position in physics at M.I.T. In 1905 he was offered a position at the General Electric Research Laboratories in Schenectady, New York. Working in lamp research, he found that sintered filaments of tungsten will lose their brittleness if passed through a rolling mill with heated rolls, a discovery that advanced the efficiency of light bulbs. Using hot tungsten filaments in high vacuum x-ray tubes, Coolidge developed the first stable x-ray source, which greatly expanded its medical uses in diagnosis and radiotherapy. During the Second World War, Coolidge was appointed to President Roosevelt's Advisory Commission on Uranium. During his long career, he received innumerable awards.

DEBYE, Peter Joseph (1884–1966) was born in Holland. He was a student and later an associate of Sommerfeld in Munich. He did his work on scattered radiation while at the Technological Institute of Zurich. In 1935 he became director of the Kaiser Wilhelm Institute of Berlin. In 1936 he received the Nobel Prize of Chemistry for his studies of diffraction of radiations in gases and of molecular structure through dipole moments. In 1940 he became professor and chairman of the Department of Chemistry at Cornell University in New York, where he taught until 1950, when he became Professor Emeritus.

DESSAUER, Friedrich (1881–1963) was born in Aschaffenburg, Germany, scion of a family of industrialists and an early manufacturer of x-ray equipment (Veifa works). He developed a high voltage generator with an original concept respecting the transformer (cascade). He became a Ph.D. at the University of Frankfurt am Mein, abandoned the commercial activities, and dedicated himself to the pragmatic development of radiotherapy. He became a deputy of the Reichstag and was a leader of the Catholic Centrum Party. He was obliged to leave Germany and took refuge first in Turkey, and later in Switzerland, where he continued his professional work. He was a prolific writer and published books on philosophy. In 1953 he returned to Frankfurt. Two of his sons became American citizens.[325] The University of Rochester, New York has a lectureship in his memory.[317]

DIRAC, Paul Adrian (1902–1984) was born in Bristol, England. Intending to study engineering, he received his B.Sc. from Bristol University (1921). He then turned to physics and received his Ph.D. from Cambridge University (1926). He was an assiduous member of the Kapitsa Club. His work on the quantum theory of the emission and absorption of radiation[153] brought harmony to the wave and light quantum descriptions

of the interaction of the atom and the field. Dirac also predicted the existence of positrons. He was a visiting professor at the universities of Wisconsin and Michigan (1929) and at Princeton University (1931). He became Lucasian Professor of Mathematics at Cambridge University (1932). He shared the Nobel Prize of Physics (1933) with Schrödinger for their discovery of new forms of atomic theory. A taciturn, deep thinker, Dirac was the target of innumerable humorous stories among his colleagues. He married Margit Wigner (1937) of Budapest, the sister of theoretical physicist Eugene Wigner. He received the Royal Medal of the Royal Society of London (1939). He was a member of the Institute of Advanced Studies at Princeton University (1948–49), received the Copley Medal of the Royal Society (1952) and became member of the Pontificial Academy of Sciences (1961). Since 1971 he was professor of physics at Florida State University in Tallahassee, Florida and spent his summers at St. John's College, Cambridge.

DUANE, William, Jr. (1900–1962) was the oldest son of William Duane; he was a 1927 graduate of the University of Pennsylvania, became a neurosurgeon and served in the U. S. Army Medical Corps in the Second World War. ARTHUR RAVENEL DUANE (1901–1928) had brilliant beginnings as a scientist; during a visit to her home, Mme. Curie noticed signs of anxiety in the young man ("il était inquiet...il est parti sans lesser d'addresse"). He had become mentally ill and died prematurely under strange circumstances. PRIOLEAU DUANE (1909–1967) changed his first name officially to JOHN in North Carolina. MARGARETTA CLARISSA DUANE, Mrs. Richard D. Wood, is the only surviving child; she revels in the memory of her father and brilliant brothers in Hurricane Hall in Wawa, Pennsylvania.

EHRENFEST, Paul (1880–1933) was born in Vienna and studied under Boltzmann; in 1904 he received his Ph.D. degree. He married a Russian mathematician (Tatayana Alexeyevna) and went to teach at Saint Petersburg. In 1913 he was appointed to succeed Lorentz in Leyden, where he remained for 20 years. In 1919 he met Bohr, and they became life friends. An Einstein confidant and frequent visitor of the Copenhagen institute, he had a keen critical mind and had given himself to abstract pursuits, such as the theory of adiabatic invariants, a generalization of relativity and quantal ideas. Always ready to rise to the occasion, he had impromptu encounters as the one at the Fifth Solvay Conference (1927), where there was furious disagreement in various languages, he wrote on the blackboard "The Lord did there confound the language of all the earth." Ehrenfest was Faust to Pauli's Mephistopheles in Gamow's parody.[214] He committed suicide in 1933. "None of us who were his students"—wrote Oppenheimer—"shall be quite free of guilt in this his desperation."[375]

FOURIER, Baron Joseph B. (1768–1830), a French mathematician, was the author of Fourier's theorem (1812); "...any single-valued periodic function of time can be expressed as a summation of a simple harmonic series having frequencies which are simple multiples of that of the given series."

FOWLER, Peter Howard (1923–), Rutherford's eldest grandchild, is Professor of Physics at the University of Bristol. He was among the first to point at the radiotherapeutic potential of pi-mesons.

FRISCH, Otto Robert (1904–1979) was born in Vienna and received a Ph.D. from its university (1926). His mother was a concert pianist and teacher; his father was a fine printer and publisher. He worked briefly for Siegmund Strauss, the developer of Mekapion, one of the earliest commercial ionization integrometers for radiotherapy. Subsequently, he worked for the Physikalisch Technische Reischsanstalt (Bureau of Standards) in Berlin. Through his aunt, Lise Meitner, and his attendance of the weekly university colloquia, he met Einstein, Planck, and Otto Hahn. In 1933 he accepted a job at the Birbeck College in London; there he was personally offered a position by Bohr. "The Almighty Himself has taken me by the waistcoat, and spoken kindly to me"—wrote Frisch to his mother. He remained single and played the piano for relaxation. He worked in Copenhagen until 1939, the year in which he made his experimental verification and coined the word *fission*. He went to England and worked under Mark Oliphant at Birmingham, where he was the houseguest of Genia and R. E. Peierls. Having studied Bohr and Wheeler's paper (1939),[60] Frisch and Peierls submitted in three pages a remarkably perceptive report to the M.A.U.D. Committee with an extraordinarily close estimate of the U-235 fission cross section[329]; the report included estimate of effects on human populations, radiation contamination of ground areas, etc.[219] From 1940 to 1943 Frisch worked under James Chadwick at Liverpool. In 1943 he went to Los Alamos as part of the British contingent. He eventually headed a group concerned with the assembly of the uranium bomb. After the war, he became Deputy Chief Scientific Officer at the Atomic Energy Research Establishment at Harwell, England. In 1951 he married Ursula Blau. Called upon by William Lawrence Bragg, he became Jacksonian Professor of Natural Philosophy and spent the last years of his professional life at the Cavendish Laboratories; he wrote a charming little volume of his reminiscences, shortly before his death.[212]

GAMOW, George (1904–1967), a native of Russia and a graduate of the University of Leningrad (1928); he spent a summer at Göttingen studying atom theory. Gamow did notable work in quantum mechanics. Bohr offered him a fellowship, and he remained in Copenhagen for one year. In 1933 he left the Soviet Union per-

manently and spent time in Paris, Copenhagen, and Cambridge. In 1934 he took a newly created position at George Washington University in Washington, D.C. With his Copenhagen co-worker, Edward Teller, he hosted in 1938 the Washington Conference on Theoretical Physics at which Bohr made the historical announcement of a successful nuclear fission in Germany. Gamow was a tall, fair-haired man with a fertile imagination and permanent tongue in cheek; he wrote didactic popularizations and humorous plays as well as verses that are gems in the annals of nuclear physics. In 1956 he became a member of the faculty of the University of Colorado; he has been properly memorialized by the handsome Gamow Tower on the Boulder campus.[27]

GEIGER, Hans Wilhelm (1882–1945) was a native of Neustadt, Germany and a graduate of the University of Erlangen. An excellently trained and well-rounded physicist, he worked with Schuster and later with Rutherford. Geiger was a lover of good music, a gourmet for food, and a glutton for work. After six years in Manchester, he returned to Germany (1912) and became member of the Physikalische–Technische Reichaustalt in Berlin; he also taught at the Universities of Kiel and Tübingen.

GOUDSMIT, Samuel Abraham (1902–1978) was born in The Hague, Netherlands and received his Ph.D. from the University of Leyden in 1927. He was professor of physics at the University of Michigan (1932–1946). During the Second World War, he became part of the ALSOS mission, consisting of 32 scientists and 7 agents. Goudsmit proved a capable scientific intelligence officer; ALSOS collected considerable advance information and sought in Italy, France, Belgium, Holland, and Germany any leads to European nuclear research. In Brittany and Paris, Goudsmit sought and interviewed Joliot[329]; in Belgium, information was obtained on shipments of uranium to Germany. In the early days of the occupation of Germany and ahead of French troops, the ALSOS agents captured Otto Hahn (1879–1968) and Max Theodor Felix von Laue (1879–1960) in Tailfingen in the Black Forest (20 miles south of Tübingen); Heisenberg was captured in Urfeld. Half a ton of uranium cubes, found buried outside Haigerloch (Würtenberg), were expeditiously barreled and, together with containers of heavy water, shipped out. The German scientists were flown to England, where they were capably interrogated and detained.[218] During their internment, they were informed of the atomic bombardment of Japan; their initial incredulity turned to mutual reproaches.[222] After the war, Goudsmit resumed scientific work at the Brookhaven National Laboratories in Long Island, New York; he was awarded the Medal of Freedom and the Max Planck Medal of the German Society of Physics.

GRUBBÉ, Emil Herman (1875–1960) was born in Chicago (West 31st St.); he was the son of Bertha Reetz, a nurse, and of Albert Grubbé, a merchant sailor, both of whom emigrated from the Baltic coast of Germany to Chicago in 1870. Emil graduated in Pharmacy (1895) from the Northern Indiana Normal School and established himself as a metallurgist and chemical essayer; he opened a small shop in an alley room in the back of a stationery store in 12 Pacific Avenue (now La Salle Street) and dealt with prospectors in Iowa and Colorado. He also registered as a student and was an instructor at the Hahnemann Medical College of Chicago. Grubbé associated himself with an expert in exhaust pumps and manufactured Geissler and Crookes tubes in his shop. Besides being the first to attempt radiotherapy of cancer, Grubbé developed what was probably the first x-ray facility in Chicago, at the Hahnemann Hospital (1896). He became Professor of "Electrotherapeutics and X-rayology" and owned the Illinois X-ray and Electrotherapeutic Laboratory, at 2614 Cottage Grove Avenue; wrote various articles some of which were repeatedly printed in minor publications; notable among these is a report on the treatment of 139 cases of cancer of the skin emphasizing fractionation and the need for a total dose capable of causing a strong reaction. Grubbé's hands and face became the site of numerous carcinomas of the skin; he suffered repeated amputations and died with metastases. A gruff short-tempered man, Grubbé had few friends; an inveterate mythomaniac, he discredited himself by unwarranted claims. He bequethed his fortune to the Medical Society of Chicago for the purposes of supporting training in therapeutic radiology, to establish a lectureship, to award a gold medal in his name, and to publish his biography. (Dr. R. Ludlam's letter of referral of Mrs. Rose Lee to Grubbé, dated January 28, 1896, is preserved in the Archives of the Smithsonian Institution.)[232]

von HALBAN, Hans, Jr. (1908–1964) was born in Leipzig and was educated in Austria; he received his Ph.D. in Zürich and his training under Irène Curie in Paris and Otto Frisch in Copenhagen. Although an intelligent and capable researcher, he was inflexible and an incurable authoritarian. In 1946 he accepted a position offered by Prof. Lindemann at Oxford, where he proved himself a first-rate nuclear researcher of great originality. In 1955 he returned to Paris as professor at the *Ecole Normale* and director of the Orsay Laboratories. He died November 28th, 1964.

HAVIHURST, Robert James (1900–), a Harvard graduate student under Duane, he became professor of physics at the University of Wisconsin and professor of education at Ohio State University. He subsequently was director of the General Education Board and professor of education at the University of Chicago.

HEISENBERG, Werner Karl (1901–1976) was born in Würzburg, Germany. He received his Ph.D. degree

from the University of Munich in 1925. Following service in Göttingen, he became professor of theoretical physics at the University of Leipzig (1927–1941). In 1932 he received the Nobel Prize. During the war, he became director of the Kaiser Wilhelm Institute in Berlin and was appointed in charge of atomic research. During the earliest days of the occupation of Germany, the U. S. Alsos Mission captured Heisenberg in Urfeld and evacuated him to Heidelberg.[218] Subsequently he was detained at Farm Hall, in England, in the company of Hahn and von Laue. After the war, Heisenberg became director of the Max Planck Institute in Göttingen (1946–1058). In 1958 he moved to become director of the Planck Institute in Munich, where he died of leukemia in 1976.[31b]

de HEVESY, Georg Charles (1855–1966) was a Hungarian who had worked with Rutherford in Montreal and followed him to Manchester. He was an early supporter of Bohr's theory of the atom, he was invited after the war to join the staff of Bohr's institute in Copenhagen. de Hevesy set out to find the missing element number 72 and, in collaboration with Dirk Coster, was eventually able to identify it spectroscopically; they called it *hafnium* in honor of the ancient name of Copenhagen, where he was to live 20 years. He did pioneer work in "labeled atoms," or tracer elements, which became so valuable in biological research. He received the Nobel Prize of Chemistry in 1943. In 1978 the World Congress of Nuclear Medicine initiated a valuable award in de Hevesy's honor.

HOLZKNECHT, Guido (1872–1931) was born in Vienna and received his M.D. degree from the University of Königsberg (1899). Holzknecht was one of the leading pioneers in the use of medical radiology. Recognizing the need for dosimetry in radiotherapy, he developed a chromoradiometer, the first such device for measuring radiations on a photochemical basis. He adopted a unit, the H-Unit, which was used extensively before iometric means were developed.

HUNT, Franklin Livingston (1886–1972) did work in Cambridge (England), Paris, Berlin, and at the U. S. Bureau of Standards. Duane aroused his interest in radiation spectroscopy; they became co-authors of the Duane–Hunt Law. Hunt worked later for the Bell Telephone Laboratories before his retirement in 1948; he died in Burlington, Vermont in 1972.

KAPITSA, Petr Leonidovich (1894–1984) was born in Krondstadt and became a lecturer at the Leningrad Politechnic Institute; he became a Trinity Fellow (1925) and a Fellow of the Royal Society (1929). With Rutherford's support, a grant of the Royal Society was used for a laboratory building next to Cavendish for Kapitsa's work, the Mond Laboratory. A bas-relief of Rutherford by Eric Gill, commissioned by Kapitsa, became the subject of constroversy; the sculpture was dubbed *The Crocodile* (Kapitsa's pet name for Rutherford); it manifested some of the antagonism created by the enterprising foreigner.[327] Periodically, Kapitsa visited the Soviet Union; in 1934 he was informed that he would not be allowed to return to London. Rutherford's pleading was to no avail (the suggestion was made that in order to continue their joint work, Rutherford should go to Russia also); eventually, the expensive equipment that was his exclusive province at the Mond Laboratory was paid for and shipped to the Soviet Union. In 1978 he received the Nobel Prize for his pioneer work on low-temperature physics.

KOWARSKI, Lew (1907–1979) was born in Saint Petersburg, Russia, the son of a Ukranian singer and a Jewish businessman. He grew to a towering height in Lithuania and Belgium. A graduate of the University of Ghent, he also studied at the Sorbonne. In 1936 he was appointed secretary to Joliot and gradually participated in research to become his scientific collaborator. Originally engaged to work under von Halban, he developed his own capabilities and originality as a nuclear researcher. He was unaffected in his loyalty to Joliot. After the war, he felt dutybound to rejoin his former employer in Paris. Although he would have preferred other work, he built two reactors there. An amiable man with friends everywhere, Kowarski was a visiting professor at the American universities of Purdue, Texas, and Boston. After 1952 he helped form the European Council of Nuclear Research (CERN), a major center of particle acceleration in Geneva. He settled there with his daughter, Irène, and his gentle Kate (Freundlich). He died July 27th, 1979 after long suffering from uremia. His lectures are collected in a volume published shortly before his death (ISBN 2 8288 0006 7).[254]

KUIPER, Gerard Peter (1905–1973) was a native of The Netherlands and received his Ph.D. from the University of Leiden (1933). He was on the faculty of the University of Chicago and also lectured at Harvard as well as the University of California. During the Second World War, he was a member of the special ALSOS Mission, with the rank of colonel. Driving a jeep, he went to rescue the Plancks from the war zone; in spite of the hasty circumstances, the Plancks fetched a bottle of old Rhine wine to offer their rescuer.

LABORDE, Simone (1883–1976) was the wife of Albert Laborde and an extraordinarily capable curietherapist. She was the chief of the Division of Radiumtherapy at the Institut du Cancer, now the Gustave Roussy Institute of Villejuif, in the Parisian banlieu. She devoted considerable time to instruction of young physicians in the delicate techniques of brachytherapy.

LANDÉ, Alfred (1888–1975) was a German physicist and a Ph.D. of the University of Munich. He became a *Privat Dozent* at the University of Frankfurt and pro-

fessor of physics at the University of Tubingen (1922–1931) before coming to the United States. He was professor of physics at Ohio State University, Columbus, Ohio (1931–1975).

LANGEVIN, Paul (1872–1946) was a graduate of the Ecole de Physique et de Chimie and of the Ecole Normale Superieure (1897); he received a one-year scholarship that he used to study at Cavendish Laboratories of London under J. J. Thompson (Fig. IV-2). He did work on the ionization of gases while he continued on his return to Paris[261]; he presented his doctoral thesis at the Sorbonne in 1902. His work on magnetism and the theory of electrons brought him early attention (1905).[262] He was in the faculty of the College of France, and upon Pierre Curie's death, he became director of the Industrial School of Physics and Chemistry. During the First World War, he developed a system for the detection of submarines,[264,265] which is called sonar. He was the outstanding French advocate of the theory of relativity. All his life, he was a defender of the rights of man: of civil rights. Imprisoned during the Nazi occupation, he escaped and later returned to Paris. He died in 1946 and was given a state funeral. His remains were transferred to th Panthéon, where other great men of the French Republic are enshrined.

von LAUE, Max Theodor Felix (1879–1960), born Laue, he added *von* to his name in 1913 when his father was raised to hereditary nobility. He worked in the Physics Laboratories of the University of Munich, under Wilhelm Röntgen, studying diffraction of light waves in gratings. He suggested the experiments using x rays and copper sulphate crystals, which proved the similarity of x rays and light and opened a new vast area of radiation research. He received the Nobel Prize in 1914.

LENARD, Philipp Edward Anton (1862–1947) was an ingenious professor of physics at Breslau when he made his experiments on the transmission of cathode rays through metal foils (1892). He also observed the changing character of electrons bouncing from strips of metal subject to monochromatic light.[268] He received the Nobel Prize (1905) for his work on cathode rays. It is now obvious that Lenard as well as many others were producing x rays but had failed to recognize them as something different. He first acknowledged Röntgen's discovery and admitted that it had brought attention to his own work. Later, he gradually suggested that the discovery was his (see Röntgen, page 9).

MAJORANA, Ettore (1906–1938), a native of Catania, Sicily, was slender, dark skinned, and had large brown eyes. Reserved and shy, hesitant and timid, he was also an incurable perfectionist, severe in the criticism of others as of himself. He was subject to that peculiar imbalance of intellect and emotions that not infrequently shadows genius. Although he developed advanced quasi-prophetic concepts that were later to be rediscovered by others, he was most reluctant to publish them. In 1933, he went to Leipzig and to Copenhagen; Heisenberg persuaded him to publish some of his original ideas. Upon his return to Rome he became a recluse. Fermi felt that Majorana had the extraordinary gifts of an exceptional genius. In 1937 he was persuaded to present his credentials to the *concorso* for a chair of theoretical physics in Palermo; exercising exceptional authority, the Ministry of Education appointed him to a better position at the University of Naples. After a trial of lecturing (1938) he wrote suicide notes and disappeared; he was never found. A review of his principal contributions was published by Amaldi.[8] Subsequent investigation revealed that he had applied for admission to at least one monastery.[318]

MARDSDEN, Ernest (1890–1970) was a Hatfield Scholar when he was 20 years old in Manchester. He became professor of physics at the University of New Zealand at Wellington. He served in the English army in France. In later years, he became interested in the correlation of goiter and the radioactivity, rather than the nature of the soil. He was knighted in 1958 and was also the recipient of the U. S. Medal of Freedom and of the title of Commander of the North Star of Sweden.

MEITNER, Lise (1878–1960), an Austrian student of Boltzmann and later of Planck, remained 31 years in Berlin; she became director of nuclear physics at the Kaiser Institute. In 1936–38 she was working in collaboration with Otto Hahn who was in charge of radiochemistry; they were attempting to confirm Fermi's reported production of transuranic elements by bombarding uranium with neutrons. In March 1938 with the annexation of Austria, Meitner found herself subject to the racial laws of the Reich; she crossed the border to Holland and proceeded to Stockholm where she was offered a position at the Nobel Institute. In her absence, Hahn continued their work with the help of Fritz Strassman; they found that the bombardment of uranium resulted in production of barium but could not explain how. Hahn wrote to Meitner, and she discussed the details at a Christmas holiday near Göteborg with her nephew, Otto Robert Frisch; he agreed to her conclusion that Hahn and Strassmann had produced a "fission" of the uranium nucleus. Upon his return to Copenhagen, Frisch reported their conversation to Bohr, who was about to depart for the United States; he also agreed with their interpretation. In January 1939, attending a conference on theoretical physics, organized by George Gamow and Edward Teller in Washington, D.C., Bohr reported the findings of Otto Hahn and the Meitner–Frisch interpretation; this, together with Joliot's observation of emission of neutrons by certain products of fission, suggested the possibility of initiating chain reactions with production of fabulous amounts of energy.[211,278]

MICHELSON, Albert Abraham (1852–1941) was born in Prussia and brought to the United States when two years of age; at age 19 he entered the U. S. Naval Academy at Annapolis. He became director of the Physics Department at the University of Chicago (1892–1929). His scientific career was centered on the study of light and in particular, of the velocity of light. He invented the *interferometer* by means of which distances were measured in terms of light waves. Michelson measured the rigidity of the Earth and the diameter of stars. He was awarded the 1907 Nobel Prize, the first American to be so honored, "for his optical precision instrument and the spectroscopic and metrological investigations carried out with it." Having never "earned" an academic degree, he received innumerable honorary ones. "*...His love of the search of truth and his confident faith in the value of scientific endeavor perhaps even more than his own great achievements*"—wrote Compton—"*made Michelson an inspiring leader.*"

MILLIKAN, Robert Andrews (1858–1953) was the son of a clergyman and a college teacher. A self-taught instructor in physics, he studied under Michelson and received his Ph.D. from the University of Chicago (1895). After one year in Germany, he joined Michelson's department of physics. Largely concerned at first with didactics, he became a notable experimentalist; his early original work on the measurement of the electronic charge (1913) brought him lasting recognition. He sustained a long experimental study to test the validity of Einstein's photoelectric theory and, to his surprise, found conclusive confirmation and at the same time, provided the best measure of Planck's constant (1916). During the First World War, he served with the National Research Council and the U. S. Army Signal Corps. He left the University of Chicago (1921) and became chairman of the executive council of the recently renamed California Institute of Technology; his work and that of his associates developed the institution into a distinguished scientific center. He studied the highly penetrating radiations that came from the outer atmosphere, which he called cosmic rays; he assumed that they were photons and developed a theory as to their origin. Studying cosmic rays in a cloud chamber, his collaborator, CARL DAVID ANDERSON (1905–), discovered the positron (1932). Millikan was an outspoken exponent of the compatibility of Science and Religion. He was a member of the Royal Society of London and the Institut de France; in 1923 he received the Nobel Prize. Having built an early supervoltage unit, he and his Danish-born collaborator, CHARLES CHRISTIAN LAURITSEN (1892–1968), engaged Dr. Henri Coutard to leave Paris and undertake early experiments in supervoltage radiotherapy of cancer in Pasadena (1937).

MOSELEY, Henry Gwynn-Jeffries (1887–1915) was the heir to very reputable names in English science; he won a scholarship to Eton and another to Trinity College, where he studied physics. He went to Manchester in 1910 and was easily the hardest worker there; after his work with Rutherford, he returned to Oxford. As World War I broke out, he was in Australia; upon his return, he was offered a position in war research, but he preferred a commission as an officer with the Royal Engineers. He was sent to the Dardanelles and was shot through the head in the Suvla Bay landing.

NAGAOKA, Hantaro (1865–1950), a professor of physics at the University of Tokyo, suggested (1904) a Saturnian atom with electrons uniformly arranged in a ring around a central positive charge[286]; in classical electrodynamics, it was thought that the energy loss that such electrons would suffer because of radiation would make them fall to their center of rotation. Nagaoka, who was responsible for the development of theoretical and experimental physics in Japan, abandoned his Saturnian model and took up the study of spectroscopy.

PATTERSON, Robert Alexander (1890–?), one of Duane's graduate students, later became professor of physics at Rennselaer Polytechnic Institute from 1922 to 1946, a staff member of the radiation laboratories at M.I.T., and an assistant director to the Brookhaven Laboratories from 1946 to 1959.

PAULI, Wolfgang (1900–1958), the son of a professor of medical chemistry, was born in Vienna, became a student of Sommerfeld in Munich and an assistant to Born at Göttingen; very early he distinguished himself because of a comprehensive article that he wrote on the theory of relativity (Enzyklopädie der mathematischen Wissenschaften). Einstein said of Pauli's thesis: "No one studying this mature, grandly conceived work would believe that the author is a man of 21." A rather portly man with slanted eyes and a brooding, expressionless appearance, Pauli was petulant and impatient yet friendly and humorous. At age 23, invited by Bohr, he went to Copenhagen; he shared a laboratory room with de Hevesy. Deep in his thoughts, Pauli rocked in his chair while de Hevesy attempted to isolate hafnium; whenever a careful measurement was needed, de Hevesy would ask Pauli to stop rocking to avoid vibrations. Purposely irreverent, Pauli was likely to call anybody, including Bohr, stupid. Ehrenfest bluntly told him that he liked his writings better than his person; Pauli replied that he felt exactly the opposite about Ehrenfest and his works. On one occasion, unable to answer a letter from Pauli, Bohr asked his wife to send him a note promising a letter on Monday. Weeks later, Pauli wrote to Mrs. Bohr indicating that whereas Niels had not specified *which* Monday, a letter written any other day of the week would be equally welcome. ("Er soll sich keineswegs an Montag gebunden fühlen, ein Brief am ingerdeinem anderen Tag geschrieben ware genau so willkommen.") Pauli's

achievements resulted from penetrating criticism rather than imagination. "No form of approval could be more precious to physicists, not excluding Bohr"—wrote Rosenfeld—"than Pauli's benevolent nodding."[339] From Copenhagen, Pauli went to Hamburg then in 1928 became professor at the *Eidgenossische Technische Hochschule* of Zurich; from 1940 to 1945 he was at the *Institute for Advanced Studies* of Princeton, New Jersey. He predicted the existence of an atomic particle that Fermi called the *neutrino* and that was later detected (1956). In 1945 he received the Nobel Prize. He was also the *enfant terrible* of theoretical physics (Mephistopheles in Gamow's parody of Faust). On September 29th, 1933 he wrote a letter to Heisenberg taking him to task for a favorable review of Planck's views on divinity: "If you grant that statements about *'reality of the external world'* have meaning—that they constitute a possibly true or false hypothesis—you are giving the devil of 'ismphilosophy' a little finger, but soon he will take the whole hand."

PEIERLS, Rudolf Ernst (1907–) was born in Berlin and received his Ph.D. from the University of Leipzig (1929); in 1931 he married Eugenia Kannegieser, a Russian. He visited Copenhagen, taught in Zürich and did research work in Manchester (1933) and Cambridge (1935). In 1937 he became Professor of Applied Mathematics at the University of Birmingham, England. In 1939 the hospitable Peierls welcomed in their home another German emigré, Otto Frisch. Peierls and Frisch labored diligently on the remarkable report that they submitted to the M.A.U.D. Committee; Frisch went on to Liverpool. In 1941 Peierls offered an assistantship to another German emigré, a shy, taciturn mathematician highly recommended by Max Born and by Professor Nevil Mott and because the young scientist was poor and without family, the Peierls offered a place in their home to Klaus Fuchs. In 1943 Peierls went to the U. S. as deputy-chief of the British delegation of atomic scientists; Fuchs went along. At Columbia University, Peierls took active part in the discussions of gas diffusion of uranium separation and he was the first to go to Los Alamos, ahead of Bohr. In Los Alamos, Bohr visited the Peierls frequently; Laura Fermi knew of his presence in the downstairs apartment because of the long periods of quiet, during which Bohr told a story in his low voice, followed by the roar of Genia Peierls' laughter. Peierls participated in the plans to test the implosion of the plutonium bomb; he and Fuchs were present at the Alamogordo test on July 12th, 1945. In 1945 Peierls left Los Alamos to become head of a division at the Atomic Energy Establishment in Harwell, England. Although Fuchs betrayed their affection and compromised their good name, the compassionate Peierls visited him in jail during his trial. From 1963 to 1974, Peierls was Wykeham Professor at Oxford, where he lives in his retirement. He received the Lorentz Medal (Holland), the Max Planck Medal (Germany) and the Guthrie Medal (U.S.A.). He also became Sir Rudolf Peierls, Commander of the Order of the British Empire.

PONTECORVO, Bruno (1913–) was a nice-looking, athletic young man from a large family of Pisa; he graduated from the University of Rome in 1934. Trained under Rasetti, he was incorporated in Fermi's research group, became a co-signer of their original reports and a participant in the patent of their discovery. He went to Paris and was a collaborator of Joliot until the Nazi occupation. He went to the United States, worked for a well company in Tulsa, Oklahoma, and applied for American citizenship; he later accepted a position working with the British team in Canada, where he became a British citizen. He was appointed to an important position after the war working in Harwell, England. In 1950, after a visit to Paris, his Swedish wife, their three children and he went to Italy, from where they flew to the U.S.S.R. He has been seen at international meetings held in Europe but has remained in the Soviet Union.

PUSEY, William Allen (1865–1940) was a descendant of a Kentucky pioneer family; he studied at Vanderbilt (A.B., 1885) and received his M.D. from the University of the City of New York in 1888. Following post-graduate work in New York and Europe he went to Chicago (1893) and became a professor of dermatology in the College of P. and S. He became a pioneer in the therapeutic use of the roentgen ray; he was the first in the United States to use radiotherapy in dermatology. In 1901, he was the first to fruitfully irradiate a patient of Dr. Jacob Frank, with chronic lymphogenous leukemia. In 1903, he and Dr. William Caldwell published an early book "*The Roentgen Ray in Therapeutics and Diagnosis.*" He had already successfully treated patients with carcinomas of the skin and lip; he initiated or contributed to the practice of prophylactic postoperative irradiation of cancer of the breast. Dr. Pusey had a long and influential career as a teacher of dermatology and syphilology and as an historian; he was also very active in organized medicine; president of the American Dermatology Association, 1911, of the American Medical Association, 1923. Editor of Archives of Dermatology and Syphilology. Author of *The Principles and Practice of Dermatology* (1907), of *The Walderman Road to Kentucky* (1921), and of *History of Syphilis* (1933).

QUIMBY, Edith Hinckley (1891–1982) was born in Rockford, Illinois, received her B.S. degree from the Whitman College of Walla Walla, Washington (1912), and did graduate work at the University of California. She became an associate to Failla as physicist for the Memorial Hospital of New York (1919–1942); they both moved to Columbia University, where they continued their work (1943–1960). Her principal work was in the field of dosimetry of radiations and in radiation

protection as well as in the uses of radioisotopes. She was president of the American Radium Society and a trustee of the American Board of Radiology. She is remembered most affectionately by her students, for she was a most dedicated teacher and pioneer in the field of medical radiation physics.

RASETTI, Franco Dino (1901–) was born in Castiglioni del Lago, Italy; he received his Ph.D. from the University of Pisa (1923) and taught at the University of Florence until 1927 when he went to Rome. Rasetti received the sobriquet of "The Cardinal" while Fermi was "The Pope." Rasetti was awarded the Matteuci Medal (1932) and the Mussolini Medal (1938) of the Italian National Academy; he was Visiting Professor at Columbia, Cornell, and Washington Universities in the United States. In 1939 he became Professor of Physics at Laval University in Quebec and stayed until 1947 when he entered the faculty of Johns Hopkins. In 1949 he married Marie Madelaine Hannin; he received an honorary Ph.D. from Laval University (1947), the Wolcott Medal of the National Academy of Sciences (1952), and became Honorary LLD of the University of Glasgow (1957). Besides his work on nuclear physics he maintained an interest in geology and paleontology; he authored *Middle Cambrian Stratigraphy and Faunas of the Canadian Rocky Mountains* (1951).

REGAUD, Claudius (1870–1940) was born in Lyon, France and received his M.D. (1897) at the University of Lyon. He was associate professor of histology at the Faculty of Medicine of his city, where he developed original staining techniques that are used to this day. He also wrote an up-to-date study of spermatogenesis. In 1905 he reported his observation of the fact that the spermatogonia were the most radiosensitive cells in the testicular tubules and that their destruction by irradiation eventually resulted in azoospermia, although the spermatozoids remained unaffected in the seminal tubules. In 1922 he made his experiments with the testicles of the ram, showing that a smaller total dose fractionated over a period of time, was more effective than a larger dose given at one time. Regaud was director of the Radium Institute of the University of Paris and was a pioneer of techniques used today in radiumtherapy. He was a great teacher and insisted on the advantages of a background of oncologic knowledge for all workers dealing with the treatment of cancer patients.[323b]

RICHARDSON, Owen Williams (1879–1959) was born in Yorkshire, England and studied under J. J. Thomson at Cavendish. It was known that the air surrounding incandescent bodies conducted electricity because of released electrons. Working at the Cavendish with high vacuum tubes, Richardson showed that this fact was not a result of the chemical effect of surrounding gas. He worked out a simple mathematical formula for the emission of electrons by different bodies at different temperatures; Richardson's law of thermionic emission became most important in radio and long-distance telephony. In his eight years at Princeton, Richardson developed a rich laboratory in which he pursued his research and found also laws of emission of electrons by metals struck by light. An incessant experimenter and prolific writer, he was a great inspiration to his students. He returned to England to work at the University of London and in 1982 received the Nobel Prize of Physics "for his work in thermionics and for the discovery of the law named after him."

SANGIER, Edgar (1880–1960) was a Belgian engineer who spent five years in China and in 1911 was sent to the Belgian Congo. Working for the Union Minière, he recommended the mining of uranium and the extraction of radium. In the Second World War, he left Belgium and established offices in New York; he ordered the shipping of large amounts of rich uranium and stored it in Staten Island, New York (see page 151). He was presented the Medal of Honor in a private ceremony at the White House but has never received commensurate public recognition and credit.

SCHRÖDINGER, Erwin (1887–1961) was born in Vienna. He was professor at the University of Zürich (1921–1927) and subsequently at the University of Berlin; he left Germany in 1933, spent time at Oxford, at the University of Graz (1936–1938) and at Princeton, then became director of the School of Theoretical Physics of Dublin from which he retired in 1955. He shared the Nobel Prize with Dirac in 1933; he died in Vienna in 1961.

SEGRÉ, Emilio (1905–), a native of Tivoli and a resident of Rome, he was the son of a merchant and was presumed acquainted with matters of finance. Segré made a reputation for being sensitive, or even touchy, gaining the nickname of "The Basilisk" for his sudden reaction. In 1936 he married Elfriede Spiro and was appointed director of the physics laboratories at the University of Palermo; in 1938, abreast of racial repression, he accepted a position as Professor of Physics at the University of California at Berkeley where he teaches to date. He was group leader at Los Alamos (1943–46) and won the Nobel Prize (1959) for his discovery of the antiproton; he is also co-discoverer of technetium. Segré was Fermi's first student and became his collaborator, loyal friend, and dedicated biographer,[368] he also chaired the committee that edited Fermi's lifetime works.[369]

SODDY, Frederick (1877–1956), a native of Eastbourne, England, had gone to Montreal as a young teacher. After two years of work (1900–1902) with Rutherford, he returned to England to work with Sir William Ramsay (1852–1916) at the Lamons Laboratories in London. Soddy studied similarities of radioactive elements, and developed (1913) what was called

the law or *theory of radioactive displacement*; he coined the word *isotope* to describe the relationship of some elements to their radioactive counterpart; this work brought Soddy the Nobel Prize of Chemistry, in his own right, in 1921.

SHIMIZU, Takeo (1890–?), a graduate student at Harvard under Duane, also worked later at Cavendish under Rutherford. He later became professor of physics at the School of Engineering at the University of Kyoto, Japan.

SOMMERFELD, Arnold Johannes (1868–1951) the son of a physician, was born in Königsburg, Germany and received a Ph.D. from that city's university. He held positions in Göttingen, Clausthal, and Aachen before becoming professor of theoretical physics at the University of Munich (1906–1940). As a result of 13 years of effort (1897–1910), he wrote, with Christian Felix Klein (1849–1925), a four volume treatise on gyroscopes. His book on atomic structure published in 1919[377,378] put him in the forefront of atomic physics. He had a remarkably large number of advanced students. "At a stamp of your foot"—wrote Einstein—"a great number of talented young theorists spring up out of the ground." A liberal democrat, he stayed in Germany during the war. In 1949 he received the Oersted Medal of the American Association of Physics Teachers. In 1951 he was struck by an automobile and died a few weeks later in Munich.

STENSTROM, Karl Wilhelm (1891–1973) was a native of Göteberg, Sweden; he studied and did his original spectographic observations and thesis under Nobel laureate Manne Siegbahn at the University of Lund. He came to the United States on a fellowship and worked at Harvard under Duane. Upon Duane's advice, he took a position as physicist to the Roswell Park Memorial Institute of Buffalo, New York; while there, he developed an ingeniously motorized early teleradium unit. In 1926 he was invited to build a radium emanation extraction plant for the Cancer Institute of the University of Minnesota; he remained in Minneapolis, in actual charge of the Division of Radiotherapy, for 30 years. He wrote a didactic book on physics of radiations that had no rival for many years. He died in retirement in Florida on November 7, 1973.

STIFLER, William Warren (1883–1954) was a Harvard graduate student under Duane and later became professor of physics at Amherst College (1925–1952). He died in Northampton, Maine.

SZILARD, Leo (1898–1964) was born in Hungary, the son of a construction engineer. He graduated from high school (1916) and entered the Budapest Institute of Technology (Muegyetom). During the First World War, he was conscripted into the cavalry but saw no action. In 1919 he entered the Institute of Technology in Berlin–Charlottenburg and in 1920, registered at the University of Berlin. Through his friend and fellow Hungarian, Wigner, he met von Laue and Einstein at the Kaiser Wilhelm Institute; they advised him on his dissertation, which he presented for his Ph.D. in 1922. His subject was "*Expansion of Phenomenological Thermodynamics into the Field of Variations*"; it was not published until 1925. Szilard worked on ideas on refrigeration and together with Einstein, obtained seven patents in England. After living in Berlin for a decade, when the Nazis got into power, he foresightedly obtained an immigrant visa and paid a short visit to the U.S. in December 1931. He had two suitcases packed, and when the Reichstag was on fire (1933), he fetched them and took the train to Vienna. On the next day, the trains were crowded and not freely accessible to Jews. ("To succeed"—Szilard used to quip—"you don't need to be smarter; you only have to be one day earlier.") From Vienna, he went to England, where he worked for the relocation of exiled scientists. In collaboration with T. A. Chalmers, at the St. Bartholomew's Hospital of London, Szilard worked with radium and beryllium to produce a chain reaction. He applied for a patent that he entrusted to the Admiralty in order to keep it secret (1934). He was offered a fellowship at Oxford University. In September 1938, he was visiting the United States when the Munich crisis took place; he decided not to return to England. He established residence in New York and obtained permission to work at Columbia University. Szilard's work towards the development of a controlled chain reaction, his role in the Manhattan Project and with the use of the atomic bomb are given in more detail in Chapter X, page 150. In 1958 Szilard suffered from cancer of the bladder; he was treated and cured by radiotherapy. He died from a coronary occlusion in his sleep in 1964.

UHLENBECK, George Eugene (1900–), a native of Batavia and a Ph.D. of the University of Leyden (1927), became professor of physics of the University of Michigan (1927–1935). Following the suicide of his mentor, Ehrenfest, he returned to Holland and was professor of theoretical physics at Leyden (1935–1939). Returning to Ann Arbor he remained there as professor of theoretical physics (1939–1959) then went on to the Rockefeller Institute. He is principally known for the work done with Goudsmit on the electron spin hypothesis.

WENDT, Gerald Louis (1891–1973), a Harvard graduate student under Duane and a Ph.D. (1916), became dean of the Pennsylvania State University and later, director of the American Institute, City of New York, as well as science editor for *Time* magazine.

WILLIAMS, Francis Henry (1852–1936) was born in Uxbridge, Massachusetts, April 15, 1852 and was graduated from M.I.T. (1873) and Harvard Medical School (1877). He was an instructor in Materia Medica and an

assistant professor of therapeutics at Harvard Medical School. Within 6 months of the announcement of Röntgen's discovery, Williams was at work fluoroscoping patients at the Rogers Laboratory of Physics at M.I.T. Later he was given the use of a room in the basement of Boston City Hospital. With the help of William Rollins he developed a large static machine with blades several feet wide that provided strong but steady output to his Crookes tubes. He studied the usefulness of fluoroscopy in diseases of the chest. With Dr. Walter Cannon, he studied the human gastrointestinal tract by means of bismuth subnitrate. He wrote eloquently and in 1901 published his book "*The Roentgen Rays in Medicine and Surgery.*" The book contains early details of techniques and of protection and photographs of results of roentgentherapy of cancer of the skin and lip. Antoine Béclère, in Paris, was greatly impressed by the book and translated it to French. In 1902, he pointed out the beneficial effects of x rays on Hodgkin's disease. Despite long years of practice he died in June 22, 1936, without the injuries and sequelae that were so common among pioneers as a result of his serious and systematic dedication to protective measures.

WILSON, Charles Thomas Rees (1869–1959) was a Scot. In 1911 he showed that the tract of alpha particles could be made visible with his cloud chamber of expanded air containing water vapor. He was an inarticulate lecturer but a sensitive man; Wilson had become interested in the phenomena of fogs as he observed the air currents ascending to the mountain ridges and then descending to the valleys of Scotland. In 1927 he shared the Nobel Prize of Physics with Arthur H. Compton.

WU, Ta-You (1907–) was born in Canton, China and graduated from the University of Tientzin in 1929. He did graduate work under Professor Goudsmit in Ann Arbor and received his Ph.D. from the University of Michigan in 1933. He became professor at the National University of Peking (1934–1946). After the end of the Second World War, he returned to the U. S. and worked in Ann Arbor and at New York University (1947–1949). He then headed the Theoretical Physics Section of Canada's National Research Council from 1950 to 1963 in Ottawa. While in the latter position, he published some 50 papers and co-authored a book on the *Quantum Theory of Scattering* (1962). He subsequently worked in Buffalo, New York and retired to Taiwan, where he continues to teach and participate in scientific research.[212b]

ZEEMAN, Pieter (1865–1943) of Amsterdam, was born in Zealand; in 1896 he made a discovery that gave Lorentz's electron theory a wider base. Zeeman placed a gas burner between the poles of an electromagnet and introduced common salt in the flame, the resulting sodium spectrum, consisting of two very strong yellow lines of close wavelength, showed a substantial increase in width as soon as the current was connected. *Zeeman's effect* raised questions that were not to be answered for decades. In 1902 Lorentz and Zeeman shared the Nobel Prize. Zeeman took part in the sixth Solvay Conference in 1930.