Phys. Perspect. 13 (2011) 260Ð328

1422-6944/11/030260-69
DOI 10.1007/s00016-011-0056-7

Physics in Perspective

History of the New York University Physics Department*

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We trace the history of physics at New York University after its founding in 1831, focusing especially on its relatively recent history, which can be divided into Þve periods: the Gregory Breit period from 1929 to 1934; the prewar period from 1935 to 1941; the wartime period from 1942 to 1945; the postwar period from around 1961 to 1973 when several semiautonomous physics departments were united into a single all-university department under a single head; and after 1973 when the University Heights campus was sold to New York City and its physics department joined the one at the Washington Square campus. For each of these periods we comment on the careers and work of prominent members of the physics faculty and on some of the outstanding graduate students who later went on to distinguished careers at NYU and elsewhere.

Key words: Allen V. Astin; Jenny Rosenthal Bramley; Gregory Breit; David B. Douglass; Henry Draper; John C. Draper; John William Draper; Richard T. Cox; Eugene Feenberg; Gerald Goertzel; Louis P. Granath; Otto Halpern; Morton Hamermesh; Daniel Webster Hering; Norman Hilberry; Theodore Holstein; John C. Hubbard; Francis A. Jenkins; Hartmut Kallmann; Serge Korff; Alfred Lee Loomis; Elias Loomis; Francis Wheeler Loomis; James M. Mathews; Allan C.G. Mitchell; Samuel F.B. Morse; Robert S. Mulliken; Henry Primakoff; Frederick Reines; Arthur Roberts; Edward O. Salant; Clifford G. Shull; John A. Simpson; Henry Vethade; John H. Van Vleck; John A. Wheeler; Robert W. Wood; Bruno Zumino; New York University; University Heights campus; Washington Square campus; James Arthur Lectures; Stanley H. Klosk Lectures; history of physics.

Introduction

New York University was founded in 1831 by a group of visionary New Yorkers, members of the newly minted commercial leaders of the business community. The burgeoning city, a hub of commercial trafÞc between the old and new worlds, had

* We have published an extensive and somewhat different version of this article as a book, History of the NYU Physics Department 1831Ð2000 (Ashland, Ohio: Bookmasters Inc., 2010).

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created a class of civic leaders who were distinguished as much by their business acumen and Þnancial success as by their privileges of birthÑa new cultural phenomenon arising out of the industrial revolution of the nineteenth century. The intent of these men was to offer a high-quality education to the children of the new middle class that was equivalent to that already offered to high-born children who could attend the established prestigious centers of higher education such as Harvard, Yale, and Princeton. These leaders were driven by practical as well as ideological motives. The city required an educated middle class to meet the Þnancial and commercial challenges of the period, and the goal of NYU was to satisfy this need. There is some indication as well that these leaders also had hopes of simultaneously turning a proÞt.

From the beginning, NYU was designed as a university, not a college, unlike most of its illustrious predecessors in America. This indicated the lofty ambitions of its founders, who had envisioned NYU as consisting of a number of schools, after the European model, including professional schools such as medicine and law. At Þrst the granting of advanced degrees in arts and science was not a primary goalÑthe Graduate School of Arts and Science was not established until half a century after the founding of the university. The Þrst Chancellor, James M. Mathews (1785Ð1870), described the intents of the founding council as follows:

> [The] University was designed both for ÔÔyoung men whose intended pursuits in life might be considered not to require the acquisition of classical learning,ÕÕ and for ÔÔsuch whose inclinations might lead toƒ a more exalted measure of attainmentsƒ . [The] ÔÔpractical spirit of the ageÕÕ required a particular devotion to Mathematical and Physical Scienceƒ . [A] ÔÔsmatteringÕÕ of Physics led to inÞdelity; butƒ a thorough study of itƒ would conÞrm the truths of divine revelation. The day would soon comeƒ when the nation would view its institutions of higher learning as nurseries of its strength, and as its sanctuaries for preservation from evil.[1]

Apart from his remark about inÞdelity (he actually used the word here in its original meaning, which describes loss of faith, especially in religion), this was a prescient statement.

The development of NYU, from its modest beginnings, is a truly fascinating story, replete with dramatic twists and turns and Þnancial and governance crises. We refer the reader to various source materials for its fascinating history.[2] Among the most dramatic events were the development of the NYU community around Washington Square, the medical center at the upper East Side, and Þnancial and Þne art outposts on Wall Street and near the Metropolitan Museum of Art. Singularly noteworthy was the creation of an uptown campus at University Heights in the Bronx in 1894, comprising an engineering school and a liberal arts college, and its eventual sale to the city about seventy years later to rescue the rest of NYU from a devastating Þnancial crisis.

NYU was created as a secular institutionÑin contrast to its august predecessors in the United States, which were exclusively afÞliated with religious denominations. This is not to say, however, that religion (as well as moral behavior) played no major role in the educational experience. The section ÔÔGeneral RegulationsÕÕ appearing in the NYU course catalog of 1859 states:

> The scriptures are read and prayer offered every morning in the chapel, where the Chancellor or one of the Professors ofÞciates, and the students are required to be present.
>
> Habitual indolence and inattention to study, will be regarded as an offense against the laws and the spirit of the institutions; and will be made the subject of such discipline as the Faculty may deem expedient.
>
> Any student who frequents billiard rooms, taverns, or other places of corrupting inßuence, will not be allowed to remain a member of the University. No student will be permitted to leave the city during term time, unless a request to that effect be made by his parent or guardianƒ .

These proscriptions were gradually diluted, although they did not disappear entirely until the 1950s.

The early years of NYUÕs history include periods of inspiring growth as well as cliffhanging Þnancial crises, which makes fascinating reading. We are mainly concerned with the development of NYU physics. Physics as an academic discipline did not appear in the NYU course catalog until near the end of the nineteenth century. Earlier, such material generally appeared in natural-philosophy courses. Chemistry was a more mature discipline in the early days, and some physics certainly was also covered in chemistry. The intent of the founding fathers to emphasize practical and scientiÞc subjects can be gleaned from the makeup of the original faculty in 1832. It consisted of Þve professors, two of whom, Henry Vethale (1792Ð1866) and David B. Douglass (1790Ð1849), were professors of mathematics and astronomy and of natural philosophy, respectively. For many years science courses were free to matriculated students! A third chair was entitled ÔÔEvidences of Revealed ReligionÕÕÑperhaps an attempt to cloak divinity with a scientiÞc veneer. An indication of the early cantankerousness of the faculty was that virtually the entire faculty resigned after one year in a dispute with the Chancellor over academic standards.

Physics cannot claim credit for the two most famous NYU luminaries of the early days, telegraph inventor Samuel F.B. Morse (1791Ð1872) and chemist John William Draper (1811Ð1882). Morse was appointed in 1832 as Professor of Sculpture and Painting; he indeed was a successful and highly regarded artist who always considered his telegraph activities as a sideline, though an important (and lucrative) one.

Draper was the Þrst truly distinguished scientist to grace the NYU faculty. Although he was Professor of Chemistry, many of his publications were distributed over a variety of related disciplines, including physics. Specialties in those days were not so conÞned as they became in later years. He began his afÞliation with the University of the City of New York (as NYU was then called) in 1837 and continued this afÞliation until 1881, the year before his death, mostly in the College of Arts and Science. Among his many accomplishments was his leadership in founding the American Chemical Society at Washington Square. His most signiÞcant contribution to physics was his experimental work using diffraction gratings that revealed the distinction between radiation from hot glowing bodies and radiation from hot gases, that is, the difference between continuous and line spectraÑwork that preceded that of Gustav Kirchhoff (1824Ð1887) by about ten years.[3] Draper also was among the Þrst to exploit daguerreotypes to photograph human faces, as well as the surface of the moon. Two of his sons, John C. Draper (1835Ð1885) and Henry Draper (1837Ð1882),[4] also served for many years as NYU faculty members, the latter becoming a noted astronomer who was known, among other things, for the Draper astronomical star catalog, which between 1918 and 1924 listed spectroscopic classiÞcations for over 225,000 stars, and was later extended even further.

The Þrst mention of advanced degrees appeared in the 1883 course catalog. The Graduate School of Arts and Science was formally created in 1886 with the intention of granting M.A., M.S., and Ph.D. degrees, although the Þrst Ph.D. degree in physics actually granted by NYU was in 1904 to Frederick Gregory Reynolds on ÔÔThe Viscosity CoefÞcient of Air, with an Inquiry on the Effect of the Röntgen Rays Thereon.ÕÕ[5] The Þrst reference we found to a NYU thesis in physics appeared in a footnote in an article of 1907 by William J. Fisher.[6]

Early Physics

Early physics at NYU was dominated by a few outstanding individuals whose lives we describe brießy in the next section. It is true that the European inßuence on these early leaders was not as great as on those at the prestigious ivy league colleges at the timeÑNYUÕs faculty was primarily American-educated until just before World War II when such exceptional physicists as Gregory Breit, Otto Halpern, and Allan G.C. Mitchell appeared on the scene (see below).

We shall also see that many young NYU physicists did noteworthy work early in their careers and then went on to other institutions where their work and reputations ßourished. A disconcerting characteristic of NYU physicsÑperhaps a general American oneÑis its lack of written records. Departmental Þles are sadly incomplete; in many cases there are none for important individuals. We therefore were forced to seek information elsewhere, the best and most relevant source being the published literature, the most important of which after its founding in 1893 is *The Physical Review*, the ßagship of the American Physical Society (APS). Earlier, the principal venues for physics and related subjects such as astronomy, meteorology, and physical chemistry were the *American Journal of Science* (AJS), the *Proceedings of the National Academy of Sciences* (PNAS), and the *Transactions* and *Proceedings* of the American Philosophical Society. The AJS has been published at Yale University since 1818. In its early years it was in the hands of the Silliman family. Benjamin Silliman (1779Ð1864) reigned for decades, and was succeeded by his son and grandson. Most of NYUÕs early ÒÒphysicsÓÓ papers appeared in it; after the arrival of The Physical Review in 1893, the AJS became a journal specializing in the Þeld of geology and related sciences.

Beginning in 1907, NYU papers in The Physical Review and records of talks at APS meetings appeared at increasingly frequent intervals. In the 1920s their topics generally concentrated in the study of ßuids, ultrasonics, electric discharges, and spectroscopy, especially molecular spectroscopy. Both Washington Square and University Heights became hotbeds for spectroscopy work, both experimental and theoretical. No fewer than thirty-two NYU papers on experimental spectroscopic measurements appeared in The Physical Review during the decade 1920Ð1930, almost all of them on molecular-band studies.

Benjamin Franklin (1706Ð1790) founded the American Philosophical Society in 1772, and NYU papers appear in its Transactions and Proceedings. NYU physicists occasionally, but rarely, also published their papers in European, primarily German scientiÞc journals. Finally, the PNAS continues to publish physics research articles, primarily though not exclusively by members of the U.S. National Academy of Sciences. We used all of the above sources to ßesh out the early history of the NYU Physics Department.

Bayrd Still (1906Ð1992), University Archivist and historian, wrote a brief history of the Physics Department in its early days, which we reproduce in Appendix 1.

University Heights

For over Þfty yearsÑthe second half of the nineteenth centuryÑa building on Washington Square East* housed NYUÕs principal activities. During this period the city grew dramatically, and NYU grew proportionately. An all-too-familiar situation developedÑthe need for more space. Growth potential at the Square was limited. The city was expanding northward at a rapid rate. A logical solution to both the need for more space and the need to take advantage of the cityÕs growth was to create a new campus farther uptown, and hence the campus at University Heights was acquired and developed. The location was (and is) a beautiful piece of land overlooking the Harlem River in the Bronx on a historic site that had played a major role in one of the skirmishes in the Revolutionary War between the British (mostly Hessian) army and WashingtonÕs troops. New buildings, many designed by the famous architectural Þrm of McKim, Mead, and White, were constructed. The NYU College of Arts and Science, along with its Physics Department, was moved,

* Washington Square is a beautiful eight-block-square park in ManhattanÕs Greenwich Village.

Fig. 1. Butler Hall, the new home of the New York University Physics Department in 1898. Credit: New York University Archives.

as were most of the other academic activities, although not the Law School. The transition took place in 1894. A few years later, the Hall of Fame of Famous Americans was established[7], part of a Sanford White complex that includes a spectacular library, the Gould Memorial Library.

In 1898 a former private residence was converted to become Butler Hall, the new home of the NYU Physics Department (Þgure 1). As time went by it began to house laboratories and shops, a better venue than could be developed at Washington Square. Heights physics gradually acquired some impressive experimental research groups and theorists. Washington Square refused to die, however, and eventually a new liberal arts college was reestablished there, including a new Physics Department (more on this later). A major addition at the Heights, the establishment of a strong College of Engineering, played a crucial role in the growth of physics. It created a second steady supply of undergraduates for required and elective physics courses. In fact, as a source of physics undergraduates, it more than equaled that of the College of Arts and Science. It also established a research environment that encouraged experimental work, which was of considerable assistance in enabling the growth of physics. All of this was lost when the Heights campus was sold in 1973.* From an administrative point of view, the Heights Physics Department became part of the School of Engineering,

* The University Heights campus was sold to the City University of New York (CUNY) in 1973 as a consequence of a near-fatal Þnancial crisis that struck NYU at the time. It now contains the Bronx Community College, a junior college that is part of the CUNY system.

reporting to its dean. Much of the history we describe below was generated at the University Heights campus, though by no means all.

The James Arthur and Stanley H. Klosk Lectures

The early history of NYU physics was pretty much home-grown; it did not match the far more advanced developments in European physics. Accordingly, until the late 1920s NYU physics was not a major player in the dramatic developments that had occurred in physics. The early leaders of the department apparently were aware of this, and made deliberate efforts to bring its physics up to the highest standards. One of the consequences of these efforts was the creation of two lecture series, the James Arthur and Stanley H. Klosk lecture series, meant to instruct and inspire its students and faculty.

James Arthur (1842Ð1930) was an Irish industrialist who established a major clock and watch collection that he donated to NYU in 1925, along with a substantial endowment that included funds for the establishment of an annual lecture series on ÔÔthe mysteries of time.ÕÕ The redoubtable Daniel Webster Hering (see below) was the curator of the horological collection for many years. It eventually left the campus, Þnally resting in the Smithsonian Institution in Washington, D.C., but the lecture series proved to be of lasting beneÞt to the NYU physics community. The Þrst twelve talks were published in a series of three volumes;[8] the lecturers through 1980 are given in the following list.

James Arthur Lecturers

1932 Robert A. Millikan
1933 John C. Merriam
1934 Harlow Shapley
1935 James H. Breasted
1936 Daniel W. Hering
1937 William F.G. Swann
1938 John Dewey
1939 Arthur H. Compton
1940 Henry N. Russell
1941 Adolph Knopf
1946 James T. Shotwell
1949 George P. Luckey
1958 William Markowitz
1972 Roland Omnès and Steven Frautschi
1975 Norman F. Ramsey
1978 Freeman J. Dyson
1980 John A. Wheeler

The Stanley H. Klosk Visiting Lectureships were instituted by the Klosk family in memory of a former NYU graduate student. The Klosk Lecturers included eminent scientists from the United States and abroad, about half of them Nobel Laureates, as given in the following list.

Stanley H. Klosk Lecturers

1966 William Shockley
1967 Charles Townes
1968 Julian Schwinger
1969 Donald A. Glaser
1970 Hans A. Bethe
1971 George von Bekesy
1975 Edward M. Purcell
1975 Michael E. Fisher
1976 Philip Morrison
1977 Malvin A. Ruderman
1979 Pierre-Gilles de Gennes
1980 Brandon Carter
1981 Claude Cohen-Tannoudji
1982 Leo P. Kadanoff
1985 Herbert Walther
1987 Mitchell J. Feigenbaum
1990 Daniel Kleppner
1993 Curtis J. Callan Jr.
1994 Roger Penrose
1998 Carl Weiman
2002 Alain Aspect

Early Physics Faculty

Elias Loomis (1811–1889)

Elias Loomis was the Þrst of three Loomises (all unrelated) who played important roles in the early history of NYU physics. He probably was the Þrst faculty member who might be termed a physicist, at least in a broad sense. He held an appointment as Professor of Mathematics, Natural Philosophy, and Astronomy from 1844Ð1860, after which he was appointed as Professor of Natural Philosophy at Yale College, his alma mater. He was the author of several important textbooks on mathematical and natural philosophy, many of which became best sellers and brought him signiÞcant wealth (although he endowed Yale, not NYU, in his will). He was noted for his work in astronomy and geomagnetism, for example, the rediscovery of HalleyÕs Comet in 1844. He carried out detailed studies of the aurora borealis during his last years at NYU, especially during a dramatic peak of solar activity in 1859. He prepared one of the Þrst comprehensive weather maps in 1846, a then-novel method for presenting meteorological data, now ubiquitous for storm and weather predictions. He also performed some electricity and telegraphy experiments. He was a member of the National Academy of Sciences[9].

Elias Loomis was the Þrst of an impressive number of NYU physicists who had appointments at NYU early in their careers and then went on to distinguished careers elsewhere. We shall see many examples of this phenomenon.

Daniel Webster Hering (1850–1938)

The Þrst mention of the word ÔÔphysicsÕÕ in the NYU course catalog was in 1883. The Þrst ofÞcially designated Professor of Physics was the formidable Daniel Webster Hering (Þgure 2), who was on the faculty from 1885Ð1915. He was for years practically a one-man physics department. He taught virtually all of the

Fig. 2. Daniel Webster Hering (1850Ð1938). Credit: New York University Archives, Hering Collection.

physics courses in the catalog and ran the seminars. He eventually became Dean of the College of Arts and Science at University Heights until he retired. He always prided himself on his insistence of having his physics students perform advanced laboratory experiments; he constructed NYUÕs Þrst student laboratory (Þgure 3). In perhaps his most purely scientiÞc achievement, he is known for what has been claimed to be the Þrst X-ray photograph of the human body (actually that of a baby), taken only a year or two after Röntgen discovered X-rays in 1895. He wrote several noteworthy books, including a popular physics text and one on *Foibles and Fallacies of Science*,[10] which was ahead of its time in debunking pseudoscientiÞc myths. In his (unpublished) autobiography he allows that his various teaching and administrative duties were so demanding as to prevent him from achieving scientiÞc renown.*

Both Elias Loomis and Hering were strictly home-grown products. Neither beneÞtted from exposure to European physics, which was far ahead of American physics during most of the nineteenth century.

* HeringÕs unpublished memoirsÑa very complete collectionÑreside in the NYU Archives at Bobst Library.

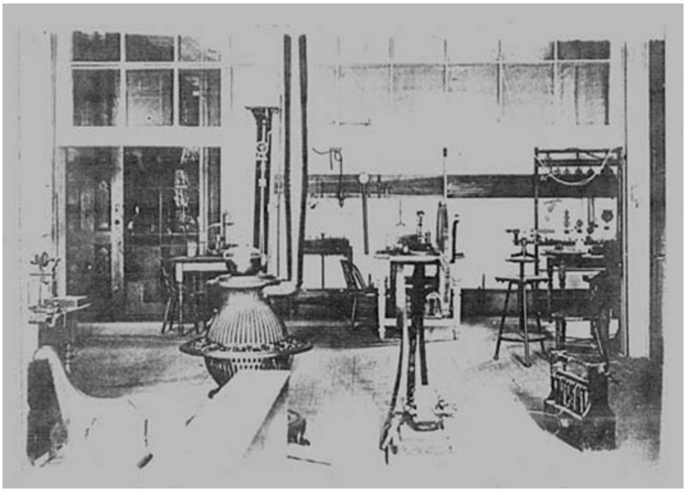

Fig. 3. New York University physics laboratory and classroom at Washington Square in 1890. Note the ÔÔeggÕÕ coal stove, as University Historian Bayrd Still describes in Appendix 1. Credit: New York University Archives, Hering Collection.

Francis Wheeler Loomis (1889–1976)

A second Loomis, Francis Wheeler Loomis (Þgure 4), was appointed as Assistant Professor of Physics in 1921 and remained at NYU until 1928, when he moved to the University of Illinois in Urbana-Champaign as Chair of its Department of Physics. He was the Þrst world-class modern physicist on the NYU faculty. In the 1921 course catalog he is listed as teaching ÔÔtheory of electrons, atomic structure and spectra,ÕÕ and the following year he gave a course on ÔÔsubatomic phenomena.ÕÕ In 1921 he published a not well-known but signiÞcant short paper in *The Physical Review* in which he exploited Robert A. MillikenÕs oil-drop data to estimate the upper bound of the protonÐelectron charge difference as 2.5×10^{-18} esu,[11] which more recent results have pushed down no more than two orders of magnitude. Frederick Seitz (1911Ð2008) recalled that:

> When Loomis joined the department, physics at New York University was as highly regarded as at Columbia University, and it appeared to some that NYU might become the leading department in the New York area.
>
> Once there, Loomis decided to work on the analysis of band spectra of diatomic molecules. He rapidly gained a worldwide reputation as the discoverer of the inßuence of the isotopic composition of the constituent atoms upon the bands, the initial work being carried out with hydrogen chloride.
>
> *f*

Fig. 4. Francis Wheeler Loomis (1889Ð1976) ca. 1929. Credit: Department of Physics, University of Illinois at Urbana-Champaign; courtesy of American Institute of Physics Emilio Segrè Visual Archives.

> This was an enormously exciting period in the evolution of quantum theory. Quantum statistics and wave mechanics were Þnally achieving permanent form, at least in so far as they apply to atomic and molecular systems, and LoomisÕs research was central to the emerging structure.[12]

Loomis had the perspicacity to link up with the famous Robert Williams Wood (1868Ð1955) of Johns Hopkins University to perform precision spectroscopic measurements of the band structure of alkali-halide dimers. For this work they utilized a 40-foot spectrograph that had been constructed at an extraordinary laboratory in Tuxedo Park in upstate New York, [13] which had been created by a third Loomis, Alfred Lee Loomis (1887Ð1975), a wealthy ÔÔamateurÕÕ with an intense interest in experimental physics. We place ÔÔamateurÕÕ in quotation marks because he was an important scientist in his own right who along with both Elias and Frances Wheeler was elected to the National Academy of Sciences. Frances Wheeler and Wood together published some signiÞcant papers, particularly on the spectra of simple molecules. Among their accomplishments was the establishment of an analytic procedure, called the LoomisÐWood diagram, still in use.* Among LoomisÕs other accomplishments at NYU were his discovery of new isotopes of carbon and oxygen, and along with Wood the demonstration that the nuclear spin of potassium was not zero,[14] correcting a serious error in the literature that was hindering the organization of elements by subshells in the periodic table.

Loomis transferred his research interests at NYU to Illinois where his graduate student, Polykarp Kusch (1911Ð1993), did his Ph.D. thesis on the band spectra of caesium.[15] Kusch shared the Nobel Prize in Physics for 1955 ÔÔfor his precision determination of the magnetic moment of the electron,ÕÕ which was made possible by using atomic-beam techniques on alkalis, including the simplest of the alkali series, atomic hydrogen. Kusch thus appears to have maintained a residue of the inßuence of the ÔÔone-electron physicsÕÕ of his thesis advisor.

During World War II, Loomis served as Associate Director of the Massachusetts Institute of Technology Radiation Laboratory, where he made important contributions to the development of radar. After the war, he became an elder statesman of physics, serving as President of the American Physical Society in 1949.

John Charles Hubbard (1879–1954)

John Charles Hubbard, with a Ph.D. degree from Clark University, was an Assistant Professor of Physics at NYU from 1904Ð1906. He left for Clark in 1906 but returned to NYU in 1916 and served as Chair of the Physics Department until 1927. He spent his subsequent career at Johns Hopkins University and at the Catholic University of America where he had a distinguished career in ultrasonics.

Hubbard published only a few papers at NYU, but one was particularly signiÞcant, which he and Arthur H. Compton published on ÔÔThe Recoil of Electrons from Scattered X-rays,ÕÕ[16] that is, the Compton effect. They concluded ÔÔthat each quantum of scattered X-rays is emitted in a de nite direction ƒ . [All] radiation occurs as deÞnitely directed quanta rather than as spherical waves.[17]ÕÕ Hubbard also published a paper with Richard Cox (more on him later), and one with the Tuxedo Park Alfred Lee Loomis on ultrasonic resonators.

Robert S. Mulliken (1896–1986)

Another noteworthy example of the ephemeral nature of the faculty appointments in physics at NYU in the early days is Robert S. Mulliken, who was Assistant Professor of Physics from 1926 to 1928 before he went to the University of Chicago to achieve fame as a molecular chemist and winner of the Nobel Prize in Chemistry for 1966. His brilliant studies of molecular structure originated in his

* The LoomisÐWood diagram is a graphical scheme for classifying lines of rotational band spectra.

research in molecular spectroscopy at NYU at Washington Square. He described his early days there and his conversion from physics to chemistry as follows:

> [In] those days basic spectroscopy and the theory of molecular electronic structure were being studied primarily by physicistsƒ . Now, however, these subjects, as well as the newer branches of spectroscopyƒ which were born in physics laboratories, are generally considered to belong primarily to chemistry. These circumstances account for the fact that, although my B.S. and Ph.D. degrees were in chemistry, I have for a long time been a member of physics departments, where I am classiÞed as a molecular physicist. Only rather recently have I become formally associated also with chemistry departments, thereby giving recognition to the migration of molecular spectroscopy and MOÕs [molecular orbitals] from physics toward chemistry. Nevertheless, the basic facts of these areas of science do still lie in the border region between physics and chemistry.[18]

In his two years at NYU, Mulliken published about Þve experimental papers on molecular spectroscopy, and an important theoretical paper on spectral analysis. Thus, as with Francis Wheeler Loomis, while MullikenÕs time at NYU was brief, his productivity was extraordinary. And he brought with him a Þne student, Francis A. Jenkins (see below), whose time at NYU just about coincided with MullikenÕs, and who then went on to an illustrious career in optics and spectroscopy at the University of California at Berkeley. Among MullikenÕs many other honors, he was elected to the National Academy of Sciences.[19]

Louis Peter Granath (1901–1972)

Louis Peter Granath was a singularly interesting early faculty member whose full career remains something of a mystery. After a short stay at the Naval Research Laboratory, he apparently arrived at NYU in 1928, having obtained an undergraduate degree in physics from the University of Minnesota. At Minnesota he had received an appointment as Assistant in Physics with an annual stipend of $600 in 1923 and had appeared in its 1926 Yearbook. He received his Ph.D. degree at NYU in 1930, probably with Gregory Breit as thesis advisor, and remained at NYU as Assistant Professor until about 1938.

During his eight years at NYU, Granath became a productive spectroscopist. He published a number of papers on optics and spectroscopy, including several signiÞcant ones on the determination of the nuclear spins of several alkali isotopes, making relatively accurate estimates of their nuclear magnetic moments. Recall that the only known method for the determination of nuclear spins and magnetic moments at this time was precision optical spectroscopy, because hyperÞne structure could be determined by observing the splitting of spectral lines or bands. (As an indication of the relatively small group of physicists then active in this Þeld, Granath thanks R.W. Wood for the loan of a Lummer plate, and the City College of New York (CCNY) for the use of a high-resolution grating.) In four important papers, Granath reported measurements of the nuclear spins and hyperÞne structures of the alkali metals lithium, sodium, and caesium.[20] In his Þrst paper, he made a deÞnitive measurement of the nuclear spin of Li^7, resolving a serious discrepancy in the literature that was hampering the understanding of nuclear shell structure. Granath was greatly encouraged by Gregory Breit, whom he acknowledged in most of his papers. (Breit appeared almost simultaneously on the University Heights campus and wrote a theoretical paper on hyperÞne structure.[21]) Later, Granath apparently became intrigued by Richard CoxÕs fascination with electric eels at NYU, and after Granath moved to Worcester Polytechnic Institute in 1938 he became a member of the National Zoological Society and devoted the remainder of his career to studies on the biological generation of electrical phenomena.

Some General Remarks

We have had considerable difÞculty in rediscovering the state of the experimental laboratories in the 1920s and 1930s at both University Heights and Washington Square. Careful reading of the published experimental papers during these periods does not reveal much concerning the experimental equipment: with the exception of GranathÕs papers, they contain little description of apparatus. One of us (HHS) recalls the remnants of a high-resolution, elaborate optical spectrometer in the basement of Language Hall at University Heights. Only some beautifully labeled glass lamps remain of what once must have been an elaborate, high-quality laboratory (Þgure 5).

During the 1920s and 1930s, several important threads appear to have connected the research interests of many of the physics faculty. As we saw, the departmentÕs Þrst modern research was in atomic and molecular spectroscopy. It focused originally on atomic and molecular structure, since spectroscopy was the basic tool for unraveling the nature of electronic orbitals. Next, as nuclear physics began to become a viable Þeld, atomic spectroscopy extended naturally to the study of hyperÞne structure, the small effect on spectra resulting from the inßuence of the nucleus on atomic electric and magnetic Þelds. Then electron and neutron scattering appeared. The electron-collision work, as we shall see, was dominated by polarized-electron experiments. The neutron-scattering work, which was connected to that on electron scattering, continued throughout the war, but the publication of some of it was deliberately postponed until after the war because of its relation to nuclear Þssion and atomic weapons. There thus was a certain unity in the research themes pursued by members of the physics department. We also note that one of the authors (BB) conducted his research at NYU in electron scattering with polarized atoms, and the other author (HHS) conducted his on high-resolution atomic spectroscopy with emphasis on nuclear properties, both, however, with no prior knowledge of their departmentÕs history.

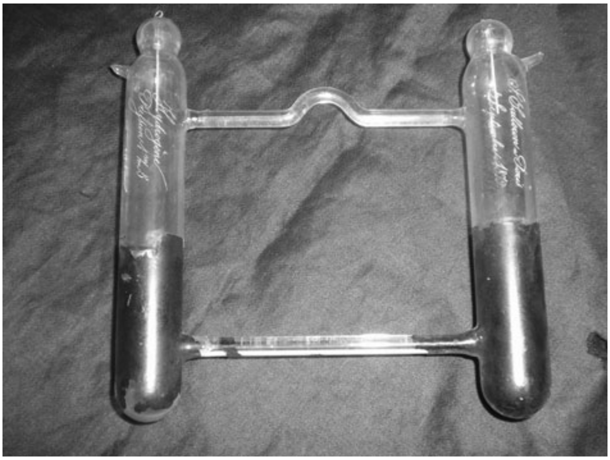

Fig. 5. Hydrogen discharge tube made in 1876, found in an old wooden drawer of spectroscopic optics at the University Heights campus. Credit: New York University Archives.

Richard Threlkold Cox (1898–1991)

Serge Korff writes in his brief history (Appendix 3) that: ÔÔIn 1940 and 1941, the Physics Department at the Heights included a number of persons whom today we would describe as ÔcolorfulÕ. One of these was Professor Richard T. Cox [Þgure 6].ÕÕ Presumably this is because at some point Cox became interested in electric eels, and devoted much of his creative talent to their study. In fact, Cox was an extremely interesting character who in his lifetime actually spanned three professional careers, on electric eels and on the study of spin polarization by the scattering of fast electrons by solids at NYU, and after he left for Johns Hopkins University in 1943 he became an important Þgure in probability and statistical analysis. Most relevant to us is his electron-scattering work: While at NYU he made measurements of the double scattering of fast electrons by heavy nuclei that led to his observation of an asymmetric effect in the spin polarization of leftÐright scattering. Historian-philosopher Allan Franklin has described this work:

> The experimental results reported in the 1920s and 1930s that, at least in retrospect, showed the nonconservation of parity in weak interactions were performed by Richard Cox and his collaborators in (1928) and by his student, Carl Chaseƒ . The anomalous nature of these experimental results was fairly well known, although the exact nature of the anomaly was not clear. One thing is certain: the relationship of the results to the principle of parity conservation was not recognized or understood by any contemporary physicists, including the authors themselves.
>
> These early experiments were part of the attempt to demonstrate the vector nature of electron wavesƒ . Cox and his collaborators thought that an experiment

Fig. 6. Richard Threlkold Cox (1898Ð1991) in 1939. Credit: Photograph by Esther Mintz; courtesy of American Institute of Physics Emilio Segrè Visual Archives, Esther Mintz Collection.

in which electrons were twice scattered from metal targets would provide evidence for the vector electron. In analogy with experiments on light and X-rays, the Þrst scattering would polarize the electrons, resulting, for example, in more electrons with spin pointing in the positive x-direction than in the negative x-direction. The second scattering would detect that polarization ƒ .

[Nevill] Mott ƒ in 1929 ƒ calculated ƒ that in the double scattering of electrons from heavy nuclei at large angles there would be a difference in the number of electrons scattered in the forward and backward directions (a 0Ð180 asymmetry). If ƒ the electron beam was initially longitudinally polarized, its spin either parallel to or opposite to the electron momentum, the number of electrons scattered at 90 and at 270 would be different, a leftÐright asymmetry ƒ .

Cox and his colleagues described their experiment as follows: ÔÔIn our experiment β-particles, twice scattered at right angles, enter a Geiger counter. The relative numbers entering are noted as the angle between the initial and Þnal segments of the path is varied ƒ . [The] angles at which most of the observations have been made are indicated ƒ as 270 and 90 . The difference between the conÞgurations of the three segments of path at these two angles is the same as the difference between right- and left-handed rectangular axes ƒ .ÕÕ[23] Their targets consisted of gold plugs, and a milligram of radium, a radioactive element, was used as the source of electrons. The scattered electrons were then detected by platinum-point Geiger counters ƒ . The weighted average of their experimental results gave the ratio of the number of events at 90 to the number at 270 as 0.91 $\pm$ 0.01. This leftÐright asymmetry was a startling and unexpected result.

The experimenters then examined the possible sources of error in their experiment. They rejected all of these as unlikelyƒ . The authors offered no theoretical explanation of their results, but they did suggest that the discrepancies in their results might be attributable to a velocity-dependent inefÞciency of their Geiger countersƒ .

CoxÕs experiments were continued by Carl Chase, a graduate student working under CoxÕs supervisionƒ . By this time MottÕs 1929 calculation had appeared, and Chase remarked that he had observed a small asymmetry between the counts at 0 and 180ƒ .

Chase continued his work and found a substantial velocity dependence in the efÞciency of the Geiger countersƒ . Chase then redesigned and modiÞed his experimental apparatus, using an electroscope rather than a Geiger counter to detect the scattered electronsƒ . His new experiment gave a ratio of 0.973 ± 0.004 (counts at 90)/(counts at 270). He concluded, ÔÔThe following can be said of the present experiments: the asymmetry between the counts at 90 and 270 is always observed, which was in no sense true beforeƒ .ÕÕ In this second experiment, Chase also obtained 0Ð180 asymmetry of 0.985 ± 0.004. This time he believed that his result was not an artifact produced by his apparatus, and he did attribute it to a Mott scattering effect.

During the 1950s, after the initial experiments that demonstrated parity nonconservation, experiments on the double scattering of electrons were again performedƒ . These later experiments obtained results quite similar to those of Cox and Chase and demonstrated the nonconservation of parity. As Cox remarked later, ÔÔIt appears now in retrospect, that our experiments and those of Chase were the Þrst to show evidence for parity nonconservation in weak interactions.ÕÕ

That was not, however, the reaction of the 1930s physics communityƒ . Bernard Kurrelmeyer, a collaborator of Cox, stated, ÔÔAs to our understanding of parity, it was nearly nil. Even the term had not been coined in 1927, and remember, this experiment was planned in 1925 and none of us were theoreticiansƒ .ÕÕ Cox, in discussing the reaction of the physics community, stated, ÔÔI should say that the experiments were widely ignored,ÕÕ and he added, ÔÔOur work was, prior to 1957, generally unaccepted, disbelieved, and poorly understood. Only by viewing it from the new theoretical framework and experimental observations of the late 50s could our results be comprehended.ÕÕ[23]

Franklin concludes that the ÔÔexperiment of Cox, McIlwraith, and Kurrelmeyer and those of Chase show, at least in retrospect, the nonconservation of parityƒ . Things are not always so clear and unambiguous in the practice of science.ÕÕ[24]

Cox also wrote popular-science books, for example, *Time, Space, and Atoms*,[25] for the Century of Progress exposition at the Chicago World Fair in 1933 in which he explained, among other things, the new quantum mechanics, without equations. His wife, Shelby Shackelford, an accomplished artist, supplied the illustrations. After Cox left NYU for Johns Hopkins in 1943 he became an expert in measurement theory, publishing a well-known book on this subject.[26] The proceedings of a conference on probability was dedicated in his honor.[27]

Both before and during World War II, NYU was a hotbed of polarized-electron work. After Cox obtained his positiv e results using fast electrons from β-decay, NYU at the Heights acquired a Van de Graaff generator working at 400,000 volts. As Franklin mentioned, at about the same time, Mott published his analysis of electron scattering by heavy nuclei, that is, by nuclei of high atomic number Z, predicting that the spinÐorbit interaction between incoming electrons and highly charged nuclei should result in electron polarization, which could be observed using double scattering. Reasoning that an electrostatic high-voltage source such as a Van de Graaff machine would produce a better deÞned and controlled electron beam,subsequent experiments, of course, could not observe polarized electrons in the Þrst scattering, since the Van de Graaff electron source is unpolarized, but Mott scattering would show polarization after double scattering. A slew of suchexperiments followed.[28]

To illustrate Serge KorffÕs description of Cox as ÔÔcolorful,ÕÕ here is a poem Cox wrote to his wife Shelby.

The Passionate Physicist to His Love

Come live with me and be my love,
And we will all the theorems prove
That Planck and Einstein, Nernst and Bohr
Have added to our physics lore.

With echelons of fair design
WeÕll trace each errant spectrum line
And charm with learned BierenÕs spell
The integrals of old Fresnel.

And we will sit upon the heights
And quantify the Northern Lights
And scan the winter skies around
To Þnd the spectrum Rayleigh found.

And I will blow thee pipes of glass
And Þll them with residual gas
Where we may watch with raptured gaze
The anode and the cathode rays.

IÕll see thee tread with airy grace
MinkowskiÕs four-dimensional space
And hear thy winsome voice declare
The principle of dÕAlembert.

WeÕll watch the wave front Thomson dreams
And hear the whirling quantum streams.
And if these pleasures may thee move
Come live with me and be my love.

Gregory Breit (1899–1981)

We would date the emergence of NYUÕs physics department as a major one in the United States to the arrival of Gregory Breit (Þgure 7) to University Heights as its Chairman in 1929. He remained for just Þve years, until 1934, when he absconded Þrst to the University of Wisconsin, and then after the war in 1947 to Yale University (where he likely believed he belonged). Why did he accept the NYU position? By 1929 he had acquired a well-deserved reputation as a theoretical physicist. In 1933 John Archibald Wheeler (1911Ð2008) chose to study with Breit at University Heights before going to Niels Bohr in Copenhagen. Wheeler recalled:

> I donÕt know the how and why of that move [of Breit to NYU in 1929]. I do know he told me once about having been in an automobile accident and not having adequate insurance, so there was a big Þnancial debt up against his name and he had to pay that off year by year so that he always felt thatƒ he was strapped Þnanciallyƒ .
>
> At the time I was Þnishing my graduate work at Johns Hopkins I had to decide what I would do next. Nuclear physics was a coming Þeld, I think everybody felt at the time, and Breit had an interest both in the theoretical and the experimental side of the subject. I must have met him at some meeting and checked out that he would be agreeable to my applying for a National Research Council Fellowship to work with him for my Þrst postdoctoral year on nuclear physicsƒ . At any rate, here I ended up at New York University in September of 1933, at the end of the summer after my Ph.D. at Johns Hopkins.
>
> Why was Breit at the Bronx division of New York University rather than downtown?ƒ It was certainly an extra expense to New York University to have to operate two campuses. I think that the uptown campus always felt a little bit on the defensive, or worried about takeover by the downtown campus. I canÕt recall any speciÞc incident that showed the interaction between Breit uptown and our downtown colleagues, but there was a weekly seminar in which Rabi took a prominent part. It was Columbia, uptown, and downtown New York University. [We returned] often after the pow-wow to RabiÕs apartment about 450 Riverside Drive in New York.
>
> Breit had another National Research Council Fellow working with him, Norman Heydenburg, who was working on scattering of resonance radiation, a problem in optics which capitalized on some of the insights which were to prove later so important in nuclear physics. Breit also had going other collaborations, one with the people at the [Department of Terrestrial Magnetism at the

Fig. 7. Gregory Breit (1899Ð1981).Credit: American Institute of Physics Emilio Segrè Visual Archives.

> Carnegie Institution]. He was very keen on getting an accelerator at work there to drive protons to produce nuclear reactions. In addition he had experimental work which I think was connected directly or indirectly with that Washington project, experimental work going at New York University itself.
>
> I never saw the encounter, but I heard about itÑBreit in a disagreement with another faculty member at the uptown physics department, and them getting into a wrestling match, ending up on the ßoor.
>
> ƒ
>
> There were other people around who collaborated with Breit in one way or another. One was Jenny Rosenthal [Bramley]ƒ . [As] I recall, it had to do again with this question of resonance and scattering and the connection between the two and domains of application of a relation like the BreitÐWigner relation.[29]

During BreitÕs relatively few years at NYU a new spirit arose in the physics department. Breit knew major physicists everywhere, and most importantly, he was instrumental in instigating the formation of a city-wide seminar that met weekly alternatively at Columbia and NYU (probably at Washington Square). This joint seminar helped cement the relationship between Breit and I.I. Rabi; doubtless they had ongoing discussions concerning the effects of magnetic Þelds on the energy levels of simple one-electron atoms. One of those fortuitous facts of nature is that one-electron atoms, that is, the alkali metals, are particularly amenable to experimental atomic-beam workÑwhich Rabi and his students were carrying out at ColumbiaÑbecause they are easy to produce in a beam and easy to detect as a result of their low ionization potentials, and because of their relatively simple atomic structure were also relatively easy to deal with theoretically. We can imagine Rabi posing the problem to Breit: how would you solve the one-electron atom Schrödinger equation in the presence of a magnetic Þeld, including nuclear effects? They presented their solution, without intermediate steps or references, in a Letter to the Editor of The Physical Review.[30] Their seemingly modest contribution has developed into a cornerstone of todayÕs world of lasers and a slew of other physics-based technologies. Breit probably believed the solution was so trivial that it would not be worth Þlling in the details.

The relatively recent history of the NYU physics department can be divided roughly into Þve periods: (1) what could be called the Breit period from 1929 to 1934; (2) the prewar period from 1935 to 1941; (3) the wartime period from 1942 to 1945; (4) the postwar period from around 1961 to 1973 when the several semiautonomous physics departments (two undergraduate departments and one graduate department) were united into a single all-university department under a single head; and (5) after 1973 when the Heights campus was sold to New York City and the Heights department moved to Washington Square, which coincided roughly with the receipt of a major National Science Foundation Development Grant that was shared with the Psychology Department.

Probably the best indication of the status of the department during these periods is the papers that its faculty members published in what by 1930 had become their journal of choice, The Physical Review, although like other physicists in America they also published papers in other American and European journals. The Breit period was noted for the preponderance of theoretical papers, although Breit also encouraged experimental work. We present a complete list of the theoretical papers published in The Physical Review and Reviews of Modern Physics during BreitÕs tenure at NYU in Appendix 2), where we see that Breit himself was author or coauthor of no fewer than twenty-Þve of these papers.

In his Þrst few papers, Breit attacked the difÞcult many-body problem as applied to simple one-electron and two-electron problems,[31] becoming a pioneer in the study of complex atomic structure. GranathÕs experiments, which we have already discussed, were inspired by Breit. Most of BreitÕs coauthorsÑhis students and junior colleagues, including Edward Salant, Jenny Rosenthal, Otto Halpern, and Lawrence Wills, went on to major careers at NYU and elsewhere. In 1931 Breit and Rabi produced their famous formula describing the magnetic-Þeld effect on hyperÞne structure.[32] In general, BreitÕs interests were at the cutting edge of atomic and nuclear-structure investigations. He and his collaborators at NYU were carrying out precision hyperÞne-structure atomic-spectroscopic measurements, and he and John Wheeler were collaborating on nuclear theoryÑwhen Rabi and his students at Columbia were just beginning to use atomic beams to study nuclear spins and magnetic moments. Breit also published three highly cited papers, one with Serge Korff, on optical dispersion in the Reviews of Modern Physics in 1931Ð1932.[33] Later, as Eugene Wigner recalled, ÔÔBreit, whom I admire very much, was at New York University . He spent a year [1935Ð1936] at the Institute [for Advanced Study in Princeton] and we wrote a couple of papers together. One of them was on what people call the BreitÐWigner [nuclear-scattering] formula.ÕÕ[34]

Three of BreitÕs students and postdocs, Lawrence Wills, Harvey Hall, and Newton Gray, eventually went on to teaching careers at the City College of New York. William Nierenberg, one of RabiÕs students who became Director of the Scripps Oceanographic Institute in La Jolla, California, recalled:

> Lawrence Wills and Harvey Hall taught the mathematical physics especially well. Wills had been a student of Gregory Breit and co-authored a famous paper on hyperÞne structure [in 1933].[35] Hall was one of OppenheimerÕs Þrst students.[36]

BreitÕs other coauthors, Otto Halpern, Edward Salant, and Jenny Rosenthal Bramley, all went on to distinguished careers, Halpern at NYU, Salant at Brookhaven National Laboratory, and Rosenthal Bramley at the U.S. Army Signal Corps and Night Vision Laboratory. Salant was Associate Professor of Physics at NYU from 1929 to 1941, worked on the proximity fuse at Johns Hopkins during World War II, and then shared his time between Hopkins and NYU, working on spectroscopy and cosmic rays before moving to Brookhaven from 1947 to 1966; he ended his career at Vanderbilt University.

BreitÕs career spanned about Þfty years, as masterfully described by McAllister Hull.[37] Since he stayed at NYU for only Þve years, we will take credit for 10% of his work. But that was some 10%!Ñat a time when his principal interests were in atomic and especially nuclear structure, a Þeld that was just on the verge of bursting out of its constraints.

Otto Halpern (1899–1982)

Otto Halpern (Þgure 8) was born in Vienna and received his Ph.D. degree at the University of Vienna under Hans Thirring with a thesis on photophoresis in 1922. A decade later they coauthored a book on the new quantum mechanics,[38] which they dedicated to NYU in honor of its centenary in 1931. Then, however, after Halpern completed his thesis in Vienna, he failed to gain an appointment as Privatdozent (lecturer) owing to anti-Semitism. He nevertheless remained in Vienna until he was awarded a Rockefeller International Education Board Fellowship to work with Werner Heisenberg at the University of Leipzig in 1928Ð1929. On HeisenbergÕs recommendation, he then accepted a position at NYU and emigrated to the United States and New York in 1930. He was made Chairman of the Physics Department on BreitÕs departure in 1934 and remained at NYU until 1940. Harvey Hall recalled:

Fig. 8. Otto Halpern (1899Ð1982).Credit: Marcus Blechman; courtesy of American Institute of Physics Emilio Segrè Visual Archives.

> During those years [at NYU] he took a lively part in the sizable group of theorists that gathered in New York and held weekly colloquia at Columbia University. Alone and in collaboration with many other physicists, he investigated topics in thermodynamics, optics, physical chemistry and neutron, atomic and electron physics, ionization energy losses of fast electrons and mesons in gases and condensed bodies. His work not only brought the theory into agreement with experiment, but also led to an improved determination of meson lifetimes.[39]

Willam A. Nierenberg has commented further:

> There was another great school in physics in NYC and that was New York UniversityÑuptown on the Bronx campus ƒ . Otto Halpern was the leading theoretical light at the time and he turned out very good students. One of them was Morton Hamermesh who was my Þrst physics teacher at CCNY. NYU attracted many very good students who would not attend Columbia University. They did not like Columbia University due to the heartless, unfeeling way they treated students and, in fact, the way staff treated each other.* To some degree, NYU had the same climate some years earlier when Gregory Breit was the number one man. He was very difÞcult.

* This was exactly how one of us (BB) ended up at NYU.

> When [John H.] Van Vleck left Wisconsin [in 1934] to go to Harvard, Breit left NYU to go to Wisconsin ƒ . BreitÕs trouble was that he demanded too much from his students. Besides the ones I mentioned like Hamermesh and [Newton] Gray, there was Jenny Rosenthal. The students often had rented rooms converted from living rooms on the ground ßoor of private homes on University Avenue. The desk would be in the protuberance of the bay window. At 11 oÕclock at night he [Breit] would walk the avenue to see if the students were still at their desks. Newton Gray, in particular, swore that he would do no more research after that experience. One of the results was an addiction to the Japanese game of GO on his part along with similarly affected faculty of CCNY and NYU. Those were days when the game was relatively unknown and JapaneseÐEnglish dictionaries had to be used to interpret the available texts. Fortunately, I had absolutely no talent for the game despite two years of application.[40]

As Chairman of the Physics Department, Halpern actively encouraged interactions with other universities in New York, and was a prime mover in organizing the Columbia-NYU (as well as CCNY) physics seminars. At one of these he encountered Julian Schwinger, whom Rabi had spotted as a very young City College student and soon succeeded in getting him transferred to Columbia. One consequence was a joint Letter to the Editor of The Physical Reviewin 1935 by Halpern and the sixteen-year-old Schwinger, ÔÔOn the Polarization of Electrons by Double Scattering.ÕÕ[41] This constituted the debut of the extraordinary phenomenon of young Schwinger into the world of physics; its subject was on a theme that ran through the subsequent history of physics at NYUÑpolarized beams, as we noted above. They showed that the discrepancy between the polarization effect predicted by Mott and observations arose because the electric Þeld of the nucleus is not a Coulomb Þeld.

In 1937 Halpern and Montgomery H. Johnson, also at NYU, published an important paper on neutron scattering, analyzing the interaction caused by the magnetic moment of the neutron with the magnetic Þeld of the scatterer.[42] Clifford Shull (more on him below) acknowledged the inßuence of this work in the neutron experiments that led to his Nobel Prize in Physics for 1994.

Halpern moved to the MIT Radiation Laboratory in 1940. Harvey Hall has described his work there and subsequent career:

> Early interest in radar before World War II led Halpern to study the possibility of devising a coating of some kind, possibly for aircraft, that would absorb radar and make enemy detection and tracking difÞcult. Although it became apparent that this would not be feasible for meter-wavelength radar, Halpern soon adapted a variation and extension of the quarter-wave plate in optics, which he reasoned might be successful against centimeter wavelengths. He developed the theory and later, at the MIT Radiation Lab, directed the development of the material, known as HARP. The material was very successful in a number of applications during World War II. After the war he moved to the University of

> Southern California and then to the Lawrence Radiation Laboratory at Livermore. He investigated the effect of the Pauli exclusion principle and negative energy states in the calculation of coherent scattering of radiation. He left Livermore in 1961 when he became physically incapacitated in a car crash. He continued to write many papers and took a keen interest in questions of national defense, living in the US until 1965, then in Vienna, Þnally in London, where he remained until his death on 29 October 1982.[43]

Otto Halpern was a worthy successor to Gregory Breit at NYU, maintaining the momentum started by Breit, which was further augmented by a third dynamic leader, Allan G.C. Mitchell (see below).

Norman Hilberry (1899–1986)

Norman Hilberry began his career as Assistant Professor at the Washington Square campus in 1925. (He originally published under his full name, Horace Van Norman Hilberry, but soon dropped the foreign-appearing Horace Van.) He received his undergraduate degree at Oberlin College in 1921, and his Ph.D. degree at the University of Chicago twenty years later! At NYU he published several papers on cosmic rays, including two with Bruno Rossi (1905Ð1993),[44] whom he met at the Þrst major international conference on cosmic rays at the University of Chicago at the end of June 1939, two weeks after Rossi and his wife Nora had immigrated to the United States. Two months later, the Rossis took Hilberry along with them to the top of Mt. Evans in Colorado to carry out high-altitude cosmic-ray measurements.[45] He subsequently received his Ph.D. degree at the University of Chicago in 1941 and the following year became an assistant to Arthur H. Compton, who was then organizing the ÔÔMetallurgical Project,ÕÕ the code name for a precursor to the Manhattan Project. Hilberry became Associate Director of Argonne National Laboratory in 1946, and Director from 1957 to 1961.

Hilberry became famous as the ÔÔhatchet manÕÕ while working under Enrico Fermi in 1942 on the construction of the Þrst nuclear reactor in Chicago: During its assembly he was stationed on a balcony above the reactor with a hatchet, ready to cut a rope that was suspending cadmium control rods in case the automatic monitor failed, thereby stopping a possible runaway reaction. Figure 9 is a photograph of a 1946 reunion of the participants that shows Hilberry and also Leona Marshall (1919Ð1986), who for a time was Professor of Physics at Washington Square.

Allan C.G. Mitchell (1902–1963)

Allan Mitchell (Þgure 10) came to NYU in 1931, became Chair of the Physics Department in 1934, and left for Indiana University in 1938. During his seven years at NYU, he proved to be an extraordinary physicist and superb administrator who was

Fig. 9. Reunion of Metallurgical Laboratory alumni posing on the steps of Eckhart Hall at the University of Chicago, December 2, 1946, with the people noted in the text in boldface. Front row (left to right): Enrico Fermi, Walter Zinn, Albert Wattenberg, Herbert Anderson. Middle row (left to right): Harold Agnew, William Sturm, Harold Lichtenberger, Leona Marshall Libby, Leo Szilard. Back row (left to right): Norman Hilberry, Samuel Allison, Thomas Brill, Robert Nobles, Warren Nyer, Marvin Wilkening. Credit: Digital Photo Archive, Department of Energy (DOE); courtesy of American Institute of Physics Emilio Segrè Visual Archives.

responsible for many improvements and important appointments. And to top it off, in 1934 he and his City College colleague Mark Zemansky, then both Assistant Professors (!), published their classic book, Resonance Radiation and Excited Atoms,[46] which for years stood as the prime source for atomic-radiation physics, becoming the motherlode for this work in the postwar period when stimulated emission, population inversion, and other advances in optical and atomic physics were leading to the development of the laser. His career has been described as follows:

> Professor Mitchell was vigorously active both as an administrator and a scientist and his research interests were characteristically concerned with problems on the frontiers of physics. Between 1921 and 1927, while he was earning a doctorate in physical chemistry at the California Institute of Technology, the quantumÐmechanical behavior of atomic structures presented the urgent problems. His Þrst studies of the interactions of excited atoms with gases were

Fig. 10. Allan C.G. Mitchell (1902Ð1963). Credit: American Institute of Physics Emilio Segrè Visual Archives.

> made at Caltech and his work continued in this vein at Göttingen and Munich in 1927Ð1928, at the Bartol Research Foundation, where he was a fellow from 1928 to 1931, and at New York University between 1931 and 1934. These studies resulted in a score of experimental and theoretical papers, and culminated in his collaboration with M. Zemansky in the writing of their book *ƒ* .
>
> Upon learning of the discovery of the neutron, Prof. MitchellÕs interest shifted to neutron scattering, and between 1934 and 1938 he published a number of pioneering studies in that Þeld. During the same years, he served as chairman of New York UniversityÕs Physics Department.
>
> When he came to Indiana University in 1938, Prof. Mitchell founded its nuclear physics laboratory. He led his young department in building one of the earliest cyclotrons and initiated work in nuclear spectroscopy.[47]

Once again, while NYU cannot claim that it was at the cutting edge of optical and nuclear physics prior to World War II, we can make a strong case that NYU, now as represented by Mitchell, was a leader in contributing to the dramatic transformation in physics after the birth of quantum mechanics and the onset of the nuclear era. On a personal note, one of us (BB), while a student at City College, had Mark Zemansky as a teacher in both mechanics and thermodynamics, both truly memorable courses.

Some Outstanding Graduate Students

A number of NYU graduate students during the prewar and wartime periods later went on to distinguished careers, including Jenny Rosenthal Bramley, Allen V. Astin, Morton Hamermesh, Henry Primakoff, Theodore Holstein, John A. Simpson, Gerald Goertzel, Arthur Roberts, Clifford Shull, Frederick Reines, Francis A. Jenkins, Edward O. Salant, and Eugene Feenberg. Several were elected to the National Academy of Sciences; all made signiÞcant contributions to physics.

Jenny Rosenthal Bramley (1909–1997)

Jenny Rosenthal Bramley (Þgure 11) had a varied and colorful career. Her obituary in *The New York Times* of June 2, 1997, states:

> Dr. Bramley, born Jenny Rosenthal in Moscow, earned a bachelorÕs degree at 16 at the University of Paris. She promptly sailed to New York, where she began her graduate studies at New York University. She earned a doctorate in 1929 at 19 [with Breit] ƒ . She did research at Johns Hopkins University and the University of Michigan and taught at Brooklyn College and New York University ƒ . Later, Dr. Jenny Bramley worked for the Navy designing cathode ray tubes.

Fig. 11. Jenny Rosenthal Bramley (1909Ð1997). Credit: American Institute of Physics Emilio Segrè Visual Archives, Goudsmit Collection.

One of us (HHS) has written an appreciation of her in the NYU Alumni Magazine (January 23, 2002):

> For those of us, atomic physicists engaged in the study of hyperÞne structure and isotope shifts, the name of Jenny Rosenthal is known from the very Þrst. HyperÞne structure in the atomic spectrum displays the effect of magnetic and electric multipole interactions of the nucleus with the atomic electron. Isotope shifts come in a couple of varieties: mass-dependent effects with which we are familiar from elementary atomic physics, when we learn that hydrogen and deuterium have slightly displaced spectral lines caused by the differences in mass between the nuclei of ^{1}H and ^{2}H. What Jenny Rosenthal studied at the old University Heights campus in the Bronx was the effect of the spatial distribution of the nuclear electric charge on the electronÐnuclear interaction. The work that she published [in 1932] with her advisor, Gregory Breit,[48]ƒ accounted for both the overall shift in energy levels caused by the Þnite nuclear charge distribution and the isotopic differences caused by the changes in nuclear radius. This is known as the volume-dependent isotope shift it served as one of the early ways to determine nuclear radii. She also calculated the effect of this distributed nuclear charge on the magnetic dipole hyperÞne interaction and its isotopic effect. The latter has become known in the literature as the BreitÐRosenthal correction.
>
> I met Jenny Rosenthal a half century after this work when she visited the Physics Department. She had left hyperÞne structure and isotope shift after her thesis work, ending up working for the Army Ordnance. In talking with her I realized that she was completely unaware that her name was attached to an effect in physics and that the BreitÐRosenthal correction is used in the analysis of such experiments to this day. How many of us, working in physics, would be eager to have our name perpetuated in this way!
>
> Jenny Rosenthal Bramley was a faithful alumna of New York University. She provided funds for an endowment to support spectroscopy in the Physics Department: the laboratory of Professor Tycho Sleator now carries the name ÔÔJenny Rosenthal Bramley Laser Spectroscopy Laboratory.[49]ÕÕ

Allen V. Astin (1905–1984)

Alan V. Astin received his Ph.D. degree in 1928, apparently with William A. Lynch as advisor, though he credits John C. Hubbard (who by then had moved to Johns Hopkins University) with having suggested his thesis subject. Astin went on to a distinguished career in applied physics, Þrst working on radio transmission and proximity fuses during World War II, which played a critical role in countering enemy bombing, and then becoming Director of the National Bureau of Standards (NBS) from 1952 to 1967.

In an unforeseen twist of fate, an incident while he was Director of the NBS brought him unexpected (and unwanted) celebrity and also played a major role in the seemingly perpetual conßict between science and politicsÑor should we say, money. His leadership at the NBS was interrupted by the famous (or infamous) AD-X2 battery-additive case. After ruling that this product was ineffective (as a result of intensive laboratory tests by NBS scientists), Astin was summarily Þred by the U.S. Secretary of Commerce, Sinclair Weeks. This caused an uproar in the scientiÞc community because of the clear inßuence of business interests over scientiÞc integrity. AstinÕs defense of the NBS position on AD-X2 was ultimately conÞrmed by independent evaluation, and the wall between science and politics was thereby signiÞcantly strengthened. He was elected to the National Academy of Sciences in 1960 and served as its home secretary after his retirement in 1967.

Morton Hamermesh (1915–2003)

Morton Hamermesh (Þgure 12), a CCNY undergraduate, received his Ph.D. degree at NYU in 1940, stayed on for a year as Instructor in Physics, and then took up two two-year wartime appointments at Stanford and Harvard before returning to NYU as Assistant and Associate Professor of Physics from 1946Ð1948. He then moved to Argonne National Laboratory where he was promoted from Senior Physicist to Associate Director of the Physics Division in 1950, where he established the style that a scientistÕs prime responsibility is to do Þrst-rate science and managementÕs role is to protect scientists from bureaucratic distractions. He joined the University of Minnesota as Professor and Head of the School of Physics and Astronomy in 1965, left for a similar post at the State University of New York in 1969, but one year later returned to his former position at Minnesota, which he held until 1975. He retired in 1985 but remained at Minnesota as an esteemed colleague, mentor, and friend until his death in 2003.

A theoretical nuclear physicist, Hamermesh made many important contributions to his Þeld. He studied the magnetic properties of the neutron. He contributed to the understanding of how Mössbauer spectroscopy works and to the design of particle accelerators. During his career, Hamermesh worked with four Nobel Prize-winners: Clifford Shull, Felix Bloch, John H. Van Vleck, and Julian Schwinger. HamermeshÕs 1962 book, Group Theory and its Applications to Physical Problems,[50] became a classic text, explaining mathematical principles important in physics to a wide readership. With a passion for languages and ßuent in Russian, Hamermesh translated L D. Landau and E.M. LifshitzÕs famous text, The Classical Theory of Fields,[51] into English, thereby alerting many readers to the riches in their books. He also was a world-class chess player. He came in sixth in the U.S. Chess Open in 1945, and he once played against a Grand Master, Samuel Rashevsky, who listed that game as being among the top 100 games of his career.[52] He was Editor of the Journal of Mathematical Physics, the major journal in its Þeld, from 1970 to 1978. He received the Townsend Harris Medal from CCNY in 1966, an honor he shared with other CCNY alumni such as Felix Frankfurter, Jonas Salk, and Colin Powell.

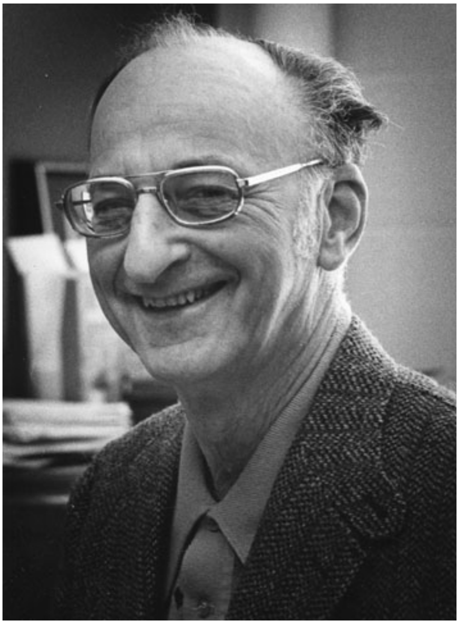

Fig. 12. Morton Hamermesh (1915Ð2003).Credit: American Institute of Physics Emilio Segrè Visual Archives, Physics Today Collection.

Henry Primakoff (1914–1983)

Henry Primakoff (Þgure 13), after graduating from Columbia University, spent a year as a graduate student at Princeton University and then came to NYU on a fellowship, completing his Ph.D. thesis in 1938. As was characteristic of those uncertain times, he then took teaching positions Þrst at Brooklyn Polytechnic Institute, followed by one at Queens College. Immediately after the war, he returned to NYU with a joint appointment in physics and in the Institute for Mathematical Science, later renamed the Courant Institute, on the initiative of Richard Courant himself. A year later he joined the Physics Department of Washington University in St. Louis, and in 1961 he moved to the University of Pennsylvania in Philadelphia where he remained for the rest of his career. Among his honors was election to the National Academy of Sciences.[53]

Primakoff wrote his Þrst paper while an NYU graduate student on second and higher-order processes in the neutrino-electron theory.[54] In it he and his coauthor, Montgomery H. Johnson (1907Ð1984), an excellent NYU faculty member in his own right, calculated the forces between neutrons and protons owing to the exchange of virtual neutrino-electron pairs in the new Fermi theory of beta decay. It was a harbinger of one of PrimakoffÕs future major interests, the study of weak interactions in nuclei.

Fig. 13. Henry Primakoff (1914Ð1983). Credit: Washington University, American Institute of Physics Emilio Segrè Visual Archives, Physics Today Collection.

Still at NYU, on a totally different topic, Primakoff and his fellow student Ted Holstein published a paper, soon to become famous, on the Þeld dependence of the intrinsic magnetization of a ferromagnet at low temperatures.[55] They succeeded in diagonalizing the Hamiltonian, including magnetic interactions as well as exchange and dipoleÐdipole interactions, showing that the spin is not localized on a particular atom, but propagated through a crystal in spin waves. Their paper has been cited almost 1,000 times, and a slew of papers on spin waves that followed demonstrated that Holstein and Primakoff initiated the entire subject.

At Washington University Primakoff collaborated with Eugene Feenberg (see below) on two papers, one on collapsed nuclei, which anticipated later ideas of T.D. Lee and G.C. Wick on superdense matter, and one on the interaction of cosmic-ray primaries with starlight and sunlight, which showed that cosmic-ray primaries should consist mainly of protons, because energetic electrons would undergo too much scattering from photons in intergalactic space (through the inverse Compton effect) to reach the vicinity of the Earth. Primakoff also wrote papers on muon decay, muon capture, and hypernuclei, which were of considerable interest to cosmic-ray physicists, the intellectual forerunners of todayÕs high-energy physicists.

Theodore Holstein (1915–1985)

Theodore Holstein (Þgure 14) earned his B.S. degree at NYU in 1935, his M.S. degree at Columbia University in 1936, and his Ph.D. degree at NYU in 1940. Following a short stay at CCNY, Holstein went to Westinghouse Research Laboratories in Pittsburgh, where he worked from 1941 until 1959. During this period he was primarily concerned with theoretical atomic physics, but beginning in the mid-1950s he devoted himself increasingly to solid-state physics, publishing papers on the optical and galvanomagnetic properties of metals and the Þrst two of his well-known set of polaron papers (see below). He joined the Physics Department of the University of Pittsburgh in 1959 and moved to Los Angeles in 1965. Although he continued his research in atomic physics, his efforts from about 1960 until his death were primarily directed toward electron and energy transport in solids.

HolsteinÕs earliest research, performed with Henry Primakoff while he was a graduate student at NYU, resulted in the Þrst paper on the strong three-body force in nuclear physics.[56] In 1940, again with Primakoff, he published his Þrst paper in solid-state physics, setting forth the famous HolsteinÐPrimakoff formulation of quantum spin-wave dynamics.[57] In the mid-1940s he began working on gas discharges, doubtless because of his afÞliation with Westinghouse, which was then a center for such work. His most important contributions here centered on the imprisonment of resonance radiationÑa critical problem for ßuorescent-light

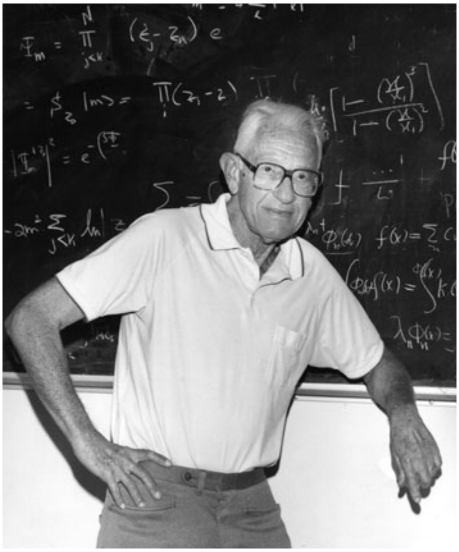

Fig. 14. Theodore Hostein (1915Ð1985). Credit: Kimberly J. Willis, University of California at Los Angeles; courtesy of American Institute of Physics Emilio Segrè Visual Archives.

sources. Further work in atomic physics included studies of the broadening of spectral lines.

The Þeld to which Holstein was most devoted, however, and to which he made his greatest contributions, was solid-state physics. Research on infrared absorption in metals in the early and mid-1950s was followed by the work with which his name is now inextricably linked, a series of monumental papers on polaron dynamics. Four papers, published from 1959 to 1969 in the *Annals of Physics*, constitute the magnum opus on the topic.[58] In 203 pages Holstein described the system, set up the formalism, and solved a series of fundamental problems. This work remains as the standard reference on the theory of small polarons. His interests in solid-state physics ranged over the entire Þeld. He made important contributions to the theories of ultrasonic attenuation in metals, the quantum Hall effect, and various types of transport phenomena. His Þnal effort was an attempt to understand and to formulate a model for charge transport in charge-density wave systems.

Holstein was elected to the National Academy of Sciences in 1981.[59]

John A. Simpson (1917–2000)

John Simpson (Þgure 15) was a graduate student of Serge Korff (see below), so his introduction to physics was in cosmic rays. After receiving his A.B. degree from Reed College in 1940 and his Ph.D. degree from NYU in 1943, he became a scientiÞc group leader for the Manhattan Project in Chicago, developing instrumentation for measuring high-intensity radiation. After the war, he applied the techniques he had developed to the study of cosmic radiation, which led directly to his invention of the monitor for measuring atmospheric neutrons produced when cosmic rays impinge on the atmosphere. This became a standard instrument for studying cosmic-ray intensity variations, and is still used throughout the world. In 1956 Simpson and colleagues were instrumental in the discovery of the heliosphere, an extended region of magnetic Þelds surrounding the Sun. Much of SimpsonÕs subsequent scientiÞc career was involved with the exploration of the heliosphere.

In 1945 Simpson helped to found the Atomic Scientists of Chicago and to launch the *Bulletin of the Atomic Scientists*. Serving as its Þrst chairman, he set the direction for this important journal, which continues to advocate international weapons control and responsible application of science to world problems. In 1957Ð1958 he was one of twelve scientiÞc organizers of the International Geophysical Year, and from 1965Ð1967 he also served as Chairman of the International Commission on Cosmic Radiation, part of the International Union of Pure and Applied Physics, which fosters international communication and coordination among scientists.

Simpson was among the Þrst to take the study of cosmic rays into space. His Þrst space experiment was carried on the Explorer 6 Earth satellite in 1959, and during his career his instruments were carried on more than thirty space missions. In 1962 he was instrumental in creating the Laboratory for Astrophysics and Space Research at the University of Chicago, where almost all of his instruments were

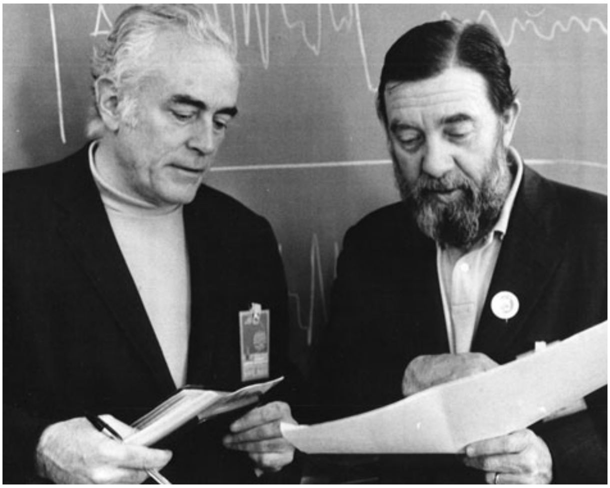

Fig. 15. John Alexander Simpson (1917Ð2000) and James Van Allen (1914Ð2006) at the Ames Research Center in Mountain View, California, ca. 1974. Credit: NASA; courtesy of American Institute of Physics Emilio Segrè Visual Archives.

designed and built, and where the ßight results were analyzed. In the mid-1980s, when he was almost 70, he invented a completely new type of detector for high-velocity dust particles, which opened a new direction for his research. These detectors so far have found application in studies of dust particles in space on Þve missions, including the Soviet Vega missions to comet Halley and the current Cassini mission to Saturn.

Among his many honors, Simpson was elected to the National Academy of Sciences.[60] Throughout his career he remained a close professional colleague of his former thesis advisor, Serge Korff.

Gerald Goertzel (1919–2002)

Goertzel obtained his Ph.D. degree at NYU in 1947 under Irving S. Lowen with a thesis on the angular correlation of gamma rays. He joined the Washington Square faculty in 1948 for four or Þve years, becoming along the way a nuclear-reactor expert. In 1994 the mathematician Herbert Wilf recalled his association with Goertzel.

> Among all of the scientiÞc staff, I remember Gerald Goertzel as one who inßuenced me very profoundly. He was at the time a Professor of Physics at NYU. In 1952, when I met him, it was, for me anyway, the dawn of the computer era, and I was doing as much programming as I could because I enjoyed it. Jerry taught me about programming and about computers. His world view was

> modular. I hadnÕt ever heard of modularity before and I found it very impressive. It meant that the way to create a complex system was to break it down into small subsystems, and to describe the desired input and output of each subsystem totally independently of all of the others. If that were done diligently then one could parcel out the various subsystems to different people or groups and ask each of them to create their assigned subsystem independently. Then all of them would be collected, wired together, and would work perfectly the Þrst time, or so the scenario went.
>
> This philosophy of wiring together little black boxes with speciÞed inputs and outputs in order to make a complex system was very profound and very effective, and Jerry Goertzel instructed me in that thought process quite thoroughly. I remember well the patience and the good humor and the joy of discovery that he brought to his work and to his mentoring of me. The combination of his personality and his forceful ideas was very potent medicine for me.[61]

Arthur Roberts (1912–2004)

Another noteworthy NYU graduate was the inimitable Arthur Roberts. Before coming to NYU, he attended the Manhattan School of Music, obtaining a piano diploma, and also Columbia University for a short time. He completed his Ph.D. degree under Frank Myers in 1936 with a thesis on the variations of range with angle of the disintegration of Li ^{7}. Roberts was exceptional in being both a Þrst-rate musician and an excellent physicist. He taught music to physicists, composed, and performed. He is particularly famous for his physics songs, which were all the rage in the late 1940s and early 1950s. Here is a short segment of what is probably his most famous song:

> Take away your billion dollars, take away your tainted gold,
> You can keep your damn ten billion volts, my soul will not be sold.
> Take away your army generals; their kiss is death, IÕm sure.
> Everything I build is mine, and every volt I make is pure.
> Take away your integration; let us learn and let us teach,
> Oh, beware this epidemic Berkelitis, I beseech.
> Oh, dammit! Engineering isnÕt physics, is that plain?
> Take, oh take, your billion dollars, letÕs be physicists again.[62]

Notwithstanding his musical talent he became an outstanding nuclear physicist at the University of Chicago, the Argonne National Laboratory, and Fermilab. His love for music lasted throughout his life.

Clifford Glenwood Shull (1916–2001)

Clifford Shull (Þgure 16) shared the Nobel Prize in Physics for 1994 ÔÔfor the development of the neutron diffraction technique.ÕÕ[63] Shull understood very early that the neutron would be an ideal probe for studying matter in the condensed state, because its lack of electronic charge would allow it to interact essentially exclusively with the nuclei of atoms. His later work on neutron diffraction earned him the Nobel Prize. Shull described in some detail his time at NYU:

> [I entered] graduate school at New York University in the fall of 1937.
>
> New York University was then a very large university, perhaps the largest in the nation, with several distributed, more or less autonomous, campuses. I was located with the Physics Department at the University Heights campus in the upper Bronx section of New York City and my teaching assistantship provided living subsistence, teaching meaning laboratory course help and problem assignment grading. We graduate students were encouraged at an early stage to join and help in one of the half dozen or so ongoing research projects within the department. I became associated with a nuclear physics group headed by Frank Myers and Robert Huntoon, who were in the process of building a 200 keV CockcroftÐWalton generator for accelerating deuterons. Much valuable experience was obtained with this exposure by Craig Crenshaw, another graduate student, and myself and we were able to help in the initial experiment with this accelerator, a study of the DÐD [deuteronÐdeuteron] nuclear reaction.
>
> During the third year of my graduate study, the Department decided that it could support the construction of a new 400 keV Van de Graaff generator to be

Fig. 16. Clifford Glenwood Shull (1916Ð2001). Credit: American Institute of Physics Emilio Segrè Visual Archives.

used for accelerating electrons. Frank Myers took on this responsibility with me as his assistant and the thought that it could be used to repeat the electron-double-scattering (EDS) experiment as a possible thesis topic for me. This EDS type of experiment loomed important at the time because it was considered a direct test that electrons have a spin or polarization. Several earlier experiments had given either negative or inconclusive results and it seemed worthwhile that the experiment be performed again under new conditions. The construction and testing of the new facility went smoothly and I turned to getting ready for my thesis EDS experiment. By this time, Frank Myers had decided to take his overdue sabbatical leave with Robert Van de Graaff at MIT. I was fortunate in getting Richard Cox, a senior professor in the department, to supervise and offer expert and friendly advice on my efforts. Finally after four months of data collection and analysis, the experiment was successful and I was able to prepare a thesis and take my PhD degree in June 1941.

Among the other research programs being pursued by the NYU department was the study of neutron interactions with materials as started by Alan [sic] Mitchell and carried on by Martin Whitaker. Using a RaÐBe neutron source surrounded by a parafÞn howitzer, a modest beam of thermalized neutrons was available for experimentation and, during my period at the Heights, this was directed towards a search for the expected paramagnetic scattering from certain materials. Theoretical prediction of this had been given by O. Halpern and M. Johnson and their students in the Department. I was familiar with this problem through my contemporary graduate student William Bright who worked with Whitaker on the experiment and indeed found myself working on the same problem a decade later.[64]

Shull described the environment in which he performed his Ph.D. research in the acknowledgements of his (unpublished) thesis, which was entitled ÔÔDouble Scattering of Electrons as a Search for Electron PolarizationÕÕ:

A list of the people who have assisted me in this problem, and the work leading up to the problem, would look like the Physics Department directory.[65] All of the preliminary work of generator construction and the research problem itself has been under the immediate supervision of Dr. F.E. Myers, who has, needless to say, given invaluable assistance and advice. To Professors Cox and Chase who have given so graciously and helpfully their time, effort and encouragement, must go the authorÕs sincere appreciation. Acknowledgement to Dr. Morton Hamermesh for generous assistance in the generator construction, as well as an acknowledgment to Dr. M.D. Whitaker whose electrical counting equipment must not be omitted.

The laboratory at what became Oak Ridge National Laboratory where he carried out his Nobel Prize-winning work now awards a Shull Fellowship in his honor. Among his many other honors, he was elected to the National Academy of Sciences.[66]

Frederick Reines (1918–1998)

Fred Reines (Þgure 17) shared the Nobel Prize in Physics for 1995 ÔÔfor the detection of the neutrino.ÕÕ[67] The seeds for his experiment were planted when he came to NYU as a graduate student in 1940. He Þrst worked for Serge Korff on cosmic rays but soon became interested in nuclear Þssion and received his Ph.D. degree under Richard D. Present in 1944 with a thesis on ÔÔNuclear Fission and the Liquid Drop Model.ÕÕ Even before receiving it, however, he found himself at Los Alamos, where his career ßourished. His thesis was eventually published after the war as a short note in *The Physical Review* entitled ÔÔThe Liquid Drop Model for Nuclear Fission,ÕÕ with Present and Julian K. Knipp of Purdue University as coauthors.[68] The Þrst footnote to their article states that, ÔÔThis work was begun in 1940 and completed in 1943. It was voluntarily withheld from publication until the end of the war.ÕÕ Reines reßected on his quest for the neutrino in his Nobel Lecture on December 8, 1995.

> I was involved during, and then subsequent to, the war in the testing of nuclear bombs, and several of us wondered whether this man-made star could be used to advance our knowledge of physicsƒ .
>
> Then in 1951, following the tests at Eniwetok Atoll in the PaciÞc, I decided I really would like to do some fundamental physics. Accordingly, I approached my boss, Los Alamos Theoretical Division Leader, J. Carson Mark, and asked him for a leave in residence so that I could ponder. He agreed, and I moved to a stark empty ofÞce, staring at a blank pad for several months searching for a meaningful question worthy of a lifeÕs work. It was a very difÞcult time. The months passed and all I could dredge up out of the subconscious was the possible utility of a bomb for the direct detection of neutrinos ƒ .
>
> It happened during the summer of 1951 that Enrico Fermi was at Los Alamos, and so I went down the hall, knocked timidly on the door and said, ÔÔIÕd like to talk to you a few minutes about the possibility of neutrino detection.ÕÕ He was very pleasant, and said, ÔÔWell, tell me whatÕs on your mind?ÕÕ I said, ÔÔFirst off as to the source, I think that the bomb is best.ÕÕ After a momentÕs thought he said, ÔÔYes, the bomb is the best source.ÕÕ So far, so good! Then I said, ÔÔBut one needs a detector which is so big. I donÕt know how to make such a detector.ÕÕ He thought about it some and said he didnÕt either. Coming from the Master that was very crushing. I put it on the back burner until a chance conversation with Clyde Cowan. We were on our way to Princeton to talk with Lyman Spitzer about controlled fusion when the airplane was grounded in Kansas City because of engine trouble. At loose ends we wandered around the place, and started to discuss what to do thatÕs interesting in physics. ÔÔLetÕs do a real challenging problem,ÕÕ I said. He said, ÔÔLetÕs work on positronium.ÕÕ I said, ÔÔNo, positronium is a very good thing but Martin Deutsch has that sewed-up. So letÕs not work on positronium.ÕÕ Then I said, ÔÔClyde letÕs work on the neutrino.ÕÕ His immediate response was, ÔÔGREAT IDEA.ÕÕ He knew as little about the neutrino as I did

Fig. 17. Frederick Reines (1918Ð1998).Credit: Los Alamos Photo Laboratory; courtesy of American Institute of Physics Emilio Segrè Visual Archives.

> but he was a good experimentalist with a sense of derring-do. So we shook hands and got off to working on neutrinos.
>
> *ƒ*
>
> However attractive the neutrino was as an explanation for beta decay, the proof of its existence had to be derived from an observation at a location other than that at which the decay process occurredÑthe neutrino had to be observed in its free state to interact with matter at a remote point.
>
> It must be recognized, however, that, independently of the observation of a free neutrino interaction with matter, the theory was so attractive in its explanation of beta decay that belief in the neutrino as a ÔÔrealÕÕ entity was general. Despite this widespread belief, the free neutrinoÕs apparent undetectability led it to be described as ÔÔelusive, a poltergeist.ÕÕ
>
> So why did we want to detect the free neutrino? Because everybody said, you couldnÕt do it. Not very sensible, but we were attracted by the challenge. After all, we had a bomb which constituted an excellent intense neutrino source. So, maybe we had an edge on others. Well, once again being brash, but nevertheless having a certain respect for certain authorities, I commented in this vein to Fermi, who agreed*ƒ* .[69]

Reines was extremely outgoing, generous with his help to students and junior colleagues. One of us (BB) well remembers a conversation he had with Reines while he was a soldier at Los Alamos during the war. Reines approached him and queried him in detail about the work he was doing. Reines was very encouraging, and offered invaluable advice on his experiment. But here too is an interesting lesson to be learned by anyone starting a career in physics: Reines essentially withdrew from day-to-day research to contemplate his future. He asked himself a simple question: what is the most important experiment I can do in my life? Fortunately, his boss gave him the luxury of thinking, in his ofÞce, without the need to do hands-on work.

Reines became Professor and Head of the Department of Physics at Case Institute of Technology in Cleveland, Ohio, in 1959, and moved to the University of California at Irvine as the founding Dean of its School of Physical Sciences in 1966. Among his many other honors, he was elected to the National Academy of Sciences.[70]

Francis A. Jenkins (1899–1960)

Francis Jenkins was at NYU only for a short time, from 1927 to 1929, but he did some important work there. He went on to a ßourishing career at the University of California at Berkeley. His principal research interest was always molecular spectroscopy. At NYU he published several papers on this subject, both with his student Jenny Rosenthal and with Robert Mullikan (who brought him to NYU from Harvard). He spent his time at NYU fruitfully by analyzing data previously taken at Harvard. He published with Mullikan a major study of the molecular bands of nitric oxide,[71] and with Rosenthal he showed that quantum analyses of boron and beryllium oxides required the use of half-integral quantum numbers,[72] the Þrst application of the new quantum mechanics to molecular spectroscopy. He is also well known for his and Harvey WhiteÕs classic textbook, Fundamentals of Optics.[73]

Edward O. Salant (1901–1979)

Ed Salant was Associate Professor of Physics at Washington Square from 1929 to 1941 and continued to work part time at NYU until 1948 while working primarily at Brookhaven National Laboratory, where he remained until 1967. He was a very versatile physicist. His Þrst two publications at NYU were an experimental paper on the scattering of mercury resonance lines by HCl and HBr and a theoretical paper with Breit on frequency shifts in the scattering of mercury resonance radiation on polar molecules in liquids.[74] There followed a number of experimental and theoretical papers, mostly on scattering in liquids; several of these were with Jenny Rosenthal.[75] In 1939 his interests moved on to nuclear physics, and he performed measurements on both resonance absorption and scattering of slow and fast neutrons by light atoms. During the war he worked on proximity fuses at Johns Hopkins, until he became attached to the Alsos Mission headed by Samuel Goudsmit whose purpose was to determine the progress the Germans had made in developing an atomic bomb (not much, as it turned out).[76] At Brookhaven after the war he worked mostly on cosmic rays, Þnally going to Vanderbilt University about 1968.

Eugene Feenberg (1906–1977)

Eugene Feenberg was a faculty member at Washington Square from 1938 through World War II, although during the last several wartime years he was on leave to perform military radar research elsewhere. He received his Ph.D. degree at Harvard in 1933, stayed on as an Instructor in Physics for two years, and held appointments at the University of Wisconsin and the Institute for Advanced Study in Princeton before coming to NYU. He became one of the most important theoretical physicists in the United States, working on many aspects of many-body theory as applied to both atomic and nuclear physics, for example, in quantum ßuids, general quantum theory, nuclear shell structure, and elementary excitations. During his years at NYU he published papers on the shape and stability of heavy nuclei, the spacing and energy levels in light nuclei, and symmetry effects in the spacing of nuclear energy levels. In 1946 he joined Washington University in St. Louis and remained there for the rest of his career. A memorial medal in his honor is issued periodically by the International Conference on Many Body Physics.

FeenbergÕs productivity during his few years at NYU was prodigious. Among the coauthors of his papers in *The Physical Review* were Melba Phillips, Eugene Wigner, Gregory Breit, John Bardeen, and Lloyd MotzÑquite a collection! Among his honors, he was elected to the National Academy of Sciences.[77]

Serge Korff (1906–1989)

Serge Korff (Þgure 18) joined the NYU Physics Department in 1941 and remained an active member of it until his death in 1989. An early indication of his quality as a physicist is an extraordinary paper he published with Gregory Breit on optical dispersion in the *Reviews of Modern Physics* in 1932,[78] while he was a National Research Fellow at Mt. Wilson Observatory. It is a masterful summary of the state of theoretical and experimental optical-dispersion physics, then one of the central themes of physics, the interaction of light and matter. Korff published a number of papers on spectroscopy before coming to NYU, but by then his interest had evolved into geophysical, and most importantly, cosmic-ray physics. He developed a major research group at NYU in this Þeld, and became famous for his numerous balloon ßights and expeditions throughout the world. He described some of his work at NYU in a 1951 article in *Physics Today*.[79] There is a substantial Korff collection in the NYU Archives,[80] which includes a short history of NYU physics spanning the period 1940Ð1970 that we reproduce in Appendix 3, and the following brief biography:

Sergei Alexander Korff was born in Helsingfors, Finland, in 1906. Immigrating to the United States with his family in 1917, he became a citizen in 1927. Korff attended Princeton receiving his A.B. in 1928, M.A. in 1929 and Ph.D. in 1931. Between 1932 and 1940, he completed research fellowships at the Mt. Wilson Observatory, the California Institute of Technology, the Carnegie Institute of Washington, and the Bartol Research Foundation. Collaborating with eminent physicists in his early work, Korff investigated topics such as optical dispersion, proportional counters and neutron measurements in cosmic radiation. Korff began his tenure at New York University in 1941, and continued there until his death in 1989. He helped train at least three generations of students, taking many on research expeditions as far away as the North Pole and the South Seas.

In addition to his teaching and research, Korff lent his efforts to the international scientiÞc community. He compiled the report of the Joint Commission on High Altitude Research for ICSU-UNESCO [International Council for Science-United Nations Educational, ScientiÞc and Cultural Organization]; served on the Cosmic Ray Technical Panel for the International Geophysical Year, 1957Ð1958; organized the pole-to-pole Rockwell ScientiÞc Round-the-World Flight in 1965; and encouraged and secured support for scientiÞc work

Fig. 18. Serge Korff (1906Ð1989). Credit: Photograph by William Simmons; courtesy of American Institute of Physics Emilio Segrè Visual Archives, Physics Today Collection.

> around the world, particularly in Central and South America. Notable among his numerous professional afÞliations were his terms as president of the ExplorerÕs Club (1955Ð1958); the American Geographical Society (1966Ð1971); and New York Academy of Science (1972). For his efforts to transfer surplus scientiÞc equipment to the decimated laboratories of France after World War II, in 1952 Korff was decorated Chevalier of the Legion of Honor. For the contribution of his radiation detection devices to the study of cancer, he was awarded the Curie Medal of the International Union Against Cancer.
>
> KorffÕs Counter Project and Cosmic Ray Project attracted numerous students to NYU; many later achieved prominence as physicists. The project also brought the university substantial funding from government agencies, such as the National Air and Space Agency and the National Science Foundation. Author of over 150 scientiÞc papers and books, as well as a number of works on exploration, geology and stamps, KorffÕs contributions to science went beyond the study of cosmic raysƒ .

The NYU Korff collection covers all of his activities above. It contains ten linear feet of correspondence, notes, photographs, manuscripts, and printed materials documenting research grants, academic activities, professional organizations, conferences, and publications from 1928 to 1989,[81] the bulk of which is from 1950Ð1980. Missing from the collection are materials pertaining to his work prior to his afÞliation with NYU and to his activities during World War II. In general, the Korff Collection offers critical insight into twentieth-century physics, and science generally. SigniÞcant topics include the study of cosmic rays, neutrons, and optical dispersion; the theory, development, and uses of devices for measuring radiation; radiocarbon dating; physics research and its social and political contexts around the world; international scientiÞc cooperation, particularly the International Geophysical Year 1957Ð1958; observations of eclipses and astronomical events; high-altitude balloon ßights; and government and military funding of scientiÞc research.

Postwar

As noted above, in the prewar and wartime periods many of the best, most promising young physics faculty members eventually left NYU to pursue outstanding careers elsewhereÑa phenomenon that also played a role in setting the postwar character of the department. While many of AmericaÕs most important physics departments consciously decided to keep their faculties, where possible, and to exploit wartime priorities to build and increase their strengths, at NYU the emphasis before and during the war was on teaching, especially military trainees. No major military projects were initiated, so it was difÞcult to build on existing resources after the war when physicists returned to academia, an opportunity that other physics departments exploited to greater advantage.

Nonetheless, the physics departments at both University Heights and Washington Square gradually grew in both quantity and quality. From the late 1940s into the 1960s, NYU ofÞcially had two somewhat independent departments, although students could take courses at both centers. The Heights department had a permanent faculty consisting of Joseph C. Boyce, Yardley Beers, Leon Fisher, George Hudson, Sidney Borowitz, Fritz Reiche (in an adjunct appointment),[82] Benjamin Bederson (since 1952), Bruno Zumino (1951), Lyle Borst (1954), and John Lamarsh (1957). At Washington Square were Gerry Goertzel (1948), Hartmut Kallmann (1949), Fritz Rohrbaugh (1950), Larry Spruch (1950), Robert Hatcher (1951), and Morris Shamos (1951). In 1961 physics was uniÞed under a single head, the Þrst one being Bruno Zumino, who returned to NYU after leaving temporarily for two years in 1957. One could argue that there was yet another, phantom department housed within the Courant Institute, since many of its faculty members were theoretical physicists, and important applied research was being conducted there, especially in plasma-fusion research and ßuid dynamics. We summarize the principal postwar appointments (we exclude many other, short-term appointments) up to 2000 in Appendix 4.

Hartmut Kallmann (1896–1978)

Grace Marmor Spruch of Rutgers University Newark, who was a student of Hartmut Kallmann (Þgure 19), has described his career and work.

> Born in Berlin of wealthy parents, he grew up in a home frequented by persons prominent in industry and the arts. Although afßicted by severe illness in childhood, all that could later be associated with the ordeal were a limp and a powerful will.
>
> After completing his PhD thesis on the speciÞc heat of molecular hydrogen under Max Planck in 1920, he went to BerlinÕs Kaiser Wilhelm Institute, headed by Fritz Haber. There he developed mass-spectrographic methods for investigating ionization energies and reactions of molecular ions, and published theoretical papers on nuclear resonances, polarization, and, with Fritz London, on the quantum theory of anomalous collision cross sections in molecular reactions. Application of the mass spectrographic methods to nuclear reactions resulted in a means for accelerating particles to energies of 1 MeV through charge exchange and multiple accelerations through the same voltage. This, in turn, led to a method for producing neutronsƒ for use in neutron photography (radiography).[83]

During the war, while seven-eigths Jewish by HitlerÕs reckoning, Kallmann was able to survive in Berlin because his wife was non-Jewish, and with the help of friends such as Max von Laue. He invented the scintillation counter during this period.

> Demonstration of the counter in 1947 was followed by an invitation to the United States. After some months with the Army Signal Corps, Kallmann accepted a [full] professorship at New York University. There he established the Radiation and Solid State Laboratory. Over the next twenty years he did seminal work on liquid scintillators [with many graduate students and postdocs] andƒ with [the Chemistry DepartmentÕs] Martin Popeƒ .[84]

The story of how German «migr«s fared when they left Europe for the United States is a mixed one. While many of those distinguished scientists managed to reestablish careers in their new country, many did not, particularly experimentalists. Kallmann, however, was an extremely successful transplant. During his career in Germany he published a total of 75 papers. In the roughly nineteen years he spent at NYU he published 125!

Gerald Hine has emphasized the inßuence of KallmannÕs work: ÔÔThe modern photoelectric scintillation detector emerged just 30 years ago out of the rubble of World War II. Kallmann in Germany had the original idea of combining an organic ßuorescent (naphthalene), which is transparent to its ßuorescent light, with

Fig. 19. Hartmut Kallmann (1896Ð1978), Grace Marmor Spruch (b. 1926), and German nuclear physicist Nikolaus Riehl (1901Ð1990). Credit: American Institute of Physics Emilio Segrè Visual Archives.

an electron multiplier phototube for the detection of single scintillation events.”[85]

Bruno Zumino (b. 1923)

Bruno Zumino (figure 20) received his Ph.D. degree from the University of Rome in 1945 and came to NYU in 1951. He later spent two years at the Stevens Institute of Technology, and for a time also was head of the theory group at CERN. He was the first Head of the unified NYU Physics Department when the Heights and Square faculty moved into the new André and Bella Meyer building in 1972. Since 1982 he has been Professor at the University of California at Berkeley.

Zumino and Julian Wess are famous for their pioneering work on supersymmetry and string theory. Zumino's work in various other areas of mathematical physics and quantum field theory place him among the highest level of theoretical physicists.

The Wess–Zumino model is the first of a group of theories more broadly known as supersymmetry, in which the distinction between fermions and bosons is blurred, with every fermion having a boson ‘‘superpartner’’ and vice versa.[86] Supersymmetric particles are leading candidates for filling in the dark matter of the universe. Supersymmetry also has provided a way to tie gravity together with other fundamental forces. None of the much heavier supersymmetric partners have yet been discovered; that is one of the key targets for the Large Hadron Collider. If they are discovered, then Zumino would be a likely candidate for a Nobel Prize. In his research page at Berkeley he writes:

> I am interested in the unification of the fundamental forces of physics, i.e. of those described by the standard model of strong, weak and electromagnetic interactions, and of gravity as described by Einstein's general relativity. The path to this unification appears to be through supersymmetry, supergravity and superstring theory. I have contributed to these subjects in the past and continue to work on them. Occasionally these studies require the use of techniques of advanced algebra and differential geometry, and my work has involved, and will continue to involve, the development of new mathematical tools. The study of noncommutative differential geometry is an example.[87]

Zumino has received many honors, including the Dirac Medal in 1987, the Heineman Prize in 1988, the Wigner Medal in 1992, the Enrico Fermi Prize of the Italian Physical Society in 2005, and election to the National Academy of Sciences and American Academy of Arts and Sciences.

Epitome

Many of the postwar NYU physics faculty are still alive and kicking, so we shall not comment on them here. There are a large number of active physicists (we

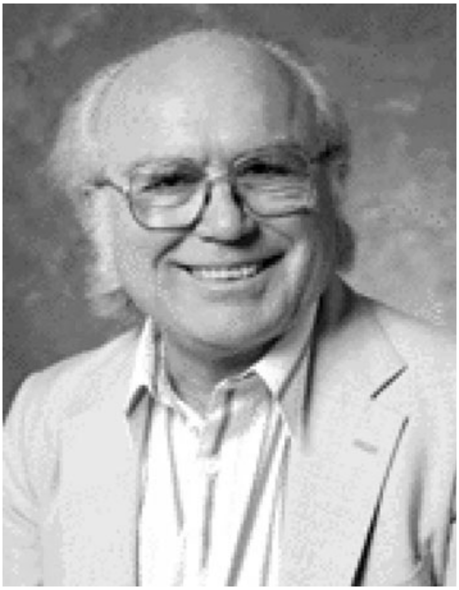

Fig. 20. Bruno Zumino (b. 1923). Source: website <http://www.physics.berkeley.edu/research/faculty/Zumino.html>.

count over 120) who either spent their entire careers at NYU or who moved on to other positions. We present in Appendix 4 a very partial list of those who were appointed after World War II and before 2000.

In due course it became clear that supporting two parallel physics departments at Washington Square in Manhattan and University Heights in the Bronx would strain University resources, and a faculty initiative, aided by a major National Science Foundation Development Grant, eventually led to unifying them at Washington Square in 1972, which allowed the recruitment of a number of faculty members, the modernization of support facilities, and the establishment of associated research and teaching laboratories. These developments were further made possible by a generous donation by French philanthropist André Meyer toward the construction of a new physics building, the André and Bella Meyer Hall of Physics, whose facade was designed by noted architect Philip Johnson. (Another famous architect, Marcel Breuer, designed the Gould Hall of Technology at University Heights, which housed the physics department at its Bronx location until its relocation to Washington Square.)

New areas of physics at NYU were initiated and others were strengthened by new appointments and by enhanced research and educational facilities. Physicists will recognize many of the people listed in Appendix 4. While several migrated to other institutions, these appointments and new facilities provided the building stones for the future development of an attractive and productive department.

An important ingredient in this process was the initiative the physics faculty took toward self-governance. Within the overall Þnancial constraints imposed on the department by the University, matters of faculty appointments, tenure, educational and internal funding allocations (particularly of the NSF Development Grant), salaries, and duties, were determined by an elected Executive Council. A parallel Experimental Research Council with an appropriate charge was also established. This openness has served the department well, by now for over four decades.

The essential part played in the successful development of the NYU Physics Department also has depended on the quality of its graduate students. For a period of ten years, the department beneÞtted from the China-US Physics Examination and Application (CUSPEA) program, set up by Nobel Laureate T.D. Lee, which brought to NYU (and a number of other American universities) some of the best Chinese graduate students. (This program now continues independently at NYU and several other American universities on a much reduced scale.) For many years, Italy also provided a large number of graduate students, mostly in theory. Most of these graduate students have found excellent employment in academia, industry, and a few in the Þnancial world. Moreover, the department has reached a point where it attracts excellent undergraduate students from the United States and from abroad, many of whom are later admitted to graduate schools at top universities.

The department today thus has once again revitalized itself with many important appointments, particularly in cosmology, astrophysics, and soft condensed matter. Its fascinating story continues.

Acknowledgments

We thank Roger H. Stuewer for his invaluable help in organizing the Þnal version of our paper. We thank the NYU archivist Nancy Cricco for her help in providing access to the (sparse) information contained in the university archives. Thanks are also due to Nancy Greenberg, former Director of Sponsored Programs, for supplying us with some useful old records. We thank Peter Levy for a critical reading of the manuscript, and Dan Zwanziger for his help in getting the project started. Finally, we thank the Physics Department and its Chair, David Grier, for Þnancial assistance.

Appendix 1: The Early Teaching of Physics at New York University. Notes by University Historian Bayrd Still, February 18, 1981

From the lecture notes of a student, W.F. Burroughs, enrolled in Professor E.A. LoomisÕs class in ÔÔNatural PhilosophyÕÕ in 1858, it is apparent that subjects now covered in Physics were included in the course in ÔÔNatural Philosophy.ÕÕ Burroughs took notes on lectures by Professor Loomis in pneumatics, the barometer, the suction pump, the siphon, acoustics, reßection of waves, musical sounds, vibrations of thin plates, organ of voice, heat, the steam engine, magnetism, terrestrial magnetism, optics, refraction of light. Elias Loomis was Professor of Mathematics, Natural Philosophy, and Astronomy from 1844 to 1860. He was succeeded by George W. Coakley [1814Ð1893], who was listed as Professor of Mathematics, Natural Philosophy, and Astronomy from 1860 through at least the academic year 1884Ð1885.

It is possible that John W. Draper, listed as Professor of Chemistry and Natural History, 1838Ð1882, included some teaching of natural philosophy in his courses. He wrote A Text-Book on Natural Philosophy (1st edn., 1847; 3rd edn., 1859), which covers topics we would associate today with Physics. His son, Henry Draper, was listed as Professor of Analytical Chemistry from 1862 to 1870 and Professor of Analytical Chemistry and Physiology, 1870Ð1882. There is no reference to his teaching of Astronomy despite his experimentation in this Þeld. Astronomy presumably was taught by Professor George W. Coakley as late as 1893.

Presumably the academic year 1885Ð1886 was the Þrst year in which the University had a Professor of Physics, as such. This was Daniel W. Hering, appointed May 4, 1885. In his Memoirs, Hering says that Henry M. MacCracken informed him by letter on March 11, 1885, that ÔÔin a reorganization of the Faculty of the University a chair of Physics had been established.ÕÕ Hering reports that there had not been a chair of physics here separate from chemistry or mathematics nor had there ever been a physics laboratory or laboratory work in physics for undergraduate students. However, he writes that the traditions of physics here in early days were ÔÔvery creditable, the subject at one time or another having been handled by Elias Loomis, the mathematician and meteorologist, later at Yale; by the professor of Chemistry here, the distinguished Dr. John W. Draper and by the professor of mathematics, Dr. George W. Coakley.ÕÕ

Hering described the ÔÔphysics room as being in the southeast corner of the University Building [see Þgure 3]. Its seats for about forty students, a platform for the lecture table, and a corner sink for water, and several deep and high cases for apparatus left little space for any other purpose, and yet I was expected to install a laboratory here. Next to this room on the north and separated from it by a heavy partition wall was a long, narrow room which became vacantƒ . I induced the janitor to let me have the use of this room while it was not rentedƒ . Soon afterwards, the partition wall was removed and replaced by a large glazed sash, the lower half of which could be raised and lowered, and the room became permanently an annex to the physics room. The primitive nature of its equipment may be inferred from the ÔeggÕ coal stove, the only means available at that time for heating it.ÕÕ The physics instruments now in the Archives were presumably used for demonstration purposes in the course in Natural Philosophy and later in the course in Physics. The photographs of HeringÕs laboratory picture instruments similar to these. We received the instruments without description or inventory. They had been housed somewhere at the Heights. From part of a label on one item (the early telephone receiver) we deduce that it had been in the laboratory of Henry

Draper, though we are not clear as to where this was located. We are indebted to Professor Serge Korff and Dr. Rosalind Mendell for the present identiÞcation of the instruments. They are of the opinion that all of them date to the 1870s and 1880s. The pictures in the Hering Memoirs support the conclusion that the instruments were kept in the Physics Room until the University moved instruction in the College and in engineering to the Heights in 1894.

Appendix 2: NYU Physics Publications during the Breit Period, 1929–1934

1. G. Breit, ÔÔSeparation of Angles in the Two-Electron Problem,ÕÕ The Physical Review 35 (1930), 569-578.
2. G. Breit, ÔÔPossible Effects of Nuclear Spin on X-ray Terms,ÕÕ Phys. Rev. 35 (1930), 1447-1451.
3. G. Breit, ÔÔThe Fine Structure of He as a Test of the Spin Interactions of Two Electrons,ÕÕ Phys. Rev. 36 (1930), 383-397.
4. G. Breit and E.O. Salant, ÔÔNote on the Frequency Shifts in Dispersive Media,ÕÕ Phys. Rev. 36 (1930), 871-877.
5. G. Breit and F.W. Doerman, ÔÔThe Magnetic Moment of the ^{7}Li Nucleus,ÕÕ Phys. Rev. 36 (1930), 1262-1264.
6. G. Breit and F.W. Doerman, ÔÔThe HyperÞne Structure of S and P Terms of Two Electron Atoms with Special Reference to Li $^+$,ÕÕ Phys. Rev. 36 (1930), 1732-1751.
7. G. Breit, ÔÔDerivation of HyperÞne Structure Formulas for One Electron Spectra,ÕÕ Phys. Rev. 37 (1931), 51-52.
8. G. Breit, ÔÔMean Value Theories in Quantum Mechanics,ÕÕ Phys. Rev. 37 (1931), 90-91.
9. Otto Halpern, ÔÔOn the change of the spectral composition of quasi-monochromatic radiation caused by scatteringÕÕ [Abstract], Phys. Rev. 37 (1931), 111.
10. Newton M. Gray and Lawrence A. Wills, ÔÔNote on the Calculation of Zero Order Eigenfunctions,ÕÕ Phys. Rev. 38 (1931), 248-254.
11. G. Breit, ÔÔOn the HyperÞne Structure of Heavy Elements,ÕÕ Phys. Rev. 38 (1931), 463-472.
12. G. Breit and I.I. Rabi, ÔÔMeasurement of Nuclear Spin,ÕÕ Phys. Rev. 38 (1931), 2082-2083.
13. G. Breit, ÔÔDiracÕs Equation and the SpinÐSpin Interactions of Two Electrons,ÕÕ Phys. Rev. 39 (1932), 616-624.
14. Jenny E. Rosenthal and G. Breit, ÔÔThe Isotope Shift in HyperÞne Structure,ÕÕ Phys. Rev. 41 (1932), 459-470.
15. S.A. Korff and G. Breit, ÔÔOptical Dispersion,ÕÕ Reviews of Modern Physics 4 (1932), 471-503.
16. G. Breit, ÔÔQuantum Theory of Dispersion,ÕÕ Rev. Mod. Phys. 4 (1932), 504-576.

17. G. Breit, ÔÔThe Isotope Displacement in HyperÞne Structure,ÕÕ Phys. Rev. 42 (1932), 348-354.
18. E.O. Salant and Jenny E. Rosenthal, ÔÔTheory of Vibrational Isotope Effects in Polyatomic Molecules,ÕÕ Phys. Rev. 42 (1932), 812-822.
19. G. Breit, ÔÔQuantum Theory of Dispersion (Continued). Parts VI and VII,ÕÕ Rev. Mod. Phys. 5 (1933), 91-140.
20. M.H. Johnson, Jr., ÔÔThe Vector Model and the Pauli Principle,ÕÕ Phys. Rev. 43 (1933), 627-631.
21. M.H. Johnson, Jr., ÔÔNote on Almost Closed Shells,ÕÕ Phys. Rev. 43 (1933), 632-635.
22. Allan C.G. Mitchell, ÔÔHyperÞne Structure and the Polarization of Resonance Radiation. II. Magnetic Depolarization and the Determination of Mean Lives,ÕÕ Phys. Rev. 43 (1933), 887-893.
23. M.H. Johnson, Jr., and G. Breit, ÔÔThe Magnetic Interaction of a Valence Electron with Inner Shells,ÕÕ Phys. Rev. 44 (1933), 77-83.
24. G. Breit, ÔÔThe Isotope Shift of Tl,ÕÕ Phys. Rev. 44 (1933), 418-419.
25. G. Breit and Lawrence A. Wills, ÔÔHyperÞne Structure in Intermediate Coupling,ÕÕ Phys. Rev. 44 (1933), 470-490.
26. Newton M. Gray, ÔÔThe Nuclear Spin of ^{7}Li from HyperÞne Structure Data,ÕÕ Phys. Rev. 44 (1933), 570-574.
27. O. Halpern, ÔÔScattering Processes Produced by Electrons in Negative Energy States,ÕÕ Phys. Rev. 44 (1933), 855-856.
28. John A. Wheeler and G. Breit, ÔÔLi^{+} Fine Structure and Wave Functions near the Nucleus,ÕÕ Phys. Rev. 44 (1933), 948.
29. Irving S. Lowen and G. Breit, ÔÔPolarization of Fluorescence Radiation,ÕÕ Phys. Rev. 45 (1934), 120.
30. G. Breit and I.I. Rabi, ÔÔOn the Interpretation of Present Values of Nuclear Moments,ÕÕ Phys. Rev. 46 (1934), 230-231.
31. G. Breit, ÔÔNuclear Stability and Isotope Shift,ÕÕ Phys. Rev. 46 (1934), 319.
32. G. Breit and I.S. Lowen, ÔÔRadiation Damping and Polarization of Fluorescence Radiation,ÕÕ Phys. Rev. 46 (1934), 590-597.
33. J.A. Wheeler and J.A. Bearden, ÔÔThe Variation of the K Resonating Strength with Atomic Number,ÕÕ Phys. Rev. 46 (1934), 755-758.
34. G. Breit and John A. Wheeler, ÔÔCollision of Two Light Quanta,ÕÕ Phys. Rev. 46 (1934), 1087-1091.

Appendix 3: Serge A. Korff, “The Physics Department of University College during the Decades from 1930 to 1970, at University Heights” [Edited]

In the years 1936Ð1938 the Chairman of the University College Physics Department was Allan C. G. Mitchell. Mitchell was born in Houston, Texas, in 1902, and received his Ph.D. from the California Institute of Technology in 1927. He then went to the Bartol Research Foundation of the Franklin Institute, in Swarthmore, Pennsylvania, 1928Ð1931, and came to the Physics Department as an Assistant Professor in 1931. He became Associate Professor and Department Chairman in 1934. He left us to go to Indiana University in 1938. During most of this time Richard T. Cox was the only Full Professor in the Department. Associate Professors were William H. Crew and Otto Halpern, with Assistant Professors Carl T. Chase, Fritz Doerman, Norman H. Hilberry, Montgomery H. Johnson, Jr., and Frank Meyers. Martin D. Whitaker was an Instructor. [Robert N. Varney also was on the Heights faculty, 1937Ð1938.]

Mitchell was succeeded as Department Chairman by William H. Crew. Crew was the son of Henry Crew, a distinguished physicist and one of the early Presidents of the American Physical Society. William Crew was born in Evanston, Illinois, in 1899, received his Ph.D. from the Johns Hopkins University in 1926, and came to New York University as Assistant Professor in 1929. He became Associate Professor in 1931. In 1941 he left to accept a post with the National Defense Research Committee (NDRC), which later became part of the OfÞce of ScientiÞc Research and Development (OSRD). This organization was the principal supervisor of defense research during World War II, and its history has been outlined by its Chairman, Vannevar Bush, in several reports and books. Crew remained with this organization until after World War II, and then moved to Los Alamos. He was nonetheless listed in our catalog as Administrative Chairman until 1942 and as a member of the Department on leave until 1943. His research interests were in the photoelectric effect and spectroscopy.

During these years, the University had what amounted to three Physics Departments. One was the Undergraduate Department at Washington Square, the other Undergraduate Department being at University Heights, and the Graduate Department which was centered at Washington Square. However, most of the members of the faculty at the two Undergraduate Departments also were members of the Graduate Department and taught graduate courses at their respective centers. We had been giving Ph.D. courses for decades before I came here in 1941. Courses were alternated between the Heights and the Square so that a student could take a given course at either center by waiting for the year it was there. If he wanted to take it out-of-phase, he commuted, the courses of either Department being recognized by the other.

The principal research interests of the Department during the late 1930s were in electron scattering and nuclear physics. The Department had two high-voltage accelerators at the time, a horizontal Van de Graaff generator on the back porch, and a CockcroftÐWalton voltage quadrupler. Both machines were in Butler Hall. Each had been built largely with ingenuity, and with very little direct Þnancial aid. Both worked well and were used in active research programs. In the basement was also an experimental arrangement for generating and studying slow electrons. This one was operated by Cox and Chase. As the U.S. involvement in World War II drew away more and more of our staff, the machines were left idle, and after it became apparent that they would not be reactivated, they were dismantled. Indeed, the entire Butler Hall back porch was removed, after the Þre some ten years later (see below).

The Administrative Chairman at Washington Square, Carel M. Van der Merwe, was also the DepartmentÕs representative in the Graduate School. He came to us from South Africa, having his A.B. from Stellenbosch in 1911, his M.S. from Capetown in 1921, and his Ph.D. from Göttingen (Germany). At that time, in the early 1920s, Göttingen was among the top physics departments in the world. Van der Merwe was a Full Professor by 1933, and Chairman of the Department at Washington Square, as well as Chairman of the physical science group of the Graduate School of Arts and Sciences. He remained Chairman until his retirement in 1956, and then continued as Professor Emeritus for a couple of years. Later he returned to South Africa.

The undergraduate course offering at University College was not very large, and consisted of the background courses necessary for a Major in the subject, but little beyond that. For example, in 1944Ð1945 the undergraduate offering was seven courses, plus three bracketed, to be given hopefully in some other year. This offering was greatly expanded after World War II. After Crew left to go into government service, Martin Whitaker became Acting Administrative Chairman. He was in this post for about a year, when he too left. Carl T. Chase was made Executive Secretary and served as such from 1942 through 1944. Next, John Knedler served as Acting Executive Secretary for a year, after which Joseph C. Boyce was brought in as Chairman. Chase was born in Lewiston, Maine, in 1902. He received his Ph.D. from NYU in 1930, became an Instructor at Dartmouth, and returned to NYU as an Instructor in 1931. The following year he was made Assistant Professor, which title he held for the next decade. His research interest was in electron scattering.

Other persons at the Heights Department when I came included William C. Bright, Frank Myers, Edgar J. Murphy, Victor J. Young, and John L. Rose. Most of these were in the rank of Assistant Professor or Instructor. Bright was born in Youngwood, Pennsylvania, in 1915, and received his Ph.D. from NYU in 1941. He worked in nuclear physics, especially with neutrons. Frank Myers was born in Portland, Oregon, in 1906, received his Ph.D. from NYU in 1934, and was one of the excellent people sent to us from Reed College. He was an Instructor from 1930 to 1937, and then an Assistant Professor. He left us during World War II to go to the Frankford Arsenal [in northeast Philadelphia], and later became a Professor and Department Chairman at Lehigh [University in Bethlehem, Pennsylvania]. His research interests were in electron scattering, nuclear physics, and ballistics. Edgar Murphy was born in Luthersville, Georgia, in 1904, received his Ph.D. in 1934 from NYU, became Assistant Professor at Alabama Polytechnic and then returned to us as Assistant Professor from 1930 to 1940. He left us to accept a post at CCNY to work on war-related problems. His interest was in neutron scattering.

Victor J. Young was born in Albion, Michigan, in 1913, received his Ph.D. from Iowa in 1940, and was an Instructor with us.

Also teaching at University College was Fritz Doerman. He was an Assistant Professor when I arrived. He had developed a disease in which his joints became stiff. In 1942 he joined the Sperry Gyroscope Company, his interests having been in electronics as well as nuclear physics. John L. Rose was born at Washington Court House, Ohio, in 1897, got his Ph.D. from NYU in 1937, went to Furman College [in Greenville, South Carolina] and returned as Instructor in 1928. He was made Supervisor of the Physics Laboratories in 1941. His interests were in spectroscopy and in radioactive geochronology. He remained with us until his death in the middle 1940s; he taught classes at his home. As his disease worsened, he later moved to Florida where he died.

Others with Assistant Professor rank were Montgomery H. Johnson, who had a Ph.D. from Harvard in 1932, had come here as National Research Fellow in 1932Ð1934, Instructor 1934Ð1938, Assistant Professor 1938Ð1941. He left to join a government program. Beryl H. Dickinson, who had a Ph.D. from Chicago in 1935, was Assistant Professor and left us in 1942. Richard D. Present was an Instructor in the Department in 1943Ð1944. He and I collaborated on a paper about Geiger Counters. He left the next year to join the faculty at Vanderbilt University.

In 1940 and 1941, the Physics Department at the Heights included a number of persons whom today we would describe as ÔÔcolorful.ÕÕ One of these was Professor Richard T. Cox. He had worked on polarization and electron scattering, but his principal interest at the time was in electric eels. He and Charles Breder of the Aquarium, which was at that time located at the Battery, and Robert Matthews had gone to Brazil, to the Island of Marajo at the mouth of the Amazon, and there collected half a dozen specimens. These had been successfully brought back alive and were swimming around in tanks at the Aquarium. The largest was close to six feet long and several four-foot specimens were included. Cox set up the electrical system to measure the voltage, current, and time characteristics of the discharges. He found among other things that the eels developed approximately a hundred volts per foot of length, so that the large ones could administer a very unpleasant shock, which indeed in the proper circumstances of contact might be fatal to men. He set up a system by which the Þsh could ßash a neon light, and gave a most excellent account before a meeting of the Explorers Club. The detailed measurements have since then been published in the scientiÞc literature. When it was determined to raze the old Aquarium building and move the Aquarium contents to the Bronx Zoological Gardens to make room for the Manhattan end of the Brooklyn-Battery Tunnel, Cox came to me and asked me to allow the use of my station wagon to transport the eels from the Battery to the Bronx. The transfer took place in due course and the work continued in the new environment, which was much more accessible to the Heights Physics Department.

A year later, the Physics Department was transferred for administrative purposes to the College of Engineering. The reason was that the Physics Department was servicing many more Engineering than Arts students. Thorndike Saville, Dean of the College of Engineering, was a thoroughly practical, forthright and rather peppery engineer, and could not understand the basic motivation of a physicist studying electric eels. Cox was unhappy in the new administrative environment, and shortly thereafter accepted an appointment at Johns Hopkins, where he had a good friend and colleague in the Medical School. He could do the physics of eels and his colleague the biology. Together they did a job on the eels that thirty years later is regarded as a Þrst-rate piece of science. Cox was born in Portland, Oregon, in 1898. He received his Ph.D. from John Hopkins University in 1924. He remained there as an Instructor, and came to NYU as Assistant Professor in 1926. In 1930 he became Associate Professor, and Full Professor in 1933, remaining with us until 1943.

Martin D. Whitaker was Administrative Chairman at the time of my appointment in September 1941. His research interest was in neutrons, in particular that neutrons scattered as if they were waves, in regular patterns from crystal faces. It was indeed in precisely this connection that I had known him before I came to New York, since we had discussed many aspects of neutron physics at meetings of the American Physical Society as well as on the occasion of my visits to the Heights Campus. Since 1936 I had been at the Bartol Research Foundation of the Franklin Institute of Philadelphia, which has its laboratory on the grounds of Swarthmore College. I had been interested in neutrons, in particular those produced by the cosmic radiation. In order to calibrate the detectors we used, we needed known numbers of neutrons emerging from artiÞcial and controllable sources. In this connection I had met, talked to, and gotten to know Whitaker. In due course, after some visits to New York, we collaborated on a paper entitled ÔÔComparative EfÞciencies of Radioactive Neutron Sources,ÕÕ which was authored by Edgar C. Murphy, William C. Bright, Martin D. Whitaker, S.A. Korff, and E.T. Clarke.[88] Eric Thatcher Clarke was at that time attached to the Bartol Research Foundation. He later went to MIT, and is now [1970] at the Operations Research Corporation. The acknowledgements in that paper refer to a grant from the American Academy of Arts and Science to Whitaker, several hospitals that helped by supplying some of the radon we used, and the Radium Chemical Company of New York, which is a predecessor of the Canadian Radium and Uranium Company, in turn Canrad Precision Industries, today a public corporation.

Martin D. Whitaker was born in Ellensboro, North Carolina, in 1902. His M.A. was from the University of North Carolina in 1930, and his Ph.D. from NYU in 1935. He remained as Instructor at NYU, becoming Assistant Professor in 1941, and Acting Administrative Chairman in the same year. He became Director of the Clinton Laboratories in Oak Ridge, Tennessee, from 1942Ð1945, and President of Lehigh University in 1946, which post he occupied until his untimely death about a decade later. He received several honorary degrees. There had been some quite turbulent years in the Department previously. The Department had imported from Austria an Instructor named Otto Halpern, and shortly thereafter had jumped him in rank to Associate Professor. There had developed a feud between Halpern and other members of the Department, which had been the principal cause of the turbulence. Whatever the merits of the feud may have been, and it was before my time, Halpern was a good physicist and contributed to the DepartmentÕs reputation by good publications. He was born in Vienna, in 1899, and his Ph.D. was from the University of Vienna in 1922. He was Associate Professor at NYU, 1931Ð1941.

During the 1930s, one of the leading lights, in fact perhaps the most prominent, was Gregory Breit. He was a theoretical physicist of national stature. He did not occupy an administrative post but was the best-known research man. [He actually was Chairman during his entire tenure at NYU.] He left NYU for the University of Wisconsin, later went to Yale, was elected to the National Academy of Sciences, and is today retired. I had contacts with him as early as 1932, at which time we collaborated on a joint paper reviewing the subject of Optical Dispersion. Breit had earlier been associated with Merle Tuve at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Together they had performed the classic experiment on the ionosphere, by sending a radio signal up to it, obtaining an echo back, and from the time delay of the echo computing the height of the ÔÔKennelly-Heaviside Layer.ÕÕ This experiment was the foundation of modern ionospheric physics. As might be imagined, two strong personalities, Breit and Tuve, soon became impatient with one another, but after Breit moved to NYU the cooperation continued very well and several important publications resulted. Breit was born in Russia, in 1899 and received his Ph.D. from Hopkins in 1921. He was at NYU from 1929Ð1934, Wisconsin 1934Ð1947, and Donner Professor at Yale until his retirement in 1968.

Another member of the Physics Department when I came in 1941 was Norman Hilberry. He had been at the Washington Square Department from 1925 to 1928, and then at the Heights. He had been late in getting his Ph.D., having had the bad luck to complete a good piece of work just as someone else published the same Þndings. In the late 1930s he was given leave, went to Chicago, and got his Ph.D. in 1941. His work was in the Þeld of cosmic radiation, a study of extensive air showers. He returned to NYU and was at once promoted to Associate Professor. He left in 1942 to join the Metallurgical Laboratory in Chicago, and later became Director of the Argonne National Laboratory. He received several honorary degrees during a distinguished career.

The Department, being shorthanded, needed to recruit competent teachers and ÔÔadoptedÕÕ two Heights faculty members from other departments, both of whom had had physics as undergraduates and were excellent teachers. These were Harmon Chapman, later to become Chairman of the Philosophy Department at the Heights, and John W. Knedler, Jr., from the English Department. Knedler later became Dean at University College. During 1944Ð1945 he was also Acting Executive Secretary of the Physics Department.

At the end of World War II, the Physics Department started an active search for a person to become Chairman. After many interviews the person decided upon was Joseph Boyce of MIT. He was born in Pittsburgh in 1903 and received his Ph.D. in 1926 at Princeton, where he was a Research Assistant to Karl T. Compton. When Compton went to MIT as President, he took Boyce with him, where he remained from 1930 to 1944, doing research in ultraviolet spectroscopy. He came to NYU in 1945 and brought a vigorous outlook and a good new direction to the Physics program, which had been disorganized during the war. Many temporary courses had been instituted, some at the request of governmental agencies, which became obsolete with the advent of peace. The Graduate curriculum, which had been strong before the war, had also felt the impact, with few graduate students attending classes and most of the faculty away or occupied on war-related problems. The curricula were overhauled and the graduate-study procedures reviewed. Since both he and I had been at Princeton, we modeled the Graduate program on the procedures at that Institution, and in due course I was given charge of that part of the academic program and the title of Graduate Advisor.

Many new faculty appointments had to be made to Þll the vacancies left by the previous years. Personally, I had been recruited to NYU by Martin Whitaker as an Assistant Professor. I became Associate Professor in 1944 and Professor in 1946. Joe Boyce brought in Yardley Beers and Leon Fisher as Assistant Professors and arranged for the transfer to the Heights of George Hudson who had Full Professor rank at Washington Square. In 1950 Boyce was offered the Associate Directorship of the Argonne National Laboratory, which he accepted, and from there went on to the Illinois Institute of Technology where he became Vice President and Director of Research.

Again the process of searching for a Chairman became the rule of the day. Many candidates were interviewed. During this time, Yardley Beers was Executive Secretary of the Department. Beers was born in Philadelphia in 1913 and had a Ph.D. from Princeton in 1941. He had served a year as Instructor at NYU, 1940Ð1941, then went to Smith College, 1941Ð1942, and to MIT in the Radiation Laboratory from 1942 until he came to us. He left in 1959 to go to the National Bureau of Standards Laboratory at Boulder, Colorado, as Division Chief in his research Þeld, radiofrequency physics.

Leon Fisher came from California, having received his Ph.D. from Berkeley in 1943. He came as an Assistant Professor and became Associate Professor in 1951 and Full Professor in 1958. His interest was in electrical discharges in gases. He worked in this Þeld for many years, and in later years obtained important grants and contracts and published considerably. He left in 1960 to return to California to an industrial Þrm in Palo Alto.

Another person brought in at this time was Fritz Reiche, who had received his Ph.D. in Berlin in 1907 and had worked with all of the original Þgures, Einstein, Planck, and others, in the development of the quantum theory in the early days of the century. He knew classical physics thoroughly and was better informed on the development of quantum theory than any person I have ever met. He was appointed as Adjunct Professor, thereby bypassing the age and retirement rules, and remained for many years as a person whom everyone respected and who brought prestige to the Department.

Under Boyce, the course offerings started to climb, and we were by 1952 presenting 23 courses. This new level has been more or less maintained since then, the level ßuctuating by one or two per year, as circumstances warranted. Boyce brought in Yale K. Roots with the rank of Associate Professor to supervise the laboratories and undergraduate teaching. Roots stayed with us in that capacity until 1959 when he left to go to the University of Maryland. A graduate student named Morris Shamos received his Ph.D. from us in 1948. He remained on the faculty, and later became Professor and Chairman of the Washington Square Department. His research interest was in cosmic radiation [he later became interested in biophysics and physics education], and I was one of his thesis commission. Morton Hamermesh also was at one time an Assistant Professor at the Heights but was most of the time connected with the Washington Square Department. He left in due course to go to the Argonne National Laboratory and the University of Minnesota. He was an Assistant [and Associate] Professor in 1946Ð1948.

As the Physics Department was most of this time under the College of Engineering, until it was transferred back to University College in 1968, the various faculty members served on various College of Engineering committees. For example, Boyce, while Chairman of the Physics Department, was also Chairman of the Graduate and Research Advisory Committee of the College of Engineering.

During World War II, the overwhelming sentiment was that classiÞed contracts be accepted, and that graduate student theses in such [classiÞed] Þelds be allowed. Our point of view at that time was that all classiÞed work would ultimately be declassiÞed and therefore publishable as additions to knowledge. Further, we would rely on the good sense of the faculty member as to whether the subject matter was of sufÞcient academic quality to make an acceptable Ph.D. thesis. We sometimes had one or more additional persons in the Department who had been cleared as thesis readers, and sometimes we used outside readers. It turned out that our expectations were fulÞlled, and that the work has indeed been declassiÞed. Further, it can be stated that our faith in the integrity of faculty members was well founded, for no case has come to my attention of any thesis assignment that was clearly below Ph.D. quality. After the end of World War II, as the classiÞed contracts expired, they were not renewed. By the late 1940s, we had no classiÞed work in progress. As Graduate Advisor, when a classiÞed contract was proposed, I followed a policy of advising the proposer that classiÞed work in peacetime should be done in government laboratories, where (a) the facilities for safeguarding classiÞed work are more readily available, and (b) the fundamental purpose of a university in generating and disseminating new knowledge is not infringed.

We have gathered together the reprints, representing work done in the Physics Department, in two volumes. These were bound and entitled ÔÔContributions from the New York University Physics Department, 1942Ð1950ÕÕ and ÔÔ1950Ð1956.ÕÕ The volumes hold 55 and 54 papers, respectively, and form an impressive commentary on the quality of the work done in the Department. Bound volumes are at present in the ofÞce of the Chairman of the Department at University College. Copies also were sent to the Deans of the undergraduate colleges and the Graduate School. The overwhelming majority of the papers are in refereed journals so that the quality is guaranteed by professionals from outside organizations.

Another interesting commentary on the work done at University Heights comes from an international source. The work that was done on radiation detection devices, including Geiger, proportional, and neutron counters, some of it during World War II, but mostly both before and after, was adjudged to have contributed materially to radiation cancer therapy, so that the Curie Medal was awarded to me by the Union International Contre le Cancer, in 1957. Later, the French Société d'Encouragement au Progrès sponsored by the French Government, awarded me their Medaille d'Honneur in 1965 for this work.

In 1954, Lyle Borst was appointed Chairman. He was born in Chicago in 1912, received his Ph.D. from Chicago in 1941, and came to us from the University of Utah. He remained Chairman until 1961, when he moved to the State University Physics Department at Buffalo, New York. In 1955Ð1956, Bruno Zumino and Sidney Borowitz were members of the Physics Department. Zumino, an Italian, had the degree of Dott.M.Sci. from Rome in 1945, and was an Assistant Professor in 1954Ð1955. He left to go to the Stevens Institute of Technology in 1957, and returned in 1959 as an Associate Professor. In 1961 he became Head of the All University Physics Department. He left this post in 1969 to resume research at CERN in Geneva, Switzerland.

Another member of the faculty at University Heights is Benjamin Bederson. Born in 1921, his undergraduate degree was from CCNY, and his Ph.D. from NYU in 1950. Following his Ph.D., he was at MIT for two years, and came to the Heights with the rank of Assistant Professor in 1952, becoming an Associate Professor in 1957 and a Full Professor in 1959. His research interest has been in ionization phenomena in gases, and in particular in the scattering of slow electrons. After the departure of Leon Fisher, Bederson has operated the electron-scattering research group, one of the strong major research programs in the Department.

Sidney Borowitz received his Ph.D. from NYU in 1948. After teaching at Harvard, he returned in 1952 as Assistant Professor, became Associate Professor in 1955 and Full Professor in 1960, taking the Chairmanship of the Heights Physics Department in 1961 when the All University Department concept was activated. He relinquished this post to become Dean of University College in 1969.

In 1956, Professor of Chemistry Austin Taylor succeeded C.W. Van der Merwe as Chairman of Physical Sciences of the Graduate School. Van der Merwe returned to his native South Africa and taught at Stellenbosch University.

Gottfried Falk was brought in from Germany as Associate Professor. Joseph Lamarsh, Ph.D. MIT 1952, was made Assistant Professor, left in 1958 to go to Cornell, but returned to become Chairman of the newly formed Department of Nuclear Engineering in the School of Engineering and Science, the new name for the College of Engineering. Arthur Beiser, a former Heights graduate student, was made Assistant Professor, became Associate Professor in 1960, and left the following year to write books about physics. His books had been notably successful Þnancially, and he had undoubtedly at the time the largest income of any of our former Ph.Ds. Among his books were Concepts and Principles of Physicsby Borowitz and Beiser.

Chairman Borst brought into the Department several other foreign members, including Are Mann and Gottfried. Falk from Germany and T. Arase and S. Tani from Japan, all as Assistant Professors. In 1958Ð1959 the Assistant Professors also included Kurt Haller, Robert Haymes, Harry Nickle, and Kenneth Rubin. All left after a few years.

Chairman Borowitz brought in a number of new people, including Joseph Birman and Henry Stroke as Associate Professors. Thus, a rather complete change in personnel took place, with Beers, Borst, Fisher, and Hudson leaving from the Full Professor ranks, and several from the lower grades. These were replaced by Alfred Glassgold, who became Head of the All University Department succeeding Zumino, Henry Stroke who came in 1963 as Associate Professor, and Assistant Professors Brown, Josephson, Kohler, Rubin, and Salop. In 1966, Richardson and Robinson were added as Assistant Professors and Glassgold was promoted to Full Professor.

During the 1950s, a new building was under construction, known as Gould Hall of Technology. It was ready for occupancy in the fall of 1962 and the Physics Department moved into it. The Physics Department had previously occupied Butler Hall, a converted former residence, on the University Heights campus, for some thirty or more years. There had been a Þre in Butler Hall around 1950, after which the interior had been rebuilt, but the entire building design was not too well suited to the needs of the fast-growing Physics Department. In the new building, which was much larger than Butler Hall, the space was shared with the Departments of Mathematics and Electrical Engineering, each having one of the ßoors. In 1959Ð1960, the University administration gave consideration to implementing the recommendations of a Self-Study report, issued in 1956, with speciÞc reference to the establishment of an All University Head. The Undergraduate Department Chairmen were Sidney Borowitz for the Heights and Morris Shamos for the Square. Some of the important features of this new organization were (a) the operation of a coordinated single budget for the Department, and (b) a review of Department appointment policies consolidating them in the hands of the Head. Thus, the Head could make such new appointments as would implement the research and administrative policies, which he might determine.

Two other developments came shortly thereafter. The Þrst was the decision to seek a ÔÔCenter-of-ExcellenceÕÕ grant from the National Science Foundation, and the second to seek funds for a new Physics Building at Washington Square. Each required lengthy preparation and much negotiation. The award of the Center-of-Excellence grant was received in September 1969, and construction of the Andr«e and Bella Meyer Physics Building was begun about the same time. Another administrative change took place. In 1961, the Physics Department at the Heights was transferred back from the School of Engineering and Science to University College. As the administrative load of the All-University Department increased, the Heights Chairman, Sidney Borowitz, found he was spending more and more time at Washington Square. Hence he was appointed Assistant Head, with his ofÞce at Washington Square. In his place, Bernard Lippmann was appointed Chairman at University Heights. Lippmann was born in New York in 1914, got his Ph.D. Harvard 1948, and came to us from industry, having been Director of Research at General Research Corporation, Santa Barbara, California. Part of the thinking behind his appointment was that in due course he would encourage the department to develop some Applied Physics curricula, which the School of Engineering was anxious to have instituted.

In the following year, Bruno Zumino went to Europe on sabbatical leave and Sidney Borowitz became Acting Head. Later that same year, Zumino resigned and Borowitz was made Head. In 1969, Borowitz was designated Dean of University College and Glassgold succeeded him as Head. Lawrence Bornstein was made Chairman of the Heights Department. He had received his Ph.D. at the Heights and had been a member of the faculty since then. This brings the listing of the personnel and such comments as are appropriate on Department policies up to the present date, 1970. For the record, and for the guidance of future writers, the personnel listing of the Department as of October 1970 are: Head, Alfred E. Glassgold; Chairman, University Heights Department, Lawrence Bornstein; Chairman, Washington Square (Undergraduate) Department, Robert W. Richardson, with the title of Associate Head in charge of Undergraduate Department. Professors with ofÞces principally at University Heights: Joseph Birman, Benjamin Bederson, Serge A. Korff, Henry Stroke, Bernard A. Lippmann, Leonard Rosenberg. Associate Professors: Howard Brown, Helen Hartmann, Peter M. Levy, Robert W. Richardson, Edward J. Robinson. Assistant Professor: Burton Budick. Professors with ofÞces principally at Washington Square: Leonard Yarmus, Werner Brandt, Jerome K. Percus, Engelbert L. Schucking, Morris H. Shamos, Alberto Sirlin, Larry Spruch, Wolfhart Zimmerman. Associate Professors: Richard Brandt, Daniel Zwanziger. Assistant Professor: Julius H. Rannigcr.

At present it is planned to move most of the Heights Physics research to Washington Square, when the new Meyer Physics building becomes available. Hence, we may anticipate that several of those listed above as Heights personnel will move to the Square during the next few years. Adjunct and visiting staff are not listed here.

Appendix 4: Principal Appointments and Their Specialties after World War II until 2000

Yardley Beers (1913Ð2005)
microwave spectroscopy
Leon Fisher (b. 1918)
gaseous electronics
George E. Hudson (b. 1916)
ßuid mechanics, shock waves
John Lamarsh (1928Ð1981)
nuclear reactor physicist;
Chair of Department of
Nuclear Engineering
Leonard Yarmus
electron paramagnetic resonance;
undergraduate laboratory director
Lawrence Bornstein (1923Ð2004)
noted teacher; undergraduate chair
Martin Pope (b. 1918)
Director of Radiation and
Solid State Laboratory;
later in Chemistry Dept
Fritz Reiche (1883Ð1969)
distinguished emigré quantum theorist
Benjamin Bederson (b. 1921)
experimental atomic physics,
electronic collisions, atomic structure
H. Henry Stroke (b. 1927)
optical spectroscopy as probe
of nuclear properties;
low-temperature calorimetry
Herman Cummins (1934Ð2010)
laser physics,
condensed-matter physics
Harry Swinney (b. 1939)
laser physics, dynamical physics
Joseph L. Birman (b. 1927)
theoretical condensed-matter physics;
human rights activist
Alfred E. Glassgold (b. 1929)
astrophysics,
atomic and nuclear physics
Kurt Haller (1928Ð2004)
Þeld theory
Edward A. Spiegel (b. 1931)
Astrophysics
Bruno Zumino (b. 1923)
quantum Þeld theory, supergravity
Kurt W. Symanzi (1923Ð1983)
quantum Þeld theory
Wolfhart Zimmerman (b. 1928)
quantum Þeld theory
Morris Shamos (1917Ð2002)
biological physics, cosmic rays;
educator
Larry Spruch (1923Ð2006)
atomic and nuclear theorist
Sidney Borowitz (b. 1918)
theoretical physics;
educator and administrator
Lyle Borst (1912Ð2002)
nuclear reactor physics
Bernard A. Lippmann (b. 1914)
collision and general theory
Leona Marshall Libby (1919Ð1986)
experimental particle physics
Malvin Ruderman (b. 1927)
astrophysics
Alberto Sirlin (b. 1930)
particle theory, standard model
Leonard Rosenberg (b. 1932)
collision theory
Edward J. Robinson (b. 1936)
atomic theory, laser physics

Robert W. Richardson (b. 1935)
theoretical nuclear physics,
statistical physics, energy efÞciency

Richard A. Brandt (b. 1941)
quantum Þeld and particle theory;
sports physics

Jerome Percus (b. 1926)
mathematical physics

Werner Brandt (1925Ð1983)
experimental condensed-matter physics

Daniel Zwanziger (b. 1935)
QED, QCD, quantum Þeld theory

Peter Levy (b. 1936)
theoretical condensed-matter physics

Howard H. Brown
plasma physics; educator

Ivan A. Sellin (b. 1937)
condensed-matter physics;
high-energy probes

Samuel J. Williamson (1940Ð2005)
biological and condensed-matter physics

Thomas Miller (b. 1940)
atmospheric, atomic and molecular
physics

Charles Swenberg (1940Ð1988)
radiation physics, biophysics

Leposava Vučković
atomic, molecular and plasma physics

Boris Sinković
condensed-matter physics

Tycho Sleator (b. 1955)
atomic and optical physics

Andrew Kent (b. 1960)
condensed-matter physics

Engelbert Schucking (b. 1926)
astrophysics, astronomy

Peter G. Bergmann (1915Ð2002)
relativity

Alan Sokal (b. 1955)
mathematical, statistical physics;
sociology of science

Martin Hoffert (b. 1938)
atmospheric, environmental science;
geophysics

George Zaslavsky (1935Ð2008)
statistical physics, nonlinear science

Patrick Huggins (b. 1938)
astronomy, astrophysics

John Lowenstein (b. 1941)
Þeld theory, nonlinear systems

John Sculli
experimental particle physics

Allen Mincer (b. 1957)
experimental particle physics

Peter Nemethy (b. 1939)
experimental particle physics

James H. Christenson
experimental particle physics

Olav Redi (b. 1938)
optical, nuclear physics

Siegfried Horn
condensed-matter physics

Massimo Porrati (b. 1961)
quantum Þeld theory, gravitational physics, astrophysics, particle physics

Glennis Farrar (b. 1946)
astrophysics, particle physics

Georgi Dvali (b. 1964)
quantum Þeld theory, quantum gravity

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