"The Happy Thirties"

Despite the political upheavals of the 1930s, the decade played a pivotal role in Hans Bethe's life.

Silvan S. Schweber

Hans Bethe was born on 2 July 1906 in Strasbourg, when Alsace was part of the Wilhelminian empire. His father, Albrecht Bethe, was trained as a physician and became a widely respected physiologist. In 1915 he accepted a professorship in the newly founded Frankfurt University. Hans's mother, Ella, was raised in Strasbourg where her father was a professor of medicine. An only child, Hans grew up in a Christian household, but one in which religion did not play an important role. His father was Protestant; his mother had been Jewish but she became a Lutheran before she met Hans's father. Hans's mother was a talented and accomplished musician, but a year or two before World War I her hearing was impaired as a result of contracting influenza. The illness left psychological scars, and she became prone to what was diagnosed at the time as bouts of "nervous exhaustion," or extended periods of depression. The marriage suffered under the strain, and Hans's parents eventually divorced in 1927. From the mid-1920s on, it was Hans who looked after his mother's well-being.

One of Bethe's earliest memories was being interested in numbers and playing with numbers. His numerical and mathematical abilities manifested themselves early. His father told of Hans at age four sitting on the stoop of their house, a piece of chalk in each hand, taking square roots of numbers. By the age of five, he had fully understood fractions and could add, subtract, multiply, and divide any two of them. At age seven he was finding ever-larger prime numbers and had made a table of the powers of two and of three, up to 2^{14} and 3^{10}, and had memorized them. At age fourteen he taught himself the calculus by reading Walther Nernst and Arthur Schönflies's *Einführung in die mathematische Behandlung der Naturwissenschaften* (Introduction to the Mathematical Treatment of the Natural Sciences), which he had "stolen"[1] from his father's library and read on the sly.

Bethe started reading at the age of four and began writing in capital letters at about the same age. Very soon after mastering the art of handwriting, he began filling large numbers of little booklets with stories. His mode of writing was distinctive: He would write one line from left to right and the next line from right to left! Many years later while visiting Crete, he was pleased to learn that the Greeks wrote the same way on their tablets in 700 BC: in capital letters, left to right and then right to left.

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Though somewhat sickly as a young boy and frequently absent from school, Bethe nonetheless was an outstanding student. His mathematics teacher in Frankfurt recognized his outstanding mathematical talents and encouraged him to continue studies in mathematics and the physical sciences. By the time Bethe finished high school (gymnasium) in the spring of 1924 he knew he wanted to be a physicist because "mathematics seemed to prove things that are obvious." After completing two years of studies at Frankfurt University, he had exhausted the resources in theoretical physics in Frankfurt and was advised to go to Munich. In the summer of 1926, he joined Arnold Sommerfeld's seminar in Munich.

From Sommerfeld to Fermi

Sommerfeld was a forceful and charismatic figure,[2] and although he was very much the *Herr Geheimrat* (literally "Privy Councillor," an exclusive, greatly respected honorary title bestowed on civilians by the government), the atmosphere of the seminar was nonetheless characterized by the intellectual give-and-take between him and his students and assistants. In contrast to the usual practice at other German universities, where only invited guests spoke, Sommerfeld had his students and assistants make presentations in his seminar. Thus, shortly after coming to Munich, Bethe reported on Schrödinger's paper on perturbation theory in wave mechanics.

It was in Munich that Bethe anchored his self-confidence. There he discovered his remarkable talents and his exceptional proficiency in physics. Sommerfeld told him that he was among the very best students who had studied with him. His self-confidence in physics quickly extended to other matters. At a symposium held in October 1988 to mark the 80th birthday of his friend Victor Weisskopf, Bethe was introduced by Kurt Gottfried, who narrated the following story. In 1934 Weisskopf told Bethe that he was about to undertake a calculation of pair production for spin-0 particles, a calculation similar to one that Bethe had performed the previous year for spin-½ particles. Weisskopf wanted to know how long it would take to do the computation. Bethe answered, "Me it would take three days; you three weeks." At the start of his talk, Bethe commented, "I was very conceited at that time. I still am—but I can hide it better."

Bethe obtained his doctorate summa cum laude in 1928 with a thesis on electron diffraction in crystals. In his thesis he explained why electrons within certain energy intervals were observed to be totally reflected.[3] Building on previous work by Paul Ewald on the diffraction of x rays by crystals, and making use of the fact that the electron's wavefunction inside the crystal must be of the form $\exp(i\mathbf{k}\cdot\mathbf{r})\,u_k(\mathbf{r})$, with $u_k(\mathbf{r})$ having the periodicity of the crystal lattice, Bethe established that for certain incident

A young Hans Bethe. (Courtesy of Rose Bethe.)

directions and energy intervals there did not exist any wavefunctions corresponding to an electron propagating in the crystal. The calculation was a difficult one, and the connection between the forbidden intervals and the gaps between the energy bands of electrons in metals was not recognized until later, after Felix Bloch's work had received wide acceptance (see reference 3).

In the fall of 1929, Sommerfeld recommended Bethe for a Rockefeller Foundation fellowship. And so during 1930 Bethe spent a semester in Cambridge under the aegis of Ralph Fowler, and a semester in Rome working with Enrico Fermi.

Bethe found the openness and cordiality of his British hosts, Fowler and Patrick Blackett in particular, most engaging and attractive. Clearly the Cambridge surroundings allowed some of the stiffness that a German education bestowed on scholars to be shed, for the year 1931 opened with an astonishing short original article (*Kurze Originalmitteilung*) entitled "On the Quantum Theory of the Temperature of Absolute Zero" in the journal *Naturwissenschaften*. The paper was signed by Guido Beck, Bethe, and Wolfgang Riezler, three postdoctoral fellows at the Cavendish Laboratory. Coming on the heels of Arthur Eddington's attempt to explain the numerical value of the fine structure constant, the article pretended to give an alternative derivation of its value.[4] Since papers in respected scientific journals in those days were read with absolute trust in the honorable intentions of the authors and editors, it took a while for the community to realize that *Naturwissenschaften* had been had and that the paper was a prank. Arnold Berliner, the editor of *Naturwissenschaften*, was not amused. Nor was Sommerfeld. Berliner demanded an apology and on 6 March a "correction" appeared in the journal.

From Cambridge, Bethe went to Rome (see his reminiscences in PHYSICS TODAY, June 2002, page 28). After a few weeks there he wrote Sommerfeld

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> The best thing in Rome is unquestionably Fermi. It is absolutely fabulous how he immediately sees the solution to every problem that is put to him, and his ability to present such complicated things as quantum electrodynamics simply. . . . I am now actually sorry that I cannot stay here longer, or as the case may be, that I did not come here for all of the Rockefeller-time.[5]

Bethe returned to Rome in the spring of 1932, but in the meantime he had obligated himself to write two lengthy reviews for the new edition of the *Handbuch der Physik* that Adolf Smekal was editing. One, on electrons in metals, was to be written with Sommerfeld, and the other was to present the state of knowledge of one- and two-electron atoms.

In Rome, Bethe was exposed to the much freer and more informal mode of interaction between Fermi and his students than what he had experienced in Munich. Though only five years older than Bethe, Fermi became—besides Sommerfeld—the other great formative influence on him. Fermi helped Bethe free himself from the rigorous and exhaustive approach that was Sommerfeld's hallmark. From Fermi, Bethe learned to reason qualitatively, to obtain insights from back-of-envelope calculations, and to think of physics as easy and fun, as challenging problems to be solved.

Bethe's craftsmanship was an amalgam of what he learned from these two great physicists and teachers, combining the best of both: the thoroughness and rigor of Sommerfeld with the clarity and simplicity of Fermi. This craftsmanship is displayed in full force in the many reviews that Bethe wrote. His first, the result of Sommerfeld's asking him to collaborate in the writing of his *Handbuch der Physik* entry on solid-state physics, exhibited his remarkable powers of synthesis. Of his reviews, the two *Handbuch*[6] entries and the "Bethe bible"—three articles on nuclear physics[7] in *Reviews of Modern Physics* in 1936 and 1937—were the most famous. Calling Bethe's reviews "reviews," however, is a misnomer. They were syntheses of the fields, giving the subjects coherence and unity and charting the paths to be taken in addressing new problems. They usually contained much that was new, material that Bethe had worked out in preparing the essay.

1933 and its aftermath

Already as a teenager, and throughout the 1920s, Bethe kept abreast of the political and economic developments in Germany. As attested to by his letters to Sommerfeld from 1928 on, finding suitable employment and making ends meet were constant worries. In the fall of 1932, Bethe obtained an appointment in Tübingen as an acting assistant professor and started teaching theoretical physics there. But Adolf Hitler's rise to power on 30 January 1933 changed all that.

In April 1933, shortly after the enactment of the racial laws which forbade any Jew, half-Jew, or quarter-Jew from holding any state or federal governmental position, Bethe lost his job. Sommerfeld was able to help by awarding Bethe a fellowship in Munich for the summer of 1933. He also got William Lawrence Bragg to invite Bethe to come to Manchester for a year to replace Evan James Williams, who was going to Copenhagen to work with Niels Bohr.

The warm relationship between Bragg and Sommerfeld dated back to the 1910s, after the discovery of x-ray diffraction at Sommerfeld's institute. It had become even closer in the early 1930s when Sommerfeld helped Bragg recover from a bout of deep depression. Bethe conveyed his impression of Manchester in the first letter he wrote to Sommerfeld after arriving there:

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> The best thing in Manchester are the people at the Institute. Bragg is marvelous, humanly and physics-wise. . . . He makes very interesting experiments about the arrangement of atoms in alloys (superlattices) and I attempt to devise theory for them. It is a pleasure to tell him things: He understands all essential points in the shortest time, while that is mostly very difficult with experimenters. . . .[5]

The appointment in Manchester was for a year, and thus the question of what would happen the following year came up early on. There then occurred a confluence of events that determined Bethe's subsequent life. Cornell University was looking for a theorist, and Lloyd P. Smith, a young theorist there who had studied with Bethe in Munich, recommended him strongly for the position. At the same time, Bragg was visiting Cornell for the spring semester and could corroborate Smith's assessment of Bethe.

On 18 August 1934, R. Clifton Gibbs, chair of the Cornell physics department, wrote Robert M. Ogden, the dean of arts and sciences, recommending the "appointment of Dr. Hans Bethe as Acting Assistant Professor of Physics for the year 1934–35, at a salary of $3000":

> The strong recommendations of Profs. Sommerfeld and Bragg and our intimate knowledge of the admirable way that he exerted his influence in promoting the work in theoretical physics at the University of Munich together with his numerous outstanding publications (a list of which is attached) have convinced a large majority of the Faculty in Physics that Dr. Bethe is a most promising candidate in meeting our needs.[8]

Bethe accepted, but because he had received an offer of a yearlong fellowship in Bristol with Nevill Mott, he asked and obtained permission from Cornell to assume his duties there in the spring term rather than at the beginning of the academic year. He stayed in Bristol during the fall semester of 1934 and arrived in Ithaca, New York, in February 1935.

Cornell University

When Bethe joined the physics department at Cornell, it consisted of some 15 faculty members, and about 40 graduate students were enrolled. He very soon felt "quite at home." When he went back to Germany that summer to visit his mother, he had become convinced "that probably [he] would remain at Cornell for a long, long time." In the fall of 1935, Robert Bacher joined the department. Bethe, Bacher, and M. Stanley Livingston made Cornell into an outstanding center of nuclear research. Although Cornell's cyclotron only produced 1.2-MeV deuterons, Livingston and his associates developed an arc source that transformed the cyclotron into a particularly useful tool for neutron research. Bethe not only provided suggestions for experiments and the theory for their interpretation, but was intimately involved with their design and data analysis. At Cornell, like at the other centers where nuclear physics was being cultivated, theorists and experimenters worked closely together. At the beginning of the 1936–37 academic year, Bethe confessed to Sommerfeld that although he had gone to Cornell with mixed feelings,

> like a missionary going to the darkest parts of Africa in order to spread there the true faith . . . already half a year later I no longer held this opinion and today I hardly would return to Europe even if I would be offered the same amount of dollars as at Cornell.
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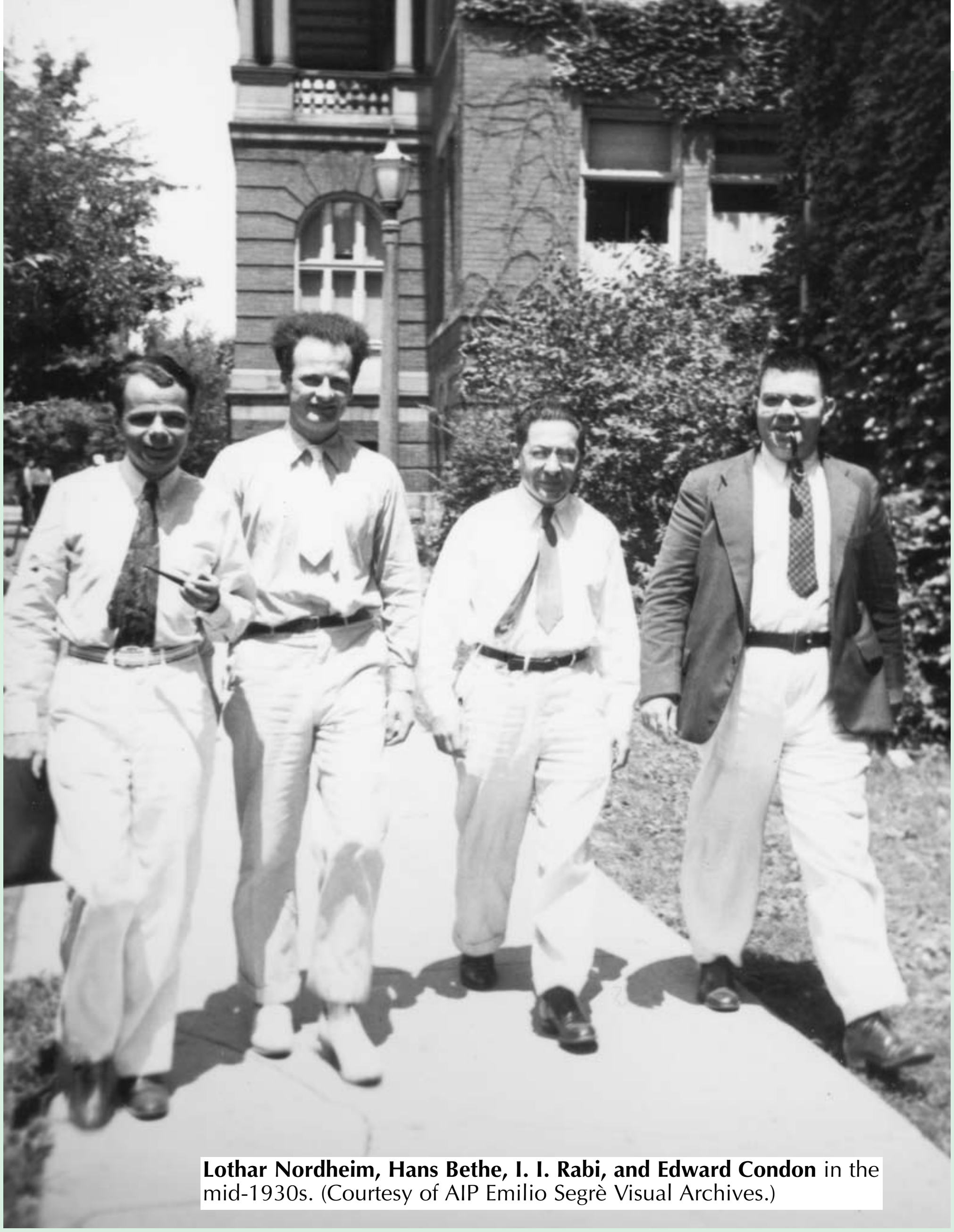
> The characteristic trait of physics in America is team work. Working together within the large institutes—in every proper one everything that physics encompasses is being done—the experimentalist constantly discusses his problems with the theorist, the nuclear physicist with the spectroscopist. By virtue of this cooperation many of the problems are immediately disposed of, [whereas] that would take months in a specialized institute. More team work [in English in the original]: the frequent conferences of the American Physical Society. . . .[5]

The influence of the émigré scientists who had come to the US was particularly noticeable at the many theoretical conferences organized to assimilate the insights that quantum mechanics was providing in many fields, especially molecular physics and the emerging field of nuclear physics. The Washington Conferences on Theoretical Physics, initiated in 1935 by Merle Tuve and John Fleming of the Carnegie Institution, jointly sponsored by the Carnegie Institution and George Washington University and held annually until 1942, were paradigmatic of such meetings. Their intellectual agenda was set by George Gamow and Bethe's friend Edward Teller. Their purpose was to evolve in the US something similar to the Copenhagen Conferences, in which a small number of theoretical physicists working on related problems would assemble to discuss in an informal way the difficulties they had met in their research. The conferences proved to be extremely influential and seminal, partly because they were restricted to theory and partly because their size was strictly regulated so they could remain working conferences (see the table on page 42).

Bethe attended the 1935 and 1937 Washington Conferences; when invited to the 1938 conference, though, he indicated to Teller that he was not interested in the problem of stellar-energy generation. It was only after Teller's repeated urgings that Bethe agreed to attend. The subject of the conference had been suggested by Gamow, who in 1938 was ideally positioned to solve the problem of energy production in stars. He recognized the interrelation of nucleosynthesis and energy production, and together with Edward Teller he fashioned the tools to solve the problem. But perhaps because of his fascination with problems of origins and genesis, he came to regard nucleosynthesis as the all-important problem and the explanation of the relative abundances of the elements the criterion by which the theory would be tested. He was unable to see that energy generation and nucleosynthesis need not be addressed simultaneously.

Bethe—always a theoretician who based his work on firm empirical data and sound phenomenological knowledge—decoupled the two aspects of the problem. Thus, after he had attended the 1938 Washington Conference and had been made aware of the problem, of the data, and of the tools at hand, Bethe was able to give the definitive answer to the problem of the energy generation in stars. He was awarded the Nobel Prize in 1967 for this work.

When World War II broke out in September 1939, Bethe certainly felt at home in the US. He had earned the affection and admiration of his colleagues at Cornell, had been recognized internationally as one of the outstanding theorists of his generation, and had married the woman he had fallen in love with. Despite the upheaval that Hitler's rise to power had engendered, for Bethe the decade had indeed been the "happy thirties." His own perspective on what had happened to him was movingly conveyed to Sommerfeld after the war, when Bethe was offered the chair in theoretical physics in Munich (see the box on page 43).



Lothar Nordheim, Hans Bethe, I. I. Rabi, and Edward Condon in the mid-1930s. (Courtesy of AIP Emilio Segrè Visual Archives.)

The 1930s in retrospect

One can't help but be overwhelmed when looking back on Bethe's scientific output during the 1930s. More than half of the papers that were particularly meaningful to him and included in his selected works[9] were from that decade. Together with Wolfgang Pauli, Sommerfeld, Felix Bloch, Rudolf Peierls, Lev Landau, John Clark Slater, and Alan Wilson, Bethe was one of the founding fathers of solid-state theory (see PHYSICS TODAY, June 2004, page 53 for David Mermin's interview with Bethe on solid-state theory).[10] He was one of the first theorists to apply group-theoretical methods to quantum mechanical calculations.[11] His theory of energy loss of charged particles in their passage through matter became the basis for extracting quantitative data from cloud chamber tracks and, later, nuclear emulsions.[12] After hole theory was formulated, his calculations of cross sections for pair production and bremsstrahlung became classics.[13] With Peierls he laid the foundations for understanding the structure of the deuteron, neutron–proton and proton–proton scattering, and the photodisintegration of the deuteron.[14] The Bethe bible summarized what was known and understood in nuclear structure and nuclear reactions. And his paper on energy generation in stars solved that problem and created the field of nuclear astrophysics.

Along the way Bethe created little gems that proved seminal. In 1931, when he had decided "to treat the problem of ferromagnetism decently [by] . . . really calculating the eigenfunctions," as he wrote to Sommerfeld, he first considered a one-dimensional chain of spins with an exchange interaction between nearest neighbors that was either positive, as in the Heisenberg model, or negative, as in the "normal" case. With the help of his famous ansatz—which in recent decades has found numerous other applications—Bethe started with the fully aligned ground state and determined the wavefunctions of states having an arbitrary number of reversed spins. Similarly, his refinement of the Bragg–Williams method[15] offered important

Participants at the 1938 Washington Conference on Theoretical Physics, the fourth of a series sponsored by the Carnegie Institution of Washington and George Washington University. The conference introduced Bethe to the problem of stellar-energy generation; his definitive solution to that problem earned him the 1967 Nobel Prize. (Courtesy of Special Collections and University Archives, George Washington University, Washington, DC.)

insights into long-range correlations near the phase-transition point in alloys—and thus into phase transitions in general.

One can identify three fairly well delineated periods in Bethe's life through the mid-1950s. Until the early 1930s, it was German culture and German institutions that molded him. The two *Handbuch der Physik* articles are the fruition of stage one.

The period from the early 1930s till 1940 reflects his interactions with Fermi and with the physicists at Cambridge, Manchester, Bristol, and Cornell. It is also indicative of the sense of belonging these communities had offered him. Unlike the *Handbuch* articles, the Bethe bible was undertaken on his initiative. It was designed to give to the American nuclear-physics community the theoretical perspectives that would direct their researches. The *Reviews of Modern Physics* articles and his solution of the problem of energy generation in stars[16] epitomize the capacities of the mature scientist who helped shape the new field of nuclear physics.

The third period, which began with the outbreak of World War II, saw Bethe solve, again on his own initiative, important problems in armor penetration and the physics and chemistry of shock waves. After Pearl Harbor, he acquired new authority at the Radiation Laboratory at MIT and at Los Alamos Laboratory: He became the charismatic leader of important divisions of those laboratories. The postwar years from 1946 to 1955 constituted one of the most exhilarating phases of Bethe's life, both scientifically and professionally. The stage for his activities became national and international. Bethe was at the center of important new developments in quantum electrodynamics and meson theory. He helped Cornell become one of the outstanding universities in the world. He was a much sought-after and highly valued consultant to the private industries trying to develop atomic energy for peaceful purposes. He was deeply involved and exerted great influence in issues concerning national security. He was happily married and the proud father of two very bright children. But the demands from his activities outside Cornell were enormous, the pace was grueling, and the activities were exacting a heavy toll both at home and in his research. In 1955 Bethe went to Cambridge University to spend a sabbatical year there. It was a year of taking stock and of narrowing his scientific focus.

The Washington Conferences 1935–42*

Date	Topic	Attendance
19–21 April 1935	Nuclear Physics	35
27–29 April 1936	Molecular Physics	60
15–20 February 1937	Elementary Particles	26
21–23 March 1938	Stellar Energy	34
26–28 January 1939	Low Temperature	53
21–23 March 1940	Interior of the Earth	56
22–24 May 1941	Elementary Particles	33
23–25 April 1942	Stellar Evolution & Cosmology	25

*The data come from material presented by Karl Hufbauer at the 1980 meeting of the History of Science Society. The attendance figures include invited members and those present informally.

Epilogue

In an article entitled "We Refugees," Hannah Arendt describes her experiences as a refugee first in France and then in the US following Hitler's rise to power:

> We lost our homes, which means the familiarity of daily life. We lost our occupation, which means the confidence that we are of some use in the world. We lost our language, which means the naturalness of reactions, the simplicity of gestures, the unaffected expression of feelings.[17]

Bethe's experience was almost the opposite of Arendt's. He did not lose the familiarity of daily life; on the contrary he became less isolated, and life in general became more intense, more rewarding, and more fulfilling for him. Nor did he lose his occupation; in fact, he obtained a temporary position that quickly became permanent and that allowed him to grow and to meet and surmount new

Hans Bethe to Arnold Sommerfeld[5]

20 May 1947

I am very gratified and very honored that you have thought of me as your successor. If everything since 1933 could be undone, I would be very happy to accept this offer. It would be lovely to return to the place where I learned physics from you, and learned to solve problems carefully. And where subsequently as your *Assistent* and as *Privatdozent* I had perhaps the most fruitful period of my life as a scientist. It would be lovely to try to continue your work and to teach the Munich students in the same sense as you have always done: With you one was certain to always hear of the latest developments in physics, and simultaneously learn mathematical exactness, which so many theoretical physicists neglect today.

Unfortunately it is not possible to extinguish the last 14 years. . . . For us who were expelled from our positions in Germany, it is not possible to forget.

Perhaps still more important than my negative memories of Germany, is my positive attitude toward America. It occurs to me (already since many years ago) that I am much more at home in America than I ever was in Germany. As if I was born in Germany only by mistake, and only came to my true homeland at 28. Americans (nearly all of them) are friendly, not stiff or reserved, nor have a brusque attitude as most Germans do. It is natural here to approach all other people in a friendly way. Professors and students relate in a comradely way without any artificially erected barrier. Scientific research is mostly cooperative, and one does not see competitive envy between researchers anywhere. Politically most professors and students are liberal and reflect about the world outside—that was a revelation to me, because in Germany it was customary to be reactionary (long before the Nazis) and to parrot the slogans of the German National ["Deutschnationaler"] party. In brief, I find it far more congenial to live with Americans than with my German "Volksgenossen." [This word is identified with Nazi rhetoric, so there is a touch of sarcasm in Bethe using it. It might be rendered in English as "national comrade."]

On top of that America has treated me very well. I came here under circumstances which did not permit me to be very choosy. In a very short time I had a full professorship, probably more quickly than I would have gotten it in Germany if Hitler had not come. Although a fairly recent immigrant, I was allowed to work and have a prominent position in military laboratories. Now, after the war, Cornell has built a large new nuclear physics laboratory essentially "around me." And 2 or 3 of the best American universities have made me tempting offers.

I hardly need mention the material side, insofar as my own salary is concerned and also the equipment for the Institute. And I hope, dear Mr. Sommerfeld, that you will understand: Understand what I love in America and that I owe America much gratitude (disregarding the fact that I like it here). Understand, what shadows lie between myself and Germany. And most of all understand, that in spite of my "no" I am very grateful to you for thinking of me.

challenges on a time scale much shorter than would have been the case had he remained in Germany. In addition, by virtue of the collective efforts he became engaged in, he became much more creative and productive. Until he had gone to England, Bethe was the sole author of his research publications. The prank with Beck and Riezler was his first collaborative effort, and a paper with Fermi his first true scientific collaboration. Many of Bethe's publications thereafter were joint efforts—with Peierls, with Livingston, with Bacher, with his graduate students and postdoctoral fellows.

Bethe didn't lose his language or suffer the consequences of its loss. He had secured his command of English during his first visit to England in 1930, and his stay in Manchester and Bristol had made him a native English speaker, except for a slight accent. Furthermore, the Anglo-American context evidently had allowed him to give genuine expression to his feelings. At a symposium on nuclear physics during the 1930s, Bethe entitled his talk "The Happy Thirties." Although he was referring primarily to developments in nuclear physics, his own personal and professional life had likewise been transformed for the better—despite the fact that "politically the thirties were anything but happy."[18]

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