

The Emergence of Princeton as a World Center for Mathematical Research, 1896-1939

1. Introduction

In 1896 the College of New Jersey changed its name to Princeton University, reflecting its ambitions for graduate education and research. At the time, Princeton, like other American universities, was primarily a teaching institution that made few significant contributions to mathematics. Just four decades later, by the mid-1930s, Princeton had become a world center for mathematical research and advanced education.¹ This paper reviews some social and institutional factors significant in this rapid rise to excellence.²

The decade of the 1930s was a critical period for American research mathematics generally, and for Princeton in particular. The charter of the Institute for Advanced Study in 1930 and the completion of a university mathematics building (Fine Hall) in 1931 frame the opening of the period in Princeton; the completion of separate quarters (Fuld Hall) for the institute mathematicians in 1939 and the entrance of the United States into World War II effectively close it. During this decade, Princeton had the unique atmosphere of an exclusive and highly productive mathematical club. This social environment changed after the war with the increase in university personnel and the move of the institute to separate quarters, and the uniqueness was challenged by the improvement of mathematical research and advanced education at other American institutions.

I appreciate the useful comments and corrections of Richard Askey, Saunders MacLane, and V. Frederick Rickey to the conference presentation and of Garrett Birkhoff and Albert W. Tucker to later drafts of the manuscript. The writing of this paper was stimulated by my participation in the Princeton Mathematical Community in the 1930s Oral History Project, which resulted from the efforts of Charles Gillespie, Frederik Nebeker, and especially Albert Tucker and from the financial support of the Alfred P. Sloan Foundation.

2. A Fine Start

Efforts to establish a research program in mathematics at Princeton University began in the first decade of the twentieth century at the hands of Henry Burchard Fine. Fine had completed an undergraduate major in classics at Princeton in 1880 and remained until 1884, first as a fellow in experimental physics and then as a tutor in mathematics. The latter position brought him into contact with George Bruce Halsted, a mathematics instructor fresh from his dissertation work under J. J. Sylvester at Johns Hopkins University.³ Fine wrote of their relationship in a testimonial:

I am glad of this opportunity of acknowledging my obligations to Dr. Halsted. Though all my early prejudices and previous training had been in favor of classical study, through his influence I was turned from the Classics to Mathematics, and under his instruction or direction almost all of my mathematical training had been acquired. (Eisenhart 1950, 31-32)

On Halsted's advice, Fine traveled to Leipzig in the spring of 1884 to study with Felix Klein. Halsted's ability to inspire proved greater than his ability to teach Fine mathematics, for Klein found Fine to know no German and little mathematics. Nevertheless, Fine was encouraged to attend lectures. He progressed quickly and was awarded the Ph.D. after only a year for his solution to a problem in algebraic geometry. In the summer of 1885, and again in 1891, Fine visited Berlin to study with Leopold Kronecker. Fine's first book and several of his papers are testimony to the profound influence of Kronecker (Fine 1891, 1892, 1914).

Fine returned to Princeton in the fall of 1885 as an assistant professor of mathematics with an admiration for the German system, which provided opportunities for young mathematicians to work closely with established researchers. He progressed steadily through the ranks. In 1889 he was promoted to professor and in 1898 to Dod Professor; by 1900, he was the senior member of the department. During Woodrow Wilson's tenure as university president, from 1903 to 1911, Fine's career and his influence on Princeton mathematics advanced most rapidly.⁴ Fine was appointed chairman of mathematics (1904-28), dean of the faculty (1903-12), and dean of the science departments (1909-28). When Wilson resigned to run for governor of New Jersey in 1911, Fine served as acting president of the university until John Grier Hibben was appointed president.

Fine published several research papers in geometry and numerical

analysis, but he was most prominent as a textbook writer (Fine 1905, 1927; Fine and Thompson 1909) and an institution builder. In the latter capacity, he was one of two professors of mathematics to support Thomas Fiske's 1888 plan to found the New York Mathematical Society, which became the American Mathematical Society (AMS) after an international meeting at the time of the Chicago World's Fair in 1893. In 1911 and 1912, Fine served as president of the society.

When Wilson was called to the Princeton presidency in 1903, his first priority was to match the quality of the educational program to the upgraded status of a university. At Wilson's instigation, the preceptorial system was introduced in 1905 to provide smaller classes and more personalized instruction. Fine was a strong proponent of the system, and he recognized the opportunity to strengthen the mathematics program through the new appointments the preceptorial system required.⁵

At the time of Wilson's appointment, the mathematics department numbered eight members—none more distinguished a researcher than Fine. Undergraduate teaching loads were heavy, salaries low, and opportunities for research limited. The department had an office in the library (East Pyne Hall), but most individual faculty members had to work at home.

Fine planned to build a strong research program in mathematics slowly through appointments to young mathematicians with research promise. In 1905 he appointed the young American mathematicians Gilbert Bliss, Luther Eisenhart, Oswald Veblen, and John Wesley Young to preceptorships. In a move that was uncharacteristic of American mathematical institutions, Fine also sought to hire English-speaking European mathematicians.⁶ That same year he hired James Jeans to a professorship in applied mathematics and offered a senior position to Jeans's fellow Englishman, Arthur Eddington, who declined it in favor of a post at the Greenwich Observatory. When Bliss left for Chicago and Young for Illinois in 1908,⁷ Fine replaced them with the promising American mathematician G. D. Birkhoff and the young Scottish algebraist J. H. M. Wedderburn. Birkhoff left for Harvard in 1912 and was replaced in 1913 by the Parisian Pierre Boutroux. Fine added the Swede Thomas Gronwall in 1913, Princeton-born and -educated James Alexander in 1915, another young Swede, Einar Hille, in 1922, and Paris-trained Solomon Lefschetz in 1924. Thus, between 1905 and 1925 many of the young mathematicians who were to become leaders in American mathematics were members of the Princeton faculty.⁸ Princeton was beginning to collect mathematical talent that ri-

valed that of the established world centers: Göttingen, Berlin, Paris, Cambridge, Harvard, and Chicago.

3. The 1920s

Although individual members of the mathematics faculty carried on intensive research activities, Princeton remained principally a teaching institution in the 1920s. As at most American universities during those years, the Princeton faculty was saddled with heavy undergraduate teaching loads and had little money to improve facilities or research opportunities. The European mathematicians who came to Princeton recognized this clearly. As Einar Hille remembers his first year there, in 1922-23: "Princeton was somewhat of a disappointment. There were in power old undergraduate teachers Gillespie, McInnes, Thompson. I think that during my first term there I had two divisions of trigonometry with endless homework" (Hille 1962). Solomon Lefschetz confirmed this situation:

When I came in 1924 there were only seven men there engaged in mathematical research.⁹ These were Fine, Eisenhart, Veblen, Wedderburn, Alexander, Einar Hille and myself. In the beginning we had no quarters. Everyone worked at home. Two rooms in Palmer [Laboratory of Physics] had been assigned to us. One was used as a library, and the other for everything else! Only three members of the department had offices. Fine and Eisenhart [as administrators] had offices in Nassau Hall, and Veblen had an office in Palmer. (Bienen 1970, 18-19)

The situation began to change around 1924 when an effort was made to raise funds to support mathematical research. With the turnover in the preceptorial rank and the disinterest of Wedderburn and others in institutional matters, the responsibility for building the Princeton research program devolved to Fine, Eisenhart, and Veblen. The first step was taken by Veblen during his term in 1923-24 as president of the American Mathematical Society.¹⁰ In an effort to improve American mathematics nationally, he arranged for mathematicians to be included in the National Research Council fellowship program already established for physicists and chemists. He also established an endowment fund for the AMS and raised funds to subsidize its publications.

Within Princeton, the move to improve the research environment was spearheaded by Fine with the assistance of Eisenhart and Veblen. As dean of the sciences, Fine assumed responsibility for helping Princeton President Hibben to raise and allocate funds for research in the sciences. In

a fund-raising document of 1926, Fine outlined the “means to the full realization for the purposes of the Mathematics Department”:

- (1) Endowment for Research Professorships.
- (2) Improvement and increase of personnel with schedules compatible with better teaching and more research.
- (3) A departmental research fund to meet changing conditions.
- (4) A visiting professorship which might well bear the name of Boutroux [in memorium].
- (5) A group of offices and other rooms for mathematical work, both undergraduate and advanced.
- (6) Continued financial support for the *Annals of Mathematics*.
- (7) A number of graduate scholarships. (Fine 1926)

It is instructive to compare this list of objectives outlined by Fine to a plan for an Institute for Mathematical Research proposed by Veblen in the period of 1924-26 to both the National Research Council and the General Education Board of the Rockefeller Foundation. Veblen’s plan not only amplifies on the reasoning behind Fine’s list, but also illustrates the greater vision of Veblen—realized in the 1930s with the founding of the Institute for Advanced Study.

Veblen’s argument began with the premise that “the surest way of promoting such research [in pure science] is to provide the opportunities for competent men to devote themselves to it” (letter to H. J. Thorkelson, 21 October 1925, Veblen Papers). According to the American system, Veblen noted, this is a “by-product of teaching. The consequence has been that although our country has produced a great many men of high abilities, very few of them have an output which corresponds to their native gifts.” Playing to the desire of funding organizations to build strong American research institutions, Veblen added that “men of considerably less ability have been able to do greater things in the European environment . . . [because] their time and energy have been free for the prosecution of their research.” Elaborating this argument elsewhere, Veblen noted that his American colleagues taught nine to fifteen hours a week as compared with three hours by a mathematician in the College de France;¹¹ and that the American mathematician’s primary task was the teaching of elementary subjects to freshmen and sophomores. These subjects were taught in the lycées and Gymnasia of Europe, and university research mathematicians there could concentrate on the teaching of more advanced subjects (letter to Vernon Kellogg, 10 June 1924, Veblen Papers).

The simplest solution, to Veblen's mind, was to provide research positions for mathematicians in which teaching duties would be limited or not required. But how was this to be accomplished? Veblen rejected the idea of "distinguished service professorships," which he was skeptical in general "would be held by men of high distinction, but who often would have passed the most active stage of research" ("Institute for Mathematical Research at Princeton"; undated, unsigned proposal, Veblen Papers).

Instead, he proposed an institute consisting of "a balanced group of first rank productive mathematicians who have opportunities for mathematical research comparable with opportunities ordinarily given those who conduct research, and train research workers, in the laboratory sciences" (document labeled "C. Mathematical Research," probably prepared for the Princeton Scientific Fund proposal to the General Education Board; undated, unsigned, Veblen Papers).

The institute he envisioned would consist of four or five senior mathematicians and an equal number of junior colleagues. The senior men would devote themselves "entirely to research and to the guidance of the research of younger men," though all institute members should "be free to offer occasional courses for advanced students" (letter to Vernon Kellogg, 10 June 1924, Veblen Papers). Beyond salaries, professorial needs were not very great: a library, a few offices, lecture rooms, a few computing machines, and money for stenographers and (human) computers. The institute could operate successfully, he maintained, either in conjunction with a university or independently.

Veblen's preference for an institute over individual research professorships was based on his and Eisenhart's assessment of the success of Göttingen over other German universities as a mathematical research center.

In those cases where a good scientific tradition has been established and has subsequently broken down, it will be found that the organization was such as to depend on a single leader. The break in the tradition came when the leader died. But if instead of having a single outstanding figure, you have a group of men of different ages who are working together so that the replacements which take place are gradual, then if you have made a good start, the conservative forces inherent in such a group tend to maintain it. A good illustration of this is to be found in the mathematical tradition of Göttingen. While there have often been men of the first magnitude at Göttingen, there has always been a large group gathered together which has maintained itself so well that the prestige of the Mathematical Institute at Göttingen is, if

possible, greater now than it ever has been. During the same period of time the other German universities, which have depended for their eminence on particular individuals, have had vicissitudes of all kinds. The preeminence of Göttingen is due to the laws of statistics and the power of tradition. (Letter to H. J. Thorkelson, 21 October 1925, Veblen Papers)

As a further incentive for funding, Veblen sought to dedicate the institute to applied mathematics, a discipline he regarded as underrepresented in the United States. He pointed out that through the work of Eisenhart, Veblen, and Tracy Thomas in topology and differential geometry, Princeton had already initiated “a very definite programme” in this direction. “This programme embraces studies in the geometry of paths and analysis situs which are becoming more and more clearly the foundations of dynamics and the quantum theory” (“Institute for Mathematical Research at Princeton”; undated, unsigned proposal, Veblen Papers).

For whatever reasons, Veblen’s plan for an institute was not realized at this time. No record of the National Research Council’s response has been found. His proposal to the General Education Board was included as part of Princeton’s general campaign to raise money to support fundamental work in the sciences, a campaign that Fine directed for President Hibben. This proposal did call for support for, among projects in astronomy, physics, chemistry, and biology, a mathematical institute with focus on applied mathematics; and it specifically referred to Veblen’s earlier contacts with the board (“Memorandum for Dr. Wickliffe Rose . . . for Endowment of Research in the Fundamental Sciences”; undated, Veblen Papers). Although this grant was made, the money was not used to form the institute Veblen desired. One reason may have been the board’s concern about the long-term productivity of research mathematicians:

(1) that one cannot be absolutely sure that a man who is appointed to a research position will continue for the rest of his life to do research of a high grade, and (2) that supposing your first appointments to be of the right quality, it is not certain that this quality will be maintained through the long future. (As repeated by Veblen in letter to H. J. Thorkelson, 21 October 1925, Veblen Papers)

Although the institute was not funded, the umbrella grant for fundamental scientific research was. The board awarded Princeton \$1 million on the condition that it raise twice that amount. By 1928 the university

had raised the \$2 million through alumni gifts, and one-fifth of the total amount (\$600,000) was made available to the mathematics department. It was used to buy library materials, support the journal *Annals of Mathematics*,¹² reduce teaching loads, and pay salaries of visiting mathematicians.¹³

Most of the other objectives on Fine's list were also met. Soon after Fine became involved with the Fund Campaign Committee in 1926, he approached Thomas Jones, an old friend and former Princeton classmate who had made a fortune through a Chicago law practice and his presidency of the Mineral Point Zinc Company. Jones endowed the Fine Professorship, the most distinguished chair in American mathematics at the time. Together with his niece Gwenthelyn, Jones also provided \$500,000 to the research fund and endowed three chairs, including the Jones Chair in Mathematical Physics, which was first held by Hermann Weyl in 1928-29.

Princeton was able to provide good financial support for doctoral and postdoctoral mathematicians in the late 1920s and the 1930s. It attracted more National Research Council fellows than any other U.S. university.¹⁴ British and French students were supported by the Commonwealth and Procter Fellowship programs and American graduate students by university funds.

Of the items on Fine's list, an endowment for research professorships, a departmental research fund, a visiting professorship, support for *Annals of Mathematics*, and graduate scholarships were all met. Only two items caused difficulty: increase in personnel and housing. Both needs were met in the early 1930s.

4. Fine Hall

In the late 1920s, the University of Chicago began construction of Eckart Hall for its mathematics department.¹⁵ Veblen, a Chicago Ph.D. with continuing ties to his alma mater, kept closely informed about the new mathematics building.¹⁶ He recognized its potential value in nurturing a mathematics community and "so he worked on Dean Fine to have this as a goal in connection with the Scientific Research Fund" (private communication from A. W. Tucker, 1985). Although Fine understood the need for adequate space (item 6 on his list), he resisted Veblen's exhortations because he knew that money was not available for similar buildings for the other sciences. Psychology, in particular, Fine regarded as having a greater space need than mathematics.

Curiously, Fine's accidental death in 1928 made possible the realization of Veblen's plan. Within a few weeks after Fine's death, the Jones family offered funds for the construction and maintenance of a mathematics building in memory of Dean Fine. Veblen and Wedderburn were given responsibility for designing the new building. Veblen took charge and designed a building that, as Jones said, "any mathematician would be loath to leave" (*Princeton University Alumni Weekly* 1931, 113). The building was constructed of red brick and limestone in the "college Gothic" style of the universities of Paris and Oxford that Veblen so admired.¹⁷ Fine Hall was situated adjacent to the Palmer Laboratory of Physics, with a connecting corridor to enable the physicists easy access to the library and Common Room.

Veblen attended to every last detail in the design and finishing of the building. He worked closely with a high-quality decorating firm from New York on the furnishings and insisted on extensive sound testing of the classrooms. All design features were carefully chosen to promote a research environment and communal interaction. As Veblen observed:

The modern American university is a complicated organism devoted to a variety of purposes among which creative scholarship is sometimes overlooked. Those universities which do recognize it as one of their purposes are beginning to feel the necessity of providing centers about which people of like intellectual interests can group themselves for mutual encouragement and support, and where the young recruit and the old campaigner can have those informal and easy contacts that are so important to each of them. (*Princeton University Alumni Weekly* 1931, 112)

The top floor housed the library for mathematics and physics. An open central court provided natural lighting and quiet space with carrels for each graduate student and postdoctoral visitor. Conversation rooms with blackboards were available in each corner. Eisenhart convinced the university administration to transfer there from the main library all books of research value to mathematicians and physicists, and all researchers had 24-hour access to the collection. Subscriptions of *Annals of Mathematics* were traded to other institutions in order to build up a complete collection of research journals, including all of the major foreign journals.

On the second floor the faculty members had "studies"—not offices—some of which were large rooms lavishly appointed with fireplaces, carved oak paneling, leather sofas, oriental rugs, concealed blackboards and coat

closets, and leaded windows with mathematical designs. To promote continued close ties with physics, the mathematical physicists were also assigned studies there.¹⁸

The second floor also housed a Common Room and a Professor's Lounge, following a tradition Veblen had admired at Oxford. Princeton faculty proved to be less interested than their Oxford colleagues in having a place to retire from their students, and the rather formal Professor's Lounge was seldom used. However, at most any time of day or night one could find graduate students, faculty members, or visitors in the Common Room discussing mathematics, playing Kriegspiel, Go, or chess, or sleeping. The social and perhaps intellectual zenith was attained each weekday afternoon when the mathematics and physics communities would gather for tea. Here twenty or thirty would meet to socialize and discuss their craft.

The first floor housed additional studies, the chairman's (Eisenhart's) office, and various classrooms sized to accommodate seminars or lectures, all with ample blackboard space, good acoustics, and carefully determined dimensions. Completing the club atmosphere was a locker room with showers to facilitate short breaks by faculty (especially Alexander) on the nearby tennis or squash courts.

Fine Hall succeeded in promoting a community atmosphere for the mathematical researchers. Because of the Depression and the rule against marriage for graduate students, many of these poor, single, male students rented small furnished rooms in town and ate meals in restaurants. The Common Room was their main living space. The many foreign faculty members, students, and visitors also congregated in Fine Hall, which they found to be a place of congeniality.¹⁹ Faculty members regularly used their studies, which contributed to the close ties between students and staff. Between 1933 and 1939, when Fuld Hall was completed for the institute, Fine Hall also accommodated the institute's faculty and many visitors.

Today, many departments have facilities similar to, if more modest than, Fine Hall. But this environment, unusual for its time, promoted a sense of community that was impossible to foster at many universities, like Harvard, where the faculty was scattered across the campus without a common meeting place.²⁰ Albert Tucker, a graduate student and later a faculty member at Princeton in the 1930s, describes the importance of Fine Hall to his career:²¹

It was the amenities of Fine Hall that certainly caused me to come back

to Princeton in 1933, after the year that I had my National Research Council Fellowship. I could have had a second year as a Fellow, just for the asking; but if I had, I would be supposed to spend it somewhere else than Fine Hall because that was where I had gotten my doctor's degree. The experiences that I had had at Cambridge, England, but particularly at Harvard and Chicago, made me long for the comforts, the social atmosphere, the library convenience of Fine Hall. Of course there were other things, Lefschetz, Eisenhart, and so on. But at the time, [when] Marston Morse told me I was a fool not to take the instructorship at Harvard . . . it was the opportunity to be in the Fine Hall community [that mattered]. (Oral history, 11 April 1984; The Princeton Mathematical Community in the 1930s Oral History Project, Princeton University Archives)

Between the time of the Jones gift in 1928 and the completion of Fine Hall in the fall of 1931, mathematics buildings opened at Chicago, Paris, Göttingen, and Jena. Yet, as one of the earliest and certainly the most successful building for this purpose, Fine Hall served frequently as an architectural model.²² For example, Dartmouth, Wisconsin, Arizona State, and Western Australia modeled their mathematics buildings after Fine Hall.

5. The Institute for Advanced Study

By the time the department moved into Fine Hall in 1931, the conditions were favorable for research. Of Fine's original list of objectives only item 2, improvement and increase of personnel with schedules compatible with better teaching and more research, was unfulfilled. This was soon to be met by the founding of the Institute for Advanced Study.

The story of the institute is well known and need not be told in detail here.²³ Money from the Bamberger and Fuld family fortunes was donated in 1930 to endow an institute for advanced research to be situated in the state of New Jersey or a contiguous area. Abraham Flexner, retired from the General Education Board and the original proponent of this advanced research institute, was appointed as director. Flexner chose Princeton as the site because he believed its rural environment was suitable to pure scholarly endeavor and because the university possessed a good research library. He decided to focus the institute's activities initially in a single area, and he chose mathematics as that area for three reasons:

- (1) It was fundamental.
- (2) It required the least investment in plant or books.

- (3) It had become obvious to me [Flexner] that I could secure greater agreement upon personnel in the field of mathematics than in any other subject. (Flexner 1940, 235)

Between 1930 and 1932, Flexner toured Europe and North America discussing his plans with leading scholars. Veblen impressed Flexner with his counsel,²⁴ and, once mathematics was chosen in 1932 as the institute's first mission, Veblen was given the first faculty appointment. On an earlier trip to Europe, Flexner had discussed with Albert Einstein and Hermann Weyl the prospect of their joining the institute faculty. Veblen assumed responsibility for selecting the other original faculty members of the institute's School of Mathematics. James Alexander, John von Neumann, Einstein, and Weyl joined the institute in 1933 and Marston Morse in 1935.

Flexner and Veblen assembled an impressive international group of research mathematicians. Alexander was a distinguished topologist. Einstein was already world-renowned for his contributions to theoretical physics. Morse was an accomplished Harvard mathematician known for his research in "analysis in the large." Veblen was the senior American geometer. Von Neumann was a brilliant young mathematician who had already made major contributions to logic, quantum mechanics, and analysis. Weyl, who was regarded as having the widest range of mathematical knowledge since Poincaré, was Hilbert's successor in the mathematics chair at Göttingen. The institute had many visitors each year and a few research associates (known as "permanent members") like Kurt Gödel, but these six constituted the regular faculty of the School of Mathematics for about ten years.²⁵

Although the research environment was undoubtedly an attraction, social factors also contributed to their decisions to accept appointments. Alexander, whose family wealth freed him from the need to work, was relieved at the release from teaching responsibility that the institute position offered. The Nazis drove Einstein, von Neumann, and Weyl from Europe: von Neumann lost his position at Berlin for being Jewish,²⁶ and Weyl feared for his Jewish wife and found the Nazi interference in the affairs of the mathematics institute at Göttingen intolerable. Morse had a better opportunity at the institute to forward his research program through the availability of funds for visiting postdoctoral researchers, and it must also have been some comfort to escape from the Harvard environment where his wife had recently divorced him to marry another of the Harvard mathematicians.

During the 1932-33 academic year, Veblen rented office space for the institute in a commercial building near the Princeton campus while retaining his research study in Fine Hall. President Hibben was sympathetic to the institute's goals and offered a five-year lease on space in Fine Hall, which had been built with expansion of the department in mind and therefore exceeded current space needs. The offer was gratefully accepted and the institute settled into Fine Hall the following year.

In the early years, it was uncertain what direction the institute might take. The charter provided for it to become an educational institution and grant doctoral degrees—in competition with the university. Others may have envisioned it as an “Ivory Tower” where distinguished mathematicians could pursue their research without distraction. Veblen steered a third course, however, emphasizing both postdoctoral education and research. The institute's School of Mathematics realized the plans for an Institute for Mathematical Research that Veblen had outlined in 1925, with the exception that applied mathematics was only the principal, not the exclusive, subject of research.

Veblen envisioned a place where promising young Ph.D.s and established research mathematicians could interact and pursue common mathematical research interests without interruption by undergraduate teaching or other routine faculty duties. To that end, he arranged for adequate funds for visitors, including funds for many young Ph.D.s to work as research assistants of the permanent institute faculty.

There was free interchange between institute and university personnel. Following Veblen's example, institute faculty members offered advanced seminars open to both institute and university faculty members, visitors, and students. For example, when Gödel presented his famous institute lectures on incompleteness in 1934, graduate students Stephen Kleene and J. Barkley Rosser prepared the course notes for distribution. Institute members were commonly employed as informal advisors of doctoral dissertations, and during this period, when both university and institute mathematicians had offices in Fine Hall, it was difficult to determine the official affiliation of visitors.

6. Growth of the Department

The founding of the institute could have seriously weakened the university's mathematics program. With Veblen, Alexander, and von Neumann accepting positions at the institute and Hille leaving for a professorship

at Yale in 1933, representing over a third of the faculty and a greater percentage of those productive in research, the university's strength in mathematics was seriously threatened.²⁷ Both the institute and the university recognized the advantages of cooperation. Both gained from having a larger community of permanent and visiting mathematicians. The university retained the services of Alexander, Veblen, and von Neumann at least to the degree that they were available to consult, help direct theses, referee articles for *Annals of Mathematics*, and present advanced seminars.²⁸ The institute gained in return a good research library and excellent physical facilities.

Nonetheless, the department confronted a major rebuilding project. The able leadership of Eisenhart and Lefschetz carried the department through this tumultuous period. As department chairman and dean of the faculty, Eisenhart was in a position to facilitate close ties with the institute, which he supported as favorable to the university. When a new dean of the faculty was appointed, the position of dean of the graduate school was assigned to Eisenhart.²⁹ Although his greatest interest had always been in the undergraduate mathematics program, he devoted himself to his new duties and was able to use his position within the university to secure adequate resources for the graduate program in mathematics.

Lefschetz was appointed to the Fine Research Professorship vacated by Veblen. Although this position did not require teaching, Lefschetz followed Veblen's example and taught a research seminar every semester, which was well attended by the graduate students. Lefschetz was also departmental representative to the Committee on the Graduate School, which enabled him to further protect the interests of the graduate mathematics program. It also stimulated him to take a personal interest in the graduate students: he meticulously inspected graduate applications to select the ten to twenty percent that he believed could handle the demanding but unstructured graduate program. He went to great lengths to meet each graduate student and monitor his progress, and he was adept at identifying dissertation problems of appropriate content and difficulty. He directed many dissertations, including those of Hugh Dowker, William Flexner, Ralph Fox, Paul Smith, Norman Steenrod, Albert Tucker, John Tukey, Robert Walker, and Henry Wallman in the period 1925-39. While Eisenhart administered the department and the relations with the rest of the university, Lefschetz built up the research and graduate programs.

After considering senior appointments to outsiders, the decision was

made to continue the Fine approach and replace the departing senior mathematicians with promising junior researchers.

It is the desire of this department to maintain its distinction by giving constant attention to the question of its personnel. Because we publish the *Annals of Mathematics*, we know rather well who the good men of the country are. Furthermore, because of the presence here of the Institute for Advanced Study, we have an additional means of keeping in contact with this situation.

Salomon Bochner, H. F. Bohnenblust, E. J. McShane, Albert Tucker, and Samuel Wilks were given junior appointments in 1933, as were Norman Steenrod, Walter Strodt, E. W. Titt, and C. B. Tompkins later in the decade.

The department continued to concentrate in a few select fields and did not try to provide uniform coverage of all areas of mathematics. Research in geometry and topology was carried out by Eisenhart, Lefschetz, Tracy Thomas, Morris Knebelman, Tucker, and Steenrod in the university and by Veblen and Alexander in the institute; mathematical physics by Eugene Wigner and H. P. Robertson in the university and by Weyl, von Neumann, and Einstein in the institute; mathematical logic by Church in the university and Gödel in the institute; and analysis by Bohnenblust, Bochner, and McShane in the university and by von Neumann and Weyl in the institute. A new area of research was initiated with the hiring of S. S. Wilks, one of the pioneers in mathematical statistics.

Measured by number or productivity of postgraduate mathematicians, the Princeton mathematical community excelled in the 1930s. Between 1930 and 1939 the university produced 39 mathematics Ph.D.s, including (with others already mentioned) Carl Allendoerfer, John Bardeen, J. L. Barnes, A. L. Foster, Wallace Givens, Robert Greenwood, Israel Halperin, Banesh Hoffmann, Nathan Jacobson, Malcolm Robertson, Ernst Snapper, Abraham Taub, Alan Turing, J. L. Vanderslice, J. H. C. Whitehead, and Shaun Wylie. Between 1923 and 1941, the years of the NRC Fellowship program in mathematics, 59 mathematicians visited Princeton, including (among others already mentioned) A. A. Albert, Gustav Hedlund, Derrick Lehmer, Neal McCoy, Deane Montgomery, Charles Morrey, Hassler Whitney, and Leo Zippin. One hundred eighty-nine mathematicians were visitors to the institute between 1933 and 1939, notably Reinhold Baer, Valentine Bargmann, Paul Bernays, Garrett Birkhoff, Eduard Cech, A. H. Clifford, P. A. M. Dirac, Witold Hurewicz, Deane Montgomery, Marshall Stone, Stanislaw Ulam, Andre Weil, and Oscar Zariski.

7. Conclusion

Institutional factors clearly helped to shape the development of the mathematics programs in Princeton in the 1930s. Careful planning by Fine, Eisenhart, and Veblen over the preceding quarter-century placed Princeton in a position to establish a world-class center of mathematics once funds started to become available in the late 1920s.

Funding for these purposes was fairly easily acquired. It may have been fortunate that the Fuld and Bamberger families were willing to endow the Institute in 1930, but it was no accident that Veblen was ready with a strong plan to build it in Princeton and to devote it to mathematical research. It is clear that the trend in the 1920s of the great foundations to support American scholarship benefited Princeton mathematics. However, it must be remembered that the bulk of the money for the university's program in mathematics came through alumni gifts. The ease at raising these matching funds is perhaps indicative of the general wealth of the United States in the late 1920s.

The existing strength of the department and a workable plan for the future were undoubtedly strong factors in attracting financial support. Several principles were consistently applied by Fine, Veblen, and others over the first forty years of the century to build excellence in the department and later in the institute. Foremost was the emphasis on research, as demonstrated in appointments and promotions, training offered to graduate students, teaching loads, and many other ways. This ran counter to the well-established tradition of American colleges as undergraduate teaching institutions. Second was the attempt to build a community of mathematical researchers so that the "old campaigner" and the "young recruit" could exchange ideas. Third was the concentration on a few areas (topology, differential geometry, mathematical physics, and logic), instead of attempting to provide uniform coverage across all of mathematics. Fourth was the adoption of an international perspective. More than any other American university in the period 1905-40, Princeton sought out students, visitors, and faculty from around the world. When the Nazi peril disrupted European mathematics, Veblen and Weyl led the way in placing émigré mathematicians in American institutions, including some in Princeton (Reingold 1981). Fifth was the decision to build up a research community through the cultivation of young mathematical talent. Although the institute took great advantage of the Nazi situation in attracting Einstein, von Neumann, and Weyl to its faculty, most of the Princeton staff was hired at the junior level and promoted from within.

Finally, great attention was given to environmental factors that would affect the research community. Prominent among these was Fine Hall. It is hard to overemphasize the importance Princeton mathematicians of the 1930s attached to their physical quarters. Soon universities throughout the world came to recognize the value of a place where their mathematicians could gather to discuss mathematics, with excellent support facilities. Another factor was the editing of professional journals (*Annals of Mathematics* and *Studies*, *Journal of Symbolic Logic*, and *Annals of Mathematical Statistics*) at Princeton. They provided the faculty and their students with an outlet for research and gave the faculty some control over the direction of American research. These journals also provided extensive contacts with the wider mathematical community and a vehicle for scouting new talent for appointments. Financial support for graduate students and visitors and for reduced teaching loads of staff also promoted the growth of a large community focused on mathematical research.

The success in Princeton is even more remarkable when it is considered that it occurred at the same time as the Great Depression and the growth of Nazism. General economic circumstances severely depressed academic salaries, limited funds for graduate and postdoctoral support, and restricted job placement for Princeton Ph.D.s and junior faculty. The political disruption of European academics resulted in an influx of European mathematicians into the United States, further straining the appointment and promotion of American-bred and -trained mathematicians.

Notes

1. Others were even more lavish in their praise of Princeton: R. C. Archibald wrote of Princeton as "the greatest center of mathematical activity in this country" (Archibald 1938, 169); the Danish mathematician Harald Bohr referred to Princeton as "the mathematical center of the world" when addressing an international scientific audience in 1936 (Chaplin 1958).

2. This paper about Princeton tells part of a larger story of the emergence of mathematics research in U.S. institutions in the period 1875-1940. The full story involves the rise of mathematics at Brown, Chicago, Clark, Johns Hopkins, Harvard, and Yale universities in the first half of this period and at Berkeley, MIT, Michigan, Stanford, and Wisconsin near the end. Harvard and Chicago, in particular, have many parallels with Princeton. Some information on this topic can be found in (Archibald 1938; Birkhoff 1977; Bocher et al. 1911; Lewis 1976; Reid 1976). Dr. Uta Merzbach of the Smithsonian Institution is preparing a history of American mathematics and mathematical institutions.

In this paper, I have focused on social and institutional issues. I am planning additional papers on the contributions in the 1930s of Princeton mathematicians to topology and logic.

3. Halsted was widely influential in the early development of American mathematics, e.g. inspiring Leonard Dickson and R. L. Moore as well as Fine (Birkhoff 1976; Lewis 1976).

4. Fine and Wilson were lifelong friends, having first become acquainted while working on the editorial board of the student newspaper, the *Princetonian*.

5. Harvard adopted the preceptorial system in 1910, using it to finance graduate students and train them to teach, rather than hiring additional junior faculty members.

6. Other distinguished European research mathematicians that came to the United States in its formative period include J. J. Sylvester at Johns Hopkins, R. Perrault at Johns Hopkins and Clark, and Oskar Bolza and Heinrich Maschke at Clark and Chicago. The number of foreign mathematicians willing to accept appointments in the United States was small. Many of the senior American mathematicians in this period were not distinguished researchers. Thus, Fine's appointment strategy appears sound.

7. Bliss became a leading figure in the Chicago department and in American mathematics generally. After two years at the University of Illinois and a year as mathematics department chairman at the University of Kansas, Young devoted many years to building up the mathematics program at Dartmouth.

8. Note the interesting, but perhaps coincidental, pattern of junior appointments at the university: 1905-10, American, trained elsewhere; 1910-25, mostly European; 1925-40, mostly American, several having been trained at Princeton. Princeton was not the first experience with U.S. institutions for some of these young European mathematicians. For example, Wedderburn first spent a year at Chicago and Hille a year at Harvard.

9. By the standards of the major European centers of the time, or of major American universities when Lefschetz made this comment in 1970, seven was not a large number of research mathematicians for an institution. But few other American universities, if any, had that large a number in 1924.

10. Veblen's interest in fund-raising dates from after World War I, perhaps stemming from his wartime administrative experience at Aberdeen Proving Grounds in Maryland.

11. At most American universities in the 1920s, mathematicians taught twelve or more hours per week. According to Garrett Birkhoff, it was considered a great coup at Harvard in 1928 when the weekly load for a mathematician was reduced to $4\frac{1}{2}$ hours of lectures, $1\frac{1}{2}$ hours of theoretical tutoring, and 3 hours of graduate student supervision (private correspondence, 4 October 1985).

12. Princeton had assumed editorial responsibility for *Annals of Mathematics* in 1911. Previously it was edited at Harvard, and before that at the University of Virginia.

13. Long-term visitors to the department in the late 1920s and 1930s included: Paul Alexandroff and Heinz Hopf (1927-28); G. H. Hardy (1928-29); Thornton Fry, John von Neumann, and Eugene Wigner (1929-30, the last two returning in subsequent years); J. H. Roberts and J. H. van Vleck (1937-38); and C. Chevalley (1939-40).

14. Veblen was one of three members of the NRC Fellowship selection committee for mathematics and was thus positioned to assist Princeton mathematics. This arrangement is characteristic of the organization of American mathematics in the 1920s and 1930s, where the power was concentrated in a small number of individuals, including G. D. Birkhoff of Harvard, G. A. Bliss of Chicago, R. G. D. Richardson of Brown, Veblen, and perhaps a few others.

15. Increased wealth in the United States in the latter 1920s redounded on the universities. Chicago's ability to construct Eckart Hall, Harvard's reduction of the teaching load, and Princeton's ease at matching the Rockefeller grant through alumni contributions all indicate this improved economic condition.

16. Veblen was at the University of Chicago from 1900 to 1905, receiving his Ph.D. in 1903 under the direction of E. H. Moore. Veblen's drive to build up American mathematics may have been stimulated by his experience at the University of Chicago, where Moore had built a strong program that produced many prominent research mathematicians, including L. E. Dickson, G. A. Bliss, G. D. Birkhoff, and Veblen, as well as supplying several major midwestern universities with their mathematics chairmen.

17. Veblen drew many ideas for Fine Hall from a visit to Oxford in 1928-29. As Savilian Professor, G. H. Hardy was expected to lecture occasionally on geometry. To avoid this responsibility, he exchanged positions that year with Veblen, whose principal mathematical interest was geometry.

18. Physics and mathematics had shared quarters earlier in Palmer Laboratory. Pro-

fessor Condon of physics was a supporter and advisor on the planning of Fine Hall; there are many references to Condon's role in the Oswald Veblen Papers.

19. Weyl reported to his former colleagues in Göttingen that German was spoken as much as English in the institute, then located in Fine Hall (Reid 1976, 157). Garrett Birkhoff reports that in the latter 1930s the official language of the institute was jokingly said to be "broken English" (private communication, 24 October 1985).

20. Harvard did have a common room, Room O, in Widener Library, but it did not have the facilities or receive the use that Fine Hall did.

21. Although Tucker may attach more significance to the environment of Fine Hall than others might care to, more than twenty mathematicians commented on the amenities of Fine Hall in the Princeton Mathematics Community of the 1930s Oral History Project.

22. The Conference Board of the Mathematical Sciences used Fine Hall as a model in a book on mathematical facilities (Frame 1963).

23. The most accessible account is in (Flexner 1940, chap. 27 and 28).

24. Flexner and Veblen held similar views about education and research. Both were enamored with the European university systems (see Flexner 1930), and both felt a need "to emphasize scholarship and the capacity for severe intellectual efforts" (Flexner 1927, 10). Both saw a need for an environment where the research faculty would be free from "routine duties . . . —from administrative burdens, from secondary instruction, from distracting tasks undertaken to piece out a livelihood" (Flexner 1930, 10-11). Both saw the research institute as a "specialized and advanced university laboratory" (Flexner 1930, 35). However, they disagreed on the addition of schools of study to the institute, support of European mathematicians, a new institute building off the university campus, administrative responsibilities for institute faculty, and other matters (see Reingold and Reingold 1982, chap. 13).

25. There is little firm evidence of who else was considered or offered an original appointment at the institute. An offer to G. D. Birkhoff was declined. Harvard countered the offer by making Birkhoff a Cabot Fellow. The address pages of Veblen's 1932 diary list five groupings of names that may have been candidates for institute positions or people whose advice Veblen sought about candidates during a 1932 tour of Europe and North America. The names (separated by semicolons the way Veblen grouped them) are as follows: Dirac, Artin, Lefschetz, Morse; Alexandroff, Wiener, Kolmogorov, von Neumann; Albert, R. Brauer, Gödel, Douglas; Bernays, Peterson, Kloosterman, Heyting, Chapin; Deuring, McShane, Whitney, Mahler.

26. Von Neumann was teaching half-time at Berlin and half-time at Princeton. After wavering for a considerable time, the university offered him a full-time position. He chose the appointment at the institute instead.

27. The 1933-34 directory of members of the mathematics department lists professors L. P. Eisenhart, W. Gillespie, S. Lefschetz, J. H. M. Wedderburn, and E. P. Wigner; associate professors H. P. Robertson and T. Y. Thomas (on leave); assistant professors H. F. Bohnenblust, A. Church, and M. S. Knebelman; and instructors E. G. McShane, J. Singer, A. W. Tucker, and S. S. Wilks. There were others listed as part-time instructors, research assistants, and advanced fellows.

28. Additional information about mathematics journals edited at Princeton in the 1930s and their contributions to the research community can be found in an oral history I conducted with Albert Tucker on 13 April 1984 (Princeton Mathematical Community in the 1930s, Oral History PMC 34).

29. In 1932-33, Eisenhart headed the Princeton administration as dean of the faculty—between the death of President Hibben and the appointment of President Dodds. Dodds appointed Eisenhart to replace the physicist Augustus Trowbridge as dean of the Graduate School and made Robert Root the new dean of the faculty.

Bibliography

The following bibliography includes only published and widely distributed printed materials. Biographies of the many distinguished Princeton mathematicians and physicists discussed herein are excluded, except those that have been quoted. *Bulletin of the American Mathematical Society*, *Dictionary of Scientific Biography*, *Proceedings of the National Academy of Sciences*, and *Princeton Alumni Weekly* have carried biographies of many of these mathematicians.

Two fertile archival sources for this research are the Oswald Veblen Papers and the Princeton Mathematical Community in the 1930s Oral History Project. The Veblen Papers are held by the Manuscripts Division of the Library of Congress, Washington, D.C. The Oral History Project records are held by the Seeley G. Mudd Manuscript Library of Princeton University. Copies are on deposit at the American Philosophical Society in Philadelphia and the Charles Babbage Institute, University of Minnesota, Minneapolis.

Archibald, R. C. 1938. *A Semicentennial History of the American Mathematical Society: 1888-1938*. Semicentennial Publications, vol. 1. Providence, R. I.: American Mathematical Society.

Bienen, Leigh Buchanan. 1970. Notes Found in a Klein Bottle. *Princeton Alumni Weekly* (April 21), pp. 17-20.

Birkhoff, Garrett. 1977. Some Leaders in American Mathematics: 1891-1941. In *The Bicentennial Tribute to American Mathematics 1776-1976*. ed. J. Dalton Tarwater. Providence, R. I.: American Mathematical Society.

Bocher, M., Curtiss, D. R., Smith, P. F., and Van Vleck, E. B. 1911. Graduate Work in Mathematics. *Bulletin of the American Mathematical Society* 18: 122-37.

Chaplin, Virginia. 1958. A History of Mathematics at Princeton. *Princeton Alumni Weekly* (May 9).

Eisenhart, Katherine. 1950. Brief Biographies of Princeton Mathematicians and Physicists. Unpublished, Princeton.

Eisenhart, L. P. 1931. The Progress of Science: Henry Burchard Fine and the Fine Memorial Hall. *Scientific Monthly* 33: 565-68.

Fine, H. B. 1891. *The Number System of Algebra Treated Theoretically and Historically*. Boston: Lench, Showall, and Sanborn.

———. 1892. Kronecker and His Arithmetical Theory of the Algebraic Equation. *Bulletin of the New York Mathematical Society* 1: 173-84.

———. 1905. *A College Algebra*. Boston: Ginn.

———. 1914. An Unpublished Theorem of Kronecker Respecting Numerical Equations. *Bulletin of the American Mathematical Society* 20: 339-58.

———. 1926. The Role of Mathematics. Limited distribution pamphlet (unsigned). The Princeton Fund Committee, Princeton University Press.

———. 1927. *Calculus*. New York: Macmillan.

Fine, H. B., and Thompson, Henry Dallas. 1909. *Coordinate Geometry*. New York: Macmillan.

Flexner, Abraham. 1927. *Do Americans Really Value Education?* The Inglis Lecture. Cambridge, Mass.: Harvard University Press.

———. 1930. *Universities: American, English, German*. New York: Oxford University Press.

———. 1940. *I Remember: The Autobiography of Abraham Flexner*. New York: Simon and Schuster.

Frame, J. Sutherland. 1963. *Buildings and Facilities for the Mathematical Sciences*. Washington, D.C.: Conference Board of the Mathematical Sciences.

Grabner, Judith V. 1977. Mathematics in America: The First Hundred Years. In *The Bicentennial Tribute to American Mathematics 1776-1976*, ed. J. Dalton Tarwater. Providence, R.I.: American Mathematical Society. 9-25.

Hille, Einar. 1962. In Retrospect. Unpublished notes dated 16 May, Yale University Mathematics Colloquium.

- Lewis, Albert. 1976. George Bruce Halsted and the Development of American Mathematics. In *Men and Institutions in American Mathematics*, ed. J. Dalton Tarwater, John T. White, and John D. Miller. Lubbock, Tex.: Texas Tech Press, Graduate Studies 13, pp. 123-30.
- Montgomery, Deane. 1963. Oswald Veblen. *Bulletin of the American Mathematical Society* 69: 26-36.
- Princeton University Alumni Weekly*. 1931. A Memorial to a Scholar-Teacher. 30 October, pp. 111-13.
- Reid, Constance. 1976. *Courant in Göttingen and New York*. New York: Springer-Verlag.
- Reingold, Nathan. 1981. Refugee Mathematicians in the United States of America, 1933-1941: Reception and Reaction. *Annals of Science* 38: 313-38.
- Reingold, Nathan, and Reingold, Ida H., eds. 1982. *Science in America: A Documentary History, 1900-1939*. Chicago: University of Chicago Press.
- Richardson, R. G. D. 1936. The Ph.D. Degree and Mathematical Research. *American Mathematical Monthly* (April), pp. 199-204.
- Stone, Marshall H. 1976. Men and Institutions in American Mathematics. In *Men and Institutions in American Mathematics*, ed. J. Dalton Tarwater, John T. White, and John D. Miller. Lubbock, Tex.: Texas Tech Press, Graduate Studies 13, pp. 7-30.
- Veblen, Oswald. 1929. Henry Burchard Fine—In Memoriam. *Bulletin of the American Mathematical Society* 35: 726-30.