# The Vision, Insight, and Influence of Oswald Veblen

*Steve Batterson*

When Oswald Veblen assumed the presidency of the American Mathematical Society in 1923, there was little support for mathematical research in the United States. University teaching loads varied from nine hours to fifteen hours per week and higher. The birth of the National Science Foundation was over a quarter century in the future. Research grants and postdoctoral positions (with little or no teaching) did not exist for mathematicians.

**Oswald Veblen, 1924.**

As a professor at Princeton University, Veblen himself was a member of a premier mathematics department. Yet just four of Veblen's colleagues were actively engaged in research, and, among them, James Alexander, Einar Hille, and Joseph Wedderburn worked with no office space. Hille, as an instructor, was assigned teaching duties that included two sections of trigonometry. Instructors at Columbia and Michigan taught twelve and sixteen hours per week respectively [1], [2], [3].

Veblen took up the task of improving the circumstances for research mathematicians. His success in this endeavor was but one facet of a career that had an enormous impact on mathematics and the profession. For example, due entirely to Veblen's initiative the young scholars Kurt Gödel and John von Neumann were recruited for academic opportunities in the United States. As a mathematician Veblen was no slouch. His work included the first rigorous proof of the Jordan Curve Theorem. It was Veblen who made Poincaré's brilliant algebraic topology concepts accessible to the field's pioneers. Among the students supervised by Veblen were R. L. Moore, Alonzo Church, and J. H. C. Whitehead, who went on to become leaders in the development of their respective specialities.

*Steve Batterson is associate professor of mathematics and computer science at Emory University. His email address is* `sb@mathcs.emory.edu`.

I first came to appreciate Veblen's significance when I began research for a book on the origins of the Institute for Advanced Study. In discussing my project with others it became evident that Veblen's contributions were largely unknown to the mathematicians of today. Oswald was frequently confused with his more famous uncle, economist Thorstein Veblen. The objective of this article is to review Oswald Veblen's overall influence as mathematician, mentor, and advocate. I am grateful to Michele Benzi and Albert Lewis for their suggestions.

## Mathematical Ascendance

Oswald Veblen was of Norwegian descent. His mother Kirsti Hougen was born in Norway while his father, Andrew, and Uncle Thorstein were first generation Americans from Wisconsin. The Hougen and Veblen families settled on nearby farms in Minnesota. Kirsti and Andrew married in 1877 [4], [5].

On June 25, 1880, Oswald Veblen was born in Decorah, Iowa, where his father was teaching at Luther College. Shortly afterward Andrew began graduate study at Johns Hopkins. In 1883 the family returned to Iowa for Andrew to teach physics and mathematics at the University of Iowa. There Oswald was educated from elementary school through an undergraduate degree at the university in 1898. Two years later he received a second B.A. from Harvard.

In 1900 Veblen began graduate school at the University of Chicago. He arrived without any financial support, "but with a hope that something might turn up." It did. Another student with a fellowship dropped out during his first quarter, and Veblen was awarded the US$320 stipend. [4/2/38, 5/2/38 Oswald Veblen to John Howe, from Oswald Veblen Papers, Manuscript Division, Library of Congress] Financial considerations aside, Chicago was a wise choice for graduate study in mathematics. The university, begun just eight years earlier, was in the midst of a historic period in the education of American mathematicians. Among the rising generation of leaders to receive Ph.D.s there at this time were Leonard Dickson (1896), Gilbert Bliss (1900), Veblen (1903), R. L. Moore (1905), and G. D. Birkhoff (1907). Each would later serve a term as president of the AMS.

The head of the Chicago department was E. H. Moore who was one of the most highly regarded mathematicians in the country. Among Moore's interests was David Hilbert's recent work on the foundations of geometry. Veblen attended Moore's fall 1901 seminar covering this topic. Hilbert had employed the undefined terms of point, line, and plane, to devise a scheme of 20 axioms. Questions soon arose over the independence of these axioms. In the seminar Moore identified and sharpened the independence deficiencies. Veblen was inspired to go further in his 1903 thesis. Creating a framework based on just the two undefined elements of point and order, Veblen proposed twelve axioms for Euclidean geometry. He showed the axioms were independent and that they were satisfied by a system that was essentially unique [6].

Veblen remained at Chicago for two notable postdoctoral years. During this period he polished his thesis for publication, proved a major theorem, began a collaboration, and joined his advisor E. H. Moore in directing the thesis research of a newly arrived student. The student was R. L. Moore and the collaborator a young Scottish algebraist, Joseph Wedderburn. The theorem was the long accepted Jordan Curve Theorem for which previous proofs were unsatisfactory. Veblen was well prepared to go out on his own.

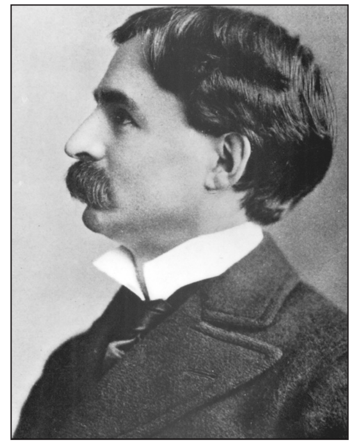
It was at this time, in 1905, that Princeton University President Woodrow Wilson embarked on a program to upgrade the university. A key element of his plan was the creation of a large number of junior faculty positions to reduce class size and individualize undergraduate education. These "preceptors" were to teach traditional classes as well as provide one-on-one supervision to upper class students. Selection of the mathematics preceptors was in the hands of mathematician and Dean of the Faculty Henry Fine.

Fine recognized an opportunity to change the direction of a department that, aside from himself and the young instructor Luther Eisenhart, had no commitment to research. When Fine contacted E. H. Moore to solicit nominations, Moore strongly recommended Veblen. Veblen and Eisenhart were joined by Gilbert Bliss and J. W. Young as the first mathematics preceptors [1].

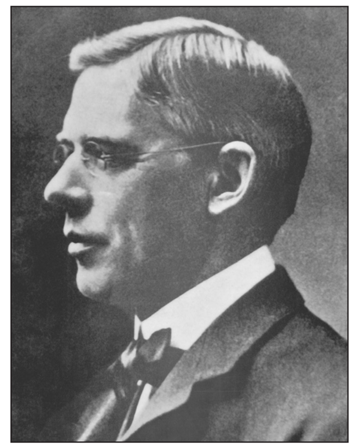
The selections were superb. Each preceptor was both a rising scholar and leader. Veblen and Eisenhart would work with Fine in engineering Princeton's advancement. Bliss and Young remained for three years before moving on. Bliss returned to Chicago and together with Dickson became the department's second generation of leaders. Young eventually settled at Dartmouth where he initiated a transformation toward research.

At Princeton Veblen began to collaborate with Young on projective geometry. Their work culminated in a classic text on the subject. The first volume appeared in 1910, with a second volume slated for the following year. The scheduling was optimistic. The authors were separated, and Young was moving from the chair duties at Kansas to the the headship at Dartmouth. Veblen, who had taken on other projects as well, finished the second volume on his own in 1917. Some indication of the enduring value of these books is given by a mid-2006 ISI Web of Knowledge citation search, which recorded twenty-seven hits among articles published since 2000.

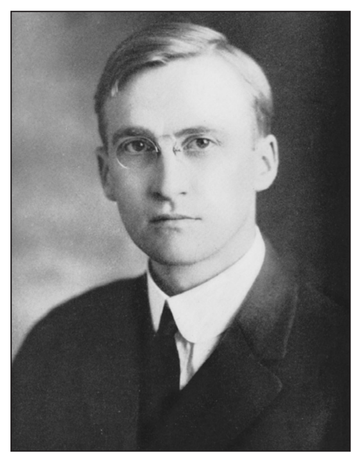
The year 1905 marks the beginning of Princeton's ascendance to world class mathematics standing. Veblen's fingerprints immediately appear all over the university's successful efforts to identify and recruit promising young talent. Prior to the completion of his first year, Veblen wrote to R. L. Moore to sound out his interest in a position. Moore became the fifth preceptor, before going to Northwestern University and then to the University of Pennsylvania and the University of Texas. With the departures of Moore, Bliss, and Young, two outstanding mathematicians came to Princeton as replacements in 1909. Both had overlapped with Veblen at Chicago. They were his collaborator Wedderburn and G.D. Birkhoff, a later E. H. Moore student.



**E. H. Moore, 1902.**



**Henry Fine, 1911.**



**G. D. Birkhoff, 1913.**

Photographs on this page are from the AMS archives.

Birkhoff was just twenty-five when his appointment began at Princeton. Frequent walks there with the four-year-older Veblen cemented a lifelong personal and professional friendship. It would have been fascinating to listen in on these conversations, for the interaction undoubtedly stimulated subsequent developments at this historic time in the emergence of mathematical research in America. Birkhoff and Veblen were pursuing different programs of Poincaré. With Birkhoff it was celestial mechanics that would lead to his seminal proof of the existence of fixed points for certain area preserving maps of the annulus. Veblen became interested in Poincaré's conceptualization of algebraic topology (known then as analysis situs) which, to this point, was largely undeveloped. Birkhoff remained at Princeton for three years and then went to Harvard where he earned acclaim as the foremost American mathematician.

Poincaré's publications on analysis situs appeared over the period 1892-1905. Jean Dieudonné provided the following assessment:

> As in so many of his papers [Poincaré] gave free rein to his imaginative powers and his extraordinary "intuition", which only very seldom led him astray; in almost every section is an original idea. But we should not look for precise definitions, and it is often necessary to guess what he had in mind by interpreting the context. For many results, he simply gave no proof at all, and when he endeavored to write down a proof hardly a single argument does not raise doubts. The paper is really a blueprint for future development of entirely new ideas, each of which demanded the creation of a new technique to put it on a sound basis. [Jean Dieudonné, *A History of Algebraic and Differential Topology 1900-1960*, Birkhäuser (1989) p. 17]

In view of these obstacles it is not surprising that the concepts of homology and fundamental group remained fallow for nearly a decade. Veblen, a remarkable connoisseur of mathematics and mathematicians, appreciated the value of Poincaré's ideas and saw the need to establish a solid foundation upon which they could be communicated to other mathematicians. Veblen set himself to the task, recruiting a brilliant young Princeton graduate student, James W. Alexander, to join him in the effort. Their combinatorial formulation of homology for polyhedra, deriving the Betti numbers, torsion coefficients, and their properties, appeared in the 1913 *Annals of Mathematics*. The notion of homology groups was still a dozen years in the future.

Even with this introduction to the subject, algebraic topology remained out of the mainstream of mathematical research. According to longtime Princeton mathematician Albert Tucker, Veblen was sufficiently concerned over the subject's standing that he advised Alexander to obtain his Ph.D. in a more fashionable area [7]. In 1915 Alexander published two important papers. His thesis, under T. H. Gronwall, was on univalent functions. In another article Alexander established that the homology of a 3-dimensional polyhedron was independent of its triangulation.

Veblen's standing as a mathematician grew steadily at Princeton. An offer from Yale contributed to his 1910 promotion to the rank of full professor. At that time, one of the most prestigious recognitions for an American mathematician was an invitation to deliver the Colloquium Lectures. These opportunities arose every few summers when two prominent scholars were selected to showcase their work in a series of talks to the entire American Mathematical Society. The lectures were closely followed and much discussed.

When Veblen was invited to deliver the 1916 Colloquium Lectures, he might well have selected the established topic of projective geometry. Instead Veblen took the decision to proselytize the less respected subject of analysis situs. Over six lectures he developed the notions of Betti number, torsion, the fundamental group, and the topological classification problem.

As was customary with the Colloquium Lectures, Veblen revised and expanded his presentation into a monograph that the AMS published in 1922. In the preface Veblen stated his goal to provide "a systematic treatment of the elements of Analysis Situs", but cautioned that it should not be viewed as "a definitive treatment. For the subject is still in such a state that the best welcome that can be offered to any comprehensive treatment is to wish it a speedy obsolescence." The words were prophetic. Through Veblen a generation of mathematicians was introduced to the concepts of algebraic topology. The ideas quickly gained traction, and new developments followed. However, even after Lefschetz' more modern discussion of the subject was published in 1930, Veblen's book continued to serve as an important (and user-friendlier) primer.

The long lag between Veblen's Colloquium Lectures and their appearance in print coincided with the onset of World War I. The war contributed to the publication delay in two ways. The AMS underwent financial difficulties that set back its book program. Second, Veblen shifted his intellectual and physical energy to the war effort. This career move illustrated his *modus operandi*. Veblen was a visionary with an unusual capacity for implementation and realization of his ideas. In this case he wanted to utilize his skills to benefit the army. That Veblen lacked both military and applied mathematics experience was no deterrent to him. He would find a way to make a substantive contribution. In 1917 Veblen was commissioned as an army reserve captain and went through basic training. He then assumed charge of experimental ballistics at the new Aberdeen Proving Ground in Maryland [8].

Veblen took up the task of producing range tables for new weapons. These tables were designed for use by artillery officers in the field. The objective was to specify values for the distance a shell would travel, presented as a function of independent variables such as the angle of the cannon barrel and the amount of charge. There is a long mathematical history to the problem of configuring artillery to reach a target, accounting for drag and other factors [9]. At Aberdeen Veblen was to conduct test fires and then utilize the data to calculate the range table.

Neither the existing theory nor the Aberdeen infrastructure were adequate to produce satisfactory tables. The mathematical, logistical, and physical obstacles that arose are recounted in [8] and [9]. Veblen overcame the difficulties with a considerable combination of ingenuity and administrative skill. Along the way he built up his staff by recruiting young mathematicians such as Joseph Ritt and Norbert Wiener. Moreover, Veblen worked closely with the army office of theoretical ballistics, headed by University of Chicago astronomer Forest Moulton, to create the needed numerical methods. In [9], Goldstine portrays the World War I ballistics project as a crucial step in the development of computational mathematics and the computer.

Veblen devoted two years to the army. Returning to Princeton in 1919, he went to work on the colloquium book manuscript. In that same year Veblen was inducted into the National Academy of Sciences. At the age of thirty-nine he had reached the pinnacle of American scholarship. His intellectual development, over the first two decades of the twentieth century, occurred amidst an overall advance of American mathematics. For the first time United States mathematicians were gaining the respect of their European counterparts [6].

At the same time, mathematical scholarship was becoming more prevalent in the United States. Unlike in the previous century, researchers were to be found, though certainly not in any abundance, at most quality universities. Despite these advances neither the American academy nor government had done much to support mathematical scholarship. Teaching and service loads remained high, particularly in comparison to those for professors at European institutions. Veblen was well aware of these discrepancies.

## Advocate for Mathematics

Membership in the National Academy gave Veblen the standing to represent research mathematicians. His forceful personality, tall frame, and tweed suits made him an effective advocate. However, it was Veblen's faith in America's potential and his international perspective that would shape his actions.


Box 21, Oswald Veblen Papers, Manuscript Division, Library of Congress, Washington, D.C.

**Veblen in U.S. Army uniform.**

Veblen had been quick to broaden his experience beyond his midwestern upbringing. In the summer of 1905 he traveled through Europe to pursue contacts that arose out of his thesis research. The appointment at Princeton, in the fall, coincided with the hiring of British scientists James Jeans and Owen Richardson. Richardson had already done the work that would later be recognized with a Nobel Prize in physics. When Richardson's sister, Elizabeth, visited from England, Veblen met the woman he would marry in 1908. The marriage lasted until Veblen's death in 1960. There were no children. Owen returned to England in 1914, giving Veblen a connection to high level European science.

The Veblens spent the fall term of 1913 touring the mathematical centers of Europe, including Oslo, Göttingen, and Berlin. Sylow, Mittag-Leffler, Klein, and Schwarz were among the nineteenth century legends whom Veblen met personally. At each stop he keenly observed the scientific culture, particularly noting local frameworks for promoting mathematical interaction and for facilitating the communication of new results. Veblen was intrigued by how American mathematicians measured up to the higher status Europeans. He concluded that the United States was generally competitive with the Göttingen faculty, excepting Hilbert who was in a class by himself. This judgment, weighing one German department against an entire country, may have been influenced by chauvinism.

There were fundamental differences in the European and American educational systems that made for an uneven playing field. Especially significant to Veblen was the huge elementary service course burden that fell upon United States mathematics faculty. In Europe the syllabi for these courses were covered in the secondary schools. Their university faculty, unencumbered by high teaching loads, were free to focus on research and advanced students. Veblen's vision was for American research mathematicians to enjoy similar circumstances. It was a laudable goal, but how could a single mathematician make a difference? Veblen would find an opportunity with his appointment to the National Research Council (NRC), the operating arm of the National Academy of Sciences.

The NRC was composed of representatives from universities, private laboratories, government, and professional societies. The NRC's original mission was to coordinate the American scientific contribution to World War I, but its political roots went deeper. In the early twentieth century astronomer George Hale sought to upgrade the profile of the National Academy of Sciences. Hale's ambitions for the Academy became part of a power struggle over the direction of United States science policy. These issues were set aside when war appeared on the horizon. At this time, in 1916, Hale conceived the NRC. Among those joining Hale's team on the Council was the director of the Rockefeller Institute for Medical Research, Simon Flexner.

After the war, the NRC's mission was unclear. Meanwhile the debate resumed over how to channel science to serve a national interest that had been redefined by war. NRC members were among scientists urging that an infusion of funds for basic research in physics and chemistry was needed to maintain American strength. Flexner's endorsement influenced the Rockefeller Foundation to consider adopting this new cause. For some time the foundation grappled with whether to create a pure science laboratory or to enhance existing university operations. The outcome, in 1919, was a new mechanism for scientific support. Rather than allocate funds to laboratories, the Rockefeller Foundation underwrote a program of postdoctoral fellowships, in physics and chemistry, that was to be administered by the NRC. The politically engaged NRC gained new influence and a connection to the Rockefeller resources [10], [11].

Although mathematics had been entirely outside the consideration for research support in pure science, the AMS was represented on the NRC. When a new mathematics appointee was needed, Veblen's war work and National Academy membership made him an ideal choice. Veblen joined the NRC in 1920. As a member of the Executive Committee and the Division of Physical Sciences, he became an insider in discussions on national science policy. It was a role that suited him well. In 1923 Veblen became chair of the NRC Division of Physical Sciences. Within a few months he singlehandedly persuaded the NRC, Flexner, and the Rockefeller Foundation to expand the postdoctoral program to include mathematics.

Given the abundance of postdoctoral opportunities in mathematics today, it is difficult to comprehend the magnitude of Veblen's breakthrough in the funding of mathematical research. Consider the obstacles he faced. There was simply no precedent for extramural support in the United States. Veblen was asking philanthropy and government to begin perceiving mathematical research as essential to the national interest. The cases for physics and chemistry had been based on the importance of these subjects to the military, medicine, and industry. Attempting the same argument for mathematics posed problems. Range tables were less compelling than explosives and gases. Any medical justification needed to pass the scrutiny of Simon Flexner. Nevertheless, Veblen succeeded by making the indirect argument that mathematics was to chemistry and physics as chemistry and physics were to medicine. In the environment of the NRC, Veblen's diplomatic skills may have served him as well as his logic. It is unclear whether the same analogy would have worked if put forward by another mathematician with the initiative to act.

When Veblen brought about the first research grants for American mathematicians, he was serving both as president of the AMS and as one of the Society's representatives on the NRC. During its previous thirty-five years the AMS had advanced American mathematics through an agenda of organizing meetings and publishing research. Veblen's 1923–1924 presidency marked an expansion of AMS activity into the realm of advocacy. This move, while largely the product of a new president's vision, was also driven by financial necessity. Since the beginning of World War I, increasing publication costs had stressed the AMS finances. Printing the *Bulletin* and *Transactions* had driven the budget to five figures. Even with a 1920 boost in dues to US$6 and a successful membership drive, revenues were insufficient to keep up with the rising costs.

The 1923 incorporation of the AMS provided new financial flexibility. To address the budget shortfall, Veblen appointed Harvard mathematician Julian Coolidge to lead an endowment campaign. A US$100,000 goal was established. Coolidge raised one fourth of this sum through solicitations of AMS members. Late in 1923 Veblen joined Coolidge in bringing the appeal to the private sector. A simultaneous campaign was undertaken to increase awareness of the importance of mathematics to civilization. Out of this two-pronged approach came the creation of the annual Josiah Willard Gibbs Lecture on mathematics and its applications [4].

Coolidge and Veblen worked hard to win over chief executives. However, the tax system was not yet configured to promote corporate donations. When industrial officers expressed reluctance to authorize outright contributions, Veblen and Coolidge devised a variety of inducements. The most successful was the patron membership, a forerunner of today's institutional version, in which companies paid annual premiums and then designated selected employees for gratis AMS memberships [12].

The outcome of the endowment drive was mixed. The US$55,000 raised in pledges fell well short of the goal, but the patron memberships added an uncapitalized US$4,000 in revenue to the annual budget. In addition Veblen secured significant subventions from the NRC and Rockefeller Foundation to assist, over a period of years, with publication expenses. The bottom line was that the budget problems were temporarily resolved.

While working with Coolidge on behalf of the AMS, Veblen independently launched his most ambitious attempt at advocacy for mathematical research. After the funding was in place for the postdoctoral fellowships, he sent new appeals to his NRC and Rockefeller connections. Veblen described the plight of research mathematicians in the United States as follows: Over the prior quarter century American universities had come to select for mathematical scholarship, but had failed to make accommodations to cultivate it. The current situation was that research mathematicians, although in demand, had little time for research after completion of their teaching and service obligations. Even so, American mathematics had made enormous progress. In Europe conditions were much better. The teaching load of nine hours at Harvard contrasted with three hours at the Collège de France.

Veblen suggested that the foundations carry support for mathematics further. He portrayed the NRC postdoctoral fellowships as a vital first step in providing research opportunities to promising young scholars. "What remains to do is to find a way of assuring the continuance of their research to men who have proved their ability." [6/10/24 Oswald Veblen to Vernon Kellogg and to Abraham Flexner, from Oswald Veblen Papers, Manuscript Division, Library of Congress] Veblen proposed two solutions. The first was the creation of a mathematics institute where research, rather than teaching, was the primary business. The second proposal was the endowment of a number of research professorships in which recipients would remain at their universities and have their salaries subsidized to reduce teaching loads.

While Veblen initially pitched a generic institute that could stand alone or be incorporated as part of a university, developments at his own university soon led him to customize the proposal. In 1925 President John Grier Hibben mounted a major fund drive for Princeton. The needs of the sciences were to be presented in a request to the General Education Board of the Rockefeller Foundation. Veblen lobbied for inclusion of a mathematics institute, targeted at applications of the department's strengths in analysis situs and geometry.

With the support of Fine and Eisenhart, Veblen succeeded in having his institute included as part of a US$3.5 million plan for the sciences. The General Education Board received the overall proposal with favor, but questioned the institute aspect. During the final Rockefeller-University negotiations, the mathematics institute was deleted from the plan. Princeton was awarded a US$1 million challenge grant toward the adjusted goal of US$3 million.

Fine played a crucial role in raising the US$2 million Princeton obligation. Alumnus Thomas Jones, a long time friend of Fine, and Jones' niece Gwethalyn endowed four chairs in the sciences. Veblen became the first Henry Fine Research Professor of Mathematics, a position with no formal teaching duties.

From the new science endowment the Princeton mathematics department gained an annual stipend to program for research. Out of these funds Wedderburn, Alexander, and Solomon Lefschetz each received salary supplements to reduce their teaching loads. The homegrown Alexander had joined the faculty in 1915 and gone on to obtain fundamental results in topology. Lefschetz arrived from Kansas in 1924 for a visiting position that was made permanent the following year. With Lefschetz, Alexander, and Veblen, Princeton was a world center for the emerging subject of algebraic topology. The stimulating environment attracted European scholars Pavel Alexandroff and Heinz Hopf for productive visits in 1927–1928.

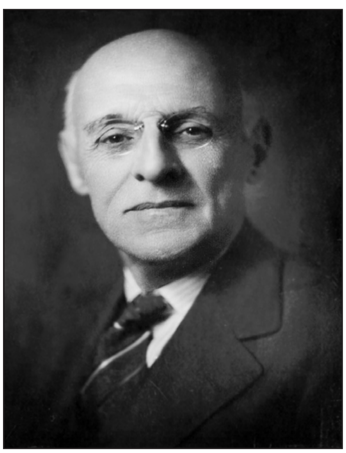
Mathematics at Princeton had come a long way since Veblen's arrival in 1905. The department stood with Harvard as the two leading mathematics institutions in the United States. Yet infrastructure remained essentially nonexistent. Fine and Eisenhart, as deans of science and of the faculty, had offices in an administration building. The rest of the department operated out of a small portion of the physics building that consisted of an office for Veblen, a library, and, according to Lefschetz, one room for "everything else". Wedderburn, Alexander, and Lefschetz worked at home [1].

The lack of physical space limited interaction among the mathematicians. Veblen was a strong believer in the notion of a community of scholars. He had observed the rich cultures at Göttingen and other European institutions. With planning under way for a mathematics building at the University of Chicago, Veblen pushed for Princeton to construct a home for its department. Any prospect of moving forward on the project required the endorsement of Fine, who had responsibility for the interests of other subjects as well. Outside funding was the surest route to the head of the queue. By the fall of 1928 some hope existed that the Rockefeller Foundation might finance the addition of a mathematics wing onto the physics laboratory. This was the situation as Veblen left for Oxford as part of a year long exchange with G. H. Hardy.

Joining Hardy at Princeton was Hermann Weyl who had accepted the Thomas Jones research professorship in mathematical physics. Weyl was on leave from his chair in Zurich, retaining the option to return, which he would. However the presence for 1928–1929 of, arguably, the world's two leading mathematicians, Hardy and Weyl, was a coup for both Princeton and the United States. Max Mason was impressed when he visited Princeton in November, just a few months after taking charge of the Rockefeller Foundation science program. Mason was an American mathematician who had been a student of David Hilbert at Göttingen.

Photograph used with the permission of Ernest D. Courant.

**Hermann Weyl (right) with David Hilbert, mid-1920s.**



Courtesy of the Archives of the Institute for Advanced Study.

**Abraham Flexner.**

In December 1928 Veblen received a letter from Fine predicting that Mason's Rockefeller group "will give us the Mathematics Building." [11/28/28 Henry Fine to Oswald Veblen, from Oswald Veblen Papers, Manuscript Division, Library of Congress] A few weeks later Fine was dead, hit from behind by an automobile while riding his bicycle at dusk. Shortly after Fine's death Thomas Jones announced a further beneficence, his intention to donate a new mathematics building as a memorial to Fine. Money was no longer an issue. The wealthy Jones intended to place the mathematics department in a home that would stand as a tribute to his friend Dean Fine. Rather than a wing added onto physics, Fine Hall would be a separate building with a corridor connecting it to physics.

The next step was to upgrade the plans that already existed for the physics wing. Wedderburn was serving as the liaison between the department and the architects. The frugal Wedderburn had been well placed when the budget and scale were limited, but he was ill suited to act on the possibilities opened by Jones' generosity. Alexander wrote to Veblen asking him to intervene: "The only thing between us and really homelike headquarters is Wedderburn's rather puritanical attitude. He acts, at times, as if he felt there was something just a little immoral about material comforts." [12/28/28 James Alexander to Oswald Veblen, from Oswald Veblen Papers, Manuscript Division, Library of Congress]

Veblen saw an opportunity, through Fine Hall, to realize crucial elements of his mathematics institute. Comfortable offices, a first class library, a modern lecture hall, and meeting places would bring together scholars for mathematical study and discussion in the manner that he had so admired in Europe. Veblen quickly took over the planning of the new building, incorporating features from Oxford, and seeking to create the ambiance of Göttingen. Many of the measures were unusual for the United States at this time. Undergraduate education received no consideration. The scope of Fine Hall was restricted to research and advanced instruction in mathematics and mathematical physics. Each member of the research faculty in these subjects received an office. A spacious library, common room, and professors' room were designed to promote study and interaction. Policies of daily afternoon teas and 24-hour access would make the first two venues into magnets for mathematical activity.

While Fine Hall proved itself to be a building of exceptional utility, the most striking feature was its opulence. Lavish oak paneling, carved figures, and fireplaces were incorporated throughout. It was all Veblen's doing. He believed that mathematical research was a high calling and that scholars deserved comfort and consideration. Veblen injected himself into every detail of the design, including the selection of each piece of quality furniture and even down to the placement of electrical sockets and choice of trash baskets. The furniture budget was over US$26,000. Nearly US$8,000 was allocated for rugs. Fine Hall opened in 1931 setting a new standard for American mathematical accommodations. A large number of graduate students, postdoctoral fellows, and visitors passed through its hallways, later lobbying their own universities to adopt aspects of its design.

## Veblen Shapes the Institute for Advanced Study

In the summer of 1930, as Veblen oversaw the planning for Fine Hall, a front page article in the *New York Times* caught his attention. A New Jersey family had donated US$5 million to endow the creation of an institution devoted entirely to research and graduate education. The Institute for Advanced Study (IAS) was to be located in the vicinity of Newark and be directed by Abraham Flexner. Veblen was acquainted with Flexner through his brother Simon. When Veblen first pitched his mathematics institute in 1924, Simon referred him to Abraham who was then a key figure at the General Education Board. Nothing had come from Veblen's follow up. However, a few months prior to the appearance of the *Times* piece, Abraham had initiated a seemingly innocuous correspondence about the state of research in the United States. Now Veblen sent Abraham a short congratulatory note in which he proposed Princeton as the site for the new institute. (For further details and references on the IAS see [14].)

Abraham Flexner's ambition was to elevate scholarship in the United States. His plan was to recruit a small number of world class scholars and provide them with ideal conditions to conduct research and train a few Ph.D. students. Flexner was interested in obtaining only the very best researchers. Subject area was less important. Over the next year Flexner traveled throughout the United States and Europe for consultations. Although he himself had no knowledge of mathematics, an interview with G. D. Birkhoff made a profound impression. Flexner decided then on mathematics as the first IAS program (or school). He would delay making Birkhoff an offer until further elements were in place.

One of the most delicate matters was the selection of a location for the IAS. The founders, Louis Bamberger and his sister Carrie Fuld, were set on Newark where they had made their fortune in the department store business. Flexner was attracted to the aesthetic and university resources of Princeton. Moreover, if space could be rented for Birkhoff in Fine Hall, then, together with the university mathematicians, the IAS would become a leading international center in its initial discipline. As Flexner moved quietly behind the scenes to explore a Princeton relationship, he was naturally drawn to the support and discretion of Veblen. Flexner worked out a Fine Hall arrangement, maintaining IAS autonomy, that he was eventually able to sell to Bamberger and Fuld.

In the midst of the diplomacy in Princeton, an important meeting took place between Veblen and Flexner. It occurred late in 1931, several months prior to an offer being made to Birkhoff. Flexner confidentially disclosed to Veblen his intention to begin the IAS with mathematics and Birkhoff. Veblen informed Flexner that a recent letter from Hermann Weyl indicated that Weyl might be movable to the United States. Following this exchange of inside information Veblen became Flexner's most influential advisor.

Flexner's first offers went to Birkhoff, Weyl, and Albert Einstein. When Birkhoff decided to remain at Harvard, Flexner turned to Veblen as a replacement. Weyl entered a long period of indecision over whether to resign the chair in which he had recently succeeded Hilbert at Göttingen. Veblen and Einstein accepted in June 1932. Veblen immediately went to work at realizing his institute through Flexner's. Along with his acceptance Veblen enclosed an elaborate plan for the School of Mathematics. His list of names to be considered for additional professorships consisted of Lefschetz, Alexander, Marston Morse, Paul Dirac, Emil Artin, Alexandroff, and Emmy Noether.

Flexner had not contemplated more than one or two professors for any school. He allowed mathematics to reach three only when extraordinary opportunities arose to obtain Weyl and the physicist Einstein. After making the initial hires in the School of Mathematics, Flexner expected to move on to economics and then to other subjects. He explained to Veblen that no more mathematics faculty were possible at the present time. Veblen temporarily pulled back, but he would soon resume his campaign for expansion. Meanwhile Flexner searched, in vain, for an economist. Although Veblen's persistent advocacy generated occasional friction, time and again he persuaded Flexner to go with one more outstanding mathematician. By 1935 the School of Mathematics faculty consisted of Veblen, Einstein, Weyl, Alexander, John von Neumann, Morse, and a one-year visitor, Wolfgang Pauli.

Von Neumann's path to the IAS, through Princeton University, illustrates Veblen's connoiseurship and his resourcefulness in building up the two institutions. Veblen, along with Eisenhart and Fine, always kept an eye out for young mathematical talent, both at home and abroad. Veblen took notice of von Neumann about the time of his Ph.D. from Budapest in 1926. Two years later they met at the International Congress of Mathematicians where Veblen broached the possibility of von Neumann coming to Princeton on an international fellowship. An opportunity at Hamburg halted von Neumann's consideration of Princeton. When Weyl resigned from the Thomas Jones chair the following year, Veblen began thinking of the twenty-six-year-old von Neumann as a possible successor. Veblen proposed to Eisenhart that von Neumann be given a visiting position as a tryout. Von Neumann came to Princeton for the spring term of 1930 and then began splitting his time between Princeton and Berlin. The Jones chair remained vacant.

The opportunity for von Neumann at the IAS also arose out of Weyl's career (in)decisions. Throughout 1932 Weyl continued to waffle on the IAS offer, prompting Bamberger to question his character and suitability for an appointment. Flexner defended Weyl, taking the risk of alienating his benefactor. Late in 1932, Weyl appeared to have decided on the IAS. Veblen then persuaded Flexner that the younger American, James Alexander, would add desirable balance to the School of Mathematics.

The appointments of Weyl and Alexander were on the docket for approval at the IAS trustees meeting in mid-January. During the week prior to the meeting, Weyl sent three telegrams, alternately accepting, withdrawing, and accepting again the IAS position. The second telegram caused Flexner to face the unpleasant prospect of explaining Weyl's peculiar behavior to a skeptical Bamberger and the board. Veblen seized the opportunity to push for another mathematician. He knew that von Neumann wanted a permanent, full-time position in the United States. Veblen urged Flexner to substitute von Neumann for Weyl.

Flexner weighed his decision carefully. With von Neumann already in Princeton, a quick acceptance was practically assured. Flexner liked the idea of giving the trustees the von Neumann good news to mitigate the Weyl bad news. The one reservation for Flexner was his genuine deference to Eisenhart who was moving to hire von Neumann for one of the university vacancies created by Veblen and Alexander. Then Flexner learned of Weyl's third telegram and everything suddenly changed. An offer to von Neumann would not only weaken the university, but it would require creation of a fifth position in the School of Mathematics. Despite Veblen's best efforts, Flexner decided to present just Weyl and Alexander to the trustees.

Two days after his appointment was approved, Weyl sent a fourth telegram with another withdrawal. Flexner then moved quickly to secure von Neumann. The IAS would open in 1933 with a faculty of Veblen, Einstein, Alexander, and von Neumann. As for Weyl, his erratic actions were taken in the midst of a nervous breakdown. The timing was catastrophic. Less than a month after Weyl spurned the IAS, Hitler became chancellor of Germany. Although Weyl himself was Aryan, his wife was Jewish. Their family was doomed.

Photo used with permission of Marina von Neumann Whitman.

**John von Neumann.**

During his recovery Weyl forthrightly poured out his feelings and fears in letters to the supportive Veblen. When Weyl regained his health and discovered the state of German society, he appealed to Veblen for reconsideration. This time Flexner was easy to convince. The problem was Bamberger, whose objections Flexner overcame. The School of Mathematics got its fifth professor. Veblen would also be instrumental in the hiring of Marston Morse who completed the first generation of IAS mathematics faculty.

Despite his role in assembling an extraordinary collection of scholars, Veblen's greatest IAS legacy may be his shaping of its postdoctoral policy. What follows is a brief description of how this crucial IAS component evolved. Flexner's vision for the IAS was inspired by Daniel Coit Gilman's original 1875 plan for Johns Hopkins University. Gilman conceived a graduate (only) university built around superior faculty devoted to research. Outside pressures forced Gilman to revise his program and include undergraduates.

Flexner was one of these undergraduates during the early years of Johns Hopkins. Out of this experience he adopted Gilman as a hero. When Flexner began to formulate his own higher education dogma, the Gilman influence pervaded his thinking. Among Flexner's strongest beliefs was that undergraduate and graduate education were incompatible. Only Ph.D. candidates were in the student plans at the founding of the IAS. In the fall of 1932 Flexner went one step further. He eliminated all degree study, replacing it with a new advanced educational class consisting of freshly minted Ph.D.s. These "students" were to be selected by individual IAS professors from whom they would receive further research mentoring. The IAS training was intended to strengthen the students' preparation for launching their own independent research programs as rookie faculty.

The switch from graduate to postdoctoral education occurred shortly after Veblen began promoting another European discovery, Kurt Gödel, for a year-long appointment. Flexner had at first balked at consideration of the twenty-six-year-old logician who was three years beyond his Ph.D. Gödel, however, fit the revised profile of a promising pre-faculty scholar. Flexner penciled in Gödel as Veblen's (and the IAS's) first student.

Veblen had his own vision for a mathematics institute: To bring together an exceptional group of scholars and provide them with an opportunity to interact and the freedom to concentrate on research. The differences with Flexner, aside from the number of personnel, were subtle. Veblen wanted a continuum of age and experience, in contrast to Flexner's polar student-professor scheme. Moreover, Veblen regarded everyone, even new Ph.D.s, as independent scholars. While he happily followed up on Flexner's suggestion of inviting Gödel, Veblen had no intention of acting as a supervisor.

In January 1933 Veblen decided to push the envelope on postdoctoral scholars. He proposed to Flexner that the IAS host one-year visits by young mathematicians who already held positions at Harvard, Johns Hopkins, and Chicago. Since these faculty were too junior to be eligible for sabbaticals, Veblen suggested that their salaries be split between the home university and the IAS. Flexner was negative. While he was anxious to advance the development of rising faculty, he expected the IAS to exert its role while the scholar was still a free agent. Supporting the research of a faculty member from a wealthy university struck Flexner as a one-sided arrangement in which the IAS was effectively making a subsidy to the other institution.

This reaction of the well meaning Flexner indicates how radical Veblen's proposal was for the time. Veblen defended his ground. He argued that all parties would benefit, with IAS personnel gaining stimulation from the interaction. Flexner agreed to try out the program on an experimental basis. The salaries of Adrian Albert and Egbertus van Kampen were shared with Chicago and Johns Hopkins.

Twenty other postdoctoral scholars joined Gödel, Albert, and van Kampen at the IAS in 1933–1934. Several were NRC fellows or Europeans on a Rockefeller Foundation program. Others found their own means of support. Together with the faculty and graduate students, Fine Hall quickly attained the standing and atmosphere that had so impressed Veblen at Göttingen. Whenever Flexner passed through the building he marveled at the mathematical activity. The postdoctoral student scheme was quietly abandoned.

Flexner began providing Veblen with an annual budget to support a class of visiting mathematicians (who became known as members). The funds went a long way. Veblen and his colleagues needed few incentives to attract the best to Princeton. In the second year of IAS operation the member roster numbered in the thirties and included more senior scholars such as Georges Lemaître, Joseph Walsh, and Oscar Zariski.

Over the past seventy-five years the School of Mathematics model has influenced the creation of numerous year-long research positions throughout the world. It would be easy to regard these opportunities, along with the sixty or so current annual IAS mathematics memberships, as simply a natural outgrowth of Veblen's initiative and vision in the early 1930s. Were it not for Veblen, however, the IAS program might well have been too short-lived for emulation. In the later 1930s severe financial exigencies forced difficult choices on Flexner. To keep the IAS solvent and complete its two other schools he reluctantly attempted to redirect money out of the mathematics members budget. Each year Veblen tenaciously battled to protect the endangered program. Cuts were made, but the essential character was maintained.

There was one unfortunate by-product of the IAS postdoctoral program. Its establishment prematurely phased out a notable career in the mentoring of graduate students. Even so, Veblen inspired a remarkable number of influential mathematicians who went on to careers in diverse specialities. R. L. Moore and Alexander were leaders in point set and algebraic topology respectively. In the 1920s Veblen supervised the theses of two students, Alonzo Church and T. Y. Thomas, who would follow Moore and Alexander into the National Academy of Sciences. Church, a Princeton undergraduate, was nurtured by Veblen to stay on for graduate school and to complete a thesis in foundations [15]. He went on to become a central figure in the development of logic in the United States. By this time Veblen's own mathematical interests had shifted. He was working on differential geometry, influenced in part by Einstein's discoveries in relativity. T. Y. Thomas pursued this thread.

Another distinguished Veblen student was the British topologist J. H. C. Whitehead. They became acquainted during Whitehead's study at Oxford in 1928. Veblen was then in residence through the exchange with G. H. Hardy. Whitehead was so inspired by Veblen's lectures that he transferred to Princeton where he completed his Ph.D. in 1932. Out of their collaboration Veblen and Whitehead introduced the modern definition of a differentiable manifold. Whitehead later returned to Oxford. His contributions to algebraic topology were recognized by election to the Royal Society.

## Statesman of Mathematics

The success of the IAS enhanced Veblen's already considerable prestige. Among American mathematical contemporaries, only G. D. Birkhoff and Leonard Dickson stood as high. While his two E. H. Moore siblings had the better theorems, the combination of Veblen's scholarship, associations, and leadership gave him enormous stature in the United States' mathematical community. Under the prevailing hiring practices of the day, departments frequently identified their job candidates by soliciting names from prominent outside scholars. Veblen was a key node in this "old boy network".

For some time Veblen used his influence to assist Princeton graduates and NRC postdoctoral fellows obtain suitable positions. When Hitler and the Nazis began to cleanse Jewish mathematicians from German universities, Veblen immediately took on a daunting challenge. He joined the Emergency Committee in Aid of Displaced Foreign Scholars, becoming a point person for the relocation of mathematicians to the United States. Through his European contacts Veblen kept abreast of the latest victims, and then pressed colleagues in American mathematics departments to consider some form of adoption. Advocating, in the 1930s, on behalf of European Jewish refugees was a delicate matter. The Great Depression was under way and jobs were scarce for American mathematicians. In addition, elements of anti-Semitism and xenophobia were prevalent on many campuses. Veblen managed to navigate this minefield while skillfully parlaying his connections with private foundations and American mathematicians to create new opportunities for Europeans.

Two examples, Richard Courant and Richard Brauer, provide some flavor of the range of these activities. Courant was the director of the Mathematics Institute at Göttingen while the thirty-two-year-old Brauer held a junior position at Königsberg. Both were dismissed in 1933. Veblen and Flexner made personal appeals on Courant's behalf. These efforts eventually led to Courant's consequential placement at New York University. A temporary position for Brauer developed out of a more general Veblen call that reached Leon Cohen at the University of Kentucky. Cohen had recently completed an NRC fellowship at Princeton. Grateful for his own career support from Veblen, Cohen managed to bring Brauer to Kentucky. The following year Brauer went to the IAS as Weyl's assistant. Local funds for both Courant and Brauer were supplemented by the Emergency Committee in Aid of Displaced Foreign Scholars [16].


Photograph from the AMS archives.

**R. G. D. Richardson.**

That Veblen was able to succeed in these humanitarian endeavors was likely what earned him the unusual appellation *statesman of mathematics*. Indeed, Veblen's bold diplomacy created manifold pathways that decisively improved the plight of mathematicians and elevated American research. A final illustration is provided by his role in the birth of *Mathematical Reviews*.

The first issue of *Mathematical Reviews* appeared in January 1940. The notion of an American journal of mathematical abstracts dates back to at least the 1920s. Veblen was among the early advocates, but, at the time, the publishing venture was infeasible for the AMS. The need for an abstracting journal was filled in 1931 by Berlin publisher Julius Springer with the creation of *Zentralblatt für Mathematik und ihre Grenzgebiete* under the able supervision of Otto Neugebauer [17], [16].

From his 1933 dealings on refugee mathematicians, Veblen was quick to anticipate future conflicts between Nazism and *Zentralblatt*. Neugebauer left Göttingen in 1934 when his political views, rather than his religious ancestry, made his situation impossible. For the next several years Neugebauer edited *Zentralblatt* from his new base in Copenhagen. Late in 1938 events unfolded rapidly. Springer removed the Italian Jewish mathematician, Tullio Levi-Civita, from the editorial board. Neugebauer questioned this action, only to receive a new decree that émigrés be excluded from reviewing the work of German authors. Neugebauer then resigned as editor of *Zentralblatt*.

Veblen learned of these developments on November 7, 1938, and sprang into action. He immediately coordinated with Courant, Tamarkin, and Hardy to resign their own associate editorships en masse. The act of protest left unresolved the sudden need for an objective international journal of mathematical abstracts. Two years earlier Veblen had had the foresight to ask Neugebauer to outline a budget for launching such an undertaking in the United States. Neugebauer estimated that an annual subvention of US$20,000 would be required. To understand the scale consider that in 1937 total AMS disbursements, including all journals and publications, were under US$33,000. In addition, there were other infrastructure demands of starting up such a personnel-intensive venture.

Veblen was determined to begin an American journal with abstracts of international mathematical publications. He discussed the problem with AMS secretary R. G. D. Richardson and other prominent mathematicians. A plan took shape to bring Neugebauer to the United States to edit a new periodical sponsored by the AMS. Placing Neugebauer, the world's foremost authority on the history of mathematics, in an American university seemed doable. However, the journal start-up funds were well beyond the reach of scientific organizations and universities. The expectation was that at least five years of operation were required before the deficit would reach a level the AMS could manage. The only solution was a large grant from a wealthy philanthropic organization, but few mathematicians had any entrée to the Rockefeller Foundation or Carnegie Corporation.

By the end of November, Veblen had laid the plans before Carnegie president Frederick Keppel and Rockefeller Director of Natural Sciences Warren Weaver. Given the disastrous economic events of the past decade, both foundations were already inundated with requests from worthy causes. It is amazing that within two months Veblen learned that Keppel was on board to back a US$66,000 grant. Meanwhile Richardson had secured a position for Neugebauer at Brown University.

On a parallel track, Veblen and Richardson lobbied the AMS leadership to formally sanction the journal abstracts project. In late December 1938 the AMS Council approved the idea in principle, establishing a special committee. The committee's charge was to investigate, and, "in case it is deemed wise," to proceed with the journal on a five-year trial. To avoid the appearance of a conflict of interest with *Zentralblatt*, Veblen was deliberately excluded from membership on the committee. Nevertheless, he served as an influential consultant, constantly pushing to bring the project to fruition.

Some mathematicians were reluctant to impinge on Springer's domain. The dismissal of Levi-Civita was attributed to outside political pressure. Substantial good will remained toward Springer for his contributions in scientific publishing. Even so, world events cast doubt over how much control he would have over future policy. The deliberations took place as Hitler was conquering Czechoslovakia.

Out of deference to Springer, the AMS committee waited until a personal meeting was possible. After several delays, Springer's representative arrived in the United States in May. The discussions were unsatisfactory, and the final decision was taken to proceed with *Mathematical Reviews*. Over the summer the Rockefeller Foundation and Carnegie Corporation awarded grants of US$60,000 and US$12,000 respectively. Veblen continued to negotiate with the American Philosophical Society for additional funds.

Without Veblen's vision, influence, and initiative, *Mathematical Reviews* would not have come into existence, let alone in such a short time. Birkhoff, who opposed the concept, was the only other mathematician in a position to obtain the funding. While Richardson and Neugebauer were important players, Veblen was the impetus behind the project.

Veblen's forceful actions could arouse strong feelings. Despite their differences on *Mathematical Reviews* and European immigration, Birkhoff and Veblen remained close friends. Others reacted differently. Among those with animus toward Veblen were Solomon Lefschetz, J. Robert Oppenheimer, and Abraham Flexner. Flexner's feelings were understandable. As Veblen was working on *Mathematical Reviews* he joined other faculty and trustees at the IAS to force the seventy-three-year-old director into retirement. Although the coup had widespread support, Flexner blamed much of his trouble on Veblen. Hostile attitudes of Lefschetz and Oppenheimer toward Veblen were reported by IAS faculty of the time.

Overall, Veblen was widely liked and respected in the scholarly community. Some indication of a mathematician's standing can be obtained from the programs of the International Congress of Mathematicians. In 1920 and 1924 Leonard Dickson became the first American to deliver two plenary lectures. After Birkhoff was selected to speak in 1928, the Bologna organizers asked Gilbert Bliss of the University of Chicago to choose another American. Bliss picked Veblen. Eight years later Birkhoff and Veblen repeated the roles in Oslo. Birkhoff died before the next Congress which was held in 1950. This gathering, in Cambridge, was the first in the United States. Veblen received the distinction of serving as president of the meeting. Ten years later he died at his summer home in Maine.

Given the ahistorical nature of mathematicians, it is not surprising that appreciation for Veblen has evaporated since his passing. Courses do not cover topics such as the first proof of the Jordan Curve Theorem, how algebraic topology entered the mainstream, or the evolution of the notion of manifold. More modern developments are presented, and the pioneers' names are lost, unless they happen to stick to the theorem or definition. In Veblen's case, an argument could be made that his discoveries were so ripe that others would have come along and obtained similar results.

Were it not for Veblen, however, extramural funding for basic research in mathematics would not have begun when it did. His diplomacy persuaded the NRC and private foundations of their interest in supporting mathematical research. It is unlikely that anyone else would have filled Veblen's role between the world wars. Today, the debate continues over mathematics' share of the federal research budget. Oswald Veblen gave mathematicians the standing to participate, singlehandedly championing the cause for the first twenty years.

## Sources

The sources for this article included records drawn from the following archival collections:

American Mathematical Society Records, John Hay Library, Brown University

R. L. Moore Papers, 1898–1974, Archives of American Mathematics, University Archives, University of Texas at Austin

G. D. Birkhoff Papers, Harvard University Archive

Archives of the Institute for Advanced Study

Oswald Veblen Papers, Manuscript Division, Library of Congress

## References


[1] William Aspray, The Emergence of Princeton as a World Center for Mathematical Research, 1896–1939, *A Century of Mathematics in America, Part II*, (Peter Duren, ed.), Amer. Math. Soc, 1988.

[2] Edgar Lorch, Mathematics at Columbia During Adolescence, *A Century of Mathematics in America, Part III*, (Peter Duren, ed.), Amer. Math. Soc., 1989.

[3] Raymond Wilder, Reminiscences of Mathematics at Michigan, *A Century of Mathematics in America, Part III*, (Peter Duren, ed.), Amer. Math. Soc., 1989.

[4] Raymond Archibald, *A Semicentennial History of the American Mathematical Society 1888–1938*, Amer. Math. Soc., 1938.

[5] Deane Montgomery, Oswald Veblen, *A Century of Mathematics in America, Part II*, (Peter Duren, ed.), Amer. Math. Soc., 1988.

[6] Karen Parshall and David Rowe, *The Emergence of the American Mathematical Community 1876–1900: J. J. Sylvester, Felix Klein, and E. H. Moore*, Amer. Math. Soc., 1994.

[7] Albert Tucker interview on "The Mathematics Community at Princeton Before 1930" in *The Princeton Mathematics Community in the 1930s: An Oral History Project*, on the Web at http://infoshare1.princeton.edu/libraries/firestone/finding_aids/mathoral/math.html.

[8] David Alan Grier, Dr. Veblen takes a uniform: Mathematics in the first world War, *American Mathematical Monthly* **108** (2001), 922–931.

[9] Herman Goldstine, *The Computer from Pascal to von Neumann*, Princeton University Press, 1972.

[10] Nathan Reingold, The Case of the Disappearing Laboratory, *Science, American Style*, Rutgers University Press, 1991.

[11] ALEXI ASSMUS, The creation of postdoctoral fellowships and the siting of American scientific research, *Minerva* **31** (1993), 151–183.
[12] LOREN BUTLER FEFFER, Oswald Veblen and the capitalization of American mathematics, *ISIS* **89** (1998), 474–497.
[13] GARRETT BIRKHOFF, Some Leaders in American Mathematics: 1891-1941, *The Bicentennial Tribute to American Mathematics 1776-1976*, Math. Assoc. Amer., 1977.
[14] STEVE BATTERSON, *Pursuit of Genius: Flexner, Einstein, and the Early Faculty at the Institute for Advanced Study*, A K Peters, 2006.
[15] ALONZO CHURCH interview in *The Princeton Mathematics Community in the 1930s: An Oral History Project*, on the Web at http://infoshare1.princeton.edu/libraries/firestone/finding_aids/mathoral/math.html.
[16] NATHAN REINGOLD, Refugee Mathematicians, 1933–1941, *Science, American Style*, Rutgers University Press, 1991 pp. 249–283.
[17] EVERETT PITCHER, *A History of the Second Fifty Years, American Mathematical Society, 1939–1988, Vol. I*, Amer. Math. Soc., 1988, 69–89.