World War I and the National Academy of Sciences / National Research Council:
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"My Dear Sir" and "My Dear George": The Relevance and Rhetoric of American Mathematics During and After World War I

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On July 23, 1917, Eliakim Hastings Moore, one of the most prominent figures in the history of the American mathematics, wrote two letters to George Ellery Hale, the first chairman of the National Research Council (NRC). One letter opened with "My dear Sir," the other with "My dear George."[1] The first, more formal letter explained that the NRC Committee on Mathematics, as a committee, had yet to learn of opportunities to help with the war effort. Officially, American mathematicians had been absent from the scene. But to make an otherwise disappointingly short letter a bit longer and less negative, Moore listed some of the ways that members of the Committee on Mathematics had contributed to the war effort under other auspices, such as G. D. Birkhoff's study of oceanic magnetic oscillations, E. W. Brown's lunar positioning tables, F. R. Moulton's memoir on numerical differential equations, and E. B. Wilson's publications on aeronautics. In his other letter, written to "George" and marked "Personal," Moore wrote, "I regret on behalf of the Committee that our report of work undertaken and accomplished is so meager. If you or Millikan know of any way in which directly or indirectly we can be of service, you know how pleased we shall be to be informed."[2]

Moore's letters told the same story in two different ways. Not wanting to send a skimpy formal report, his first letter presented various ways in which American mathematics was being used as a resource in the war effort. But his second letter, sent to his friend George, was more "personal" and seemed to apologize for the fact that the coordinated capabilities of American mathematicians, as represented by the National Research Council Committee on Mathematics, had yet to contribute to the war effort in any formal capacity.

The stories told in Moore's letters corresponded to a disconnect between American mathematicians' participation in World War I and the professional rhetoric surrounding the usefulness and isolation of early-twentieth-century American mathematics. On one hand, the skill sets of Americans who had trained in mathematics were valuable to the conduct of war. This was made especially clear by the extent to which mathematicians were commissioned to help train non-professional soldiers for combat. On the other hand, as the leading figures in early-twentieth-century American mathematics celebrated the growth and professionalization of their discipline, many were concerned that much of that growth had been inward toward increasing abstraction, leaving the study of mathematics in the United States isolated from other sciences, developing industries, and national concerns. American mathematicians before, during, and after the war often expressed qualms about how persistently their professional community had come to define itself separately from the uses and applications of their discipline.

[1] E. H. Moore to G. E. Hale July 23, 1917, Committee on Mathematics, Executive Committee, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.
[2] Ibid.

Any historical analysis of the isolation of American mathematics, as well as American mathematicians' involvement in World War I, depends on the scope of the term "mathematics," which remained equivocal in the United States throughout the early twentieth century. If mathematics meant pursuing research in "modern," or abstract, mathematical topics, then mathematics in the United States was partially put on hold during the war. From the late nineteenth through the mid twentieth century, the professional development and rhetoric of American mathematics was tied to this narrower view. But if mathematics were considered more broadly, in a way that included teaching, calculation, administration, and mathematically oriented science and technology, then American mathematics was not at all remote from, but rather was crucial to, the concerns of early-twentieth-century America, including the conduct of war.

Within the professional rhetoric of early-twentieth-century American mathematics was a tension between research work and disciplinary work. As many leaders of American mathematics sought to continue their own research in abstract, prestigious, though apparently "useless," fields, they also sought to garner support by emphasizing the more useful manifestations of their discipline. And although their most visible accomplishments—those that were displayed in publications and at professional meetings—were seemingly irrelevant to the broader American public, American mathematicians sought to establish a disciplinary narrative grounded in the value and relevance mathematics.[3] In the aftermath of World War I, the role of mathematics in the war became central to that narrative. And as American mathematicians honed their postwar narrative, organizations like the National Research Council provided the mathematics community with the institutional structure to branch out of its isolation.

Not surprisingly, the rhetoric produced by the professional leaders of early-twentieth-century American mathematics has largely informed its historiography.[4] Indeed, the ways in which American mathematicians defined and evaluated their discipline, including their concerns about its growing isolation, have been written prominently into its history. The flourishing of abstract mathematics in a nation defined

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[3] In 1915, for example, a special committee of the American Mathematical Society delivered a report to the board on "the matter of the movement against mathematics in schools." Council Minutes, Box 12, Folder 47, American Mathematical Society Records, The John Hay Library, Brown University.

[4] Thomas Archibald, Della Dumbaugh, and Deborah Kent, "A Mobilized Community: Mathematicians in the United States during the First World War," in *The War of Guns and Mathematics*, ed. David Aubin and Catherine Goldstein (Providence: American Mathematical Society, 2014), 229–71; William L. Duren Jr., "Mathematics in American Society 1888-1988: A Historical Commentary," in *A Century of Mathematics in America*, ed. Peter Duren (Providence: American Mathematical Society, 1989), 399–447; Loren Butler Feffer, "Mathematical Physics and the Planning of American Mathematics: Ideology and Institutions," *Historia Mathematica* 24, no. 1 (1997): 66–85; Karen Hunger Parshall, "Perspectives on American Mathematics," *Bulletin of the American Mathematical Society* 37, no. 4 (2000): 381–405; Alan Gluchoff, "Artillerymen and Mathematicians: Forest Ray Moulton and Changes in American Exterior Ballistics, 1885-1934," *Historia Mathematica* 38, no. 4 (2011): 506–47.

by practicality and "know how" has thus been considered historically as a sort of "paradox."[5] Yet relying on the rhetoric and concerns of the leaders of the community, who defined their field in a particularly narrow way, may obscure other parts of the story. In describing, and even lamenting, their own work as abstract, American mathematicians often overshadowed other forms of more practical, directly relevant mathematical work. Such forms of mathematics were made visible during the war. The historical record of American science during the war therefore offers an opportunity to piece together a fuller picture of American mathematics than one that is rendered solely through the voices of its leadership in peacetime. Even while lamenting its seeming isolation, the American mathematics community also celebrated American mathematicians' wartime participation—a pairing not unlike the one in Moore's "dear Sir" and "dear George" letters to the Chairman of the NRC.

Science, Preparedness, and the National Research Council

In 1915, with much of Europe at war, the buzzword among Americans, whether for or against intervention, was "preparedness."[6] Because research and development had yet to become a strong suit of the United States military, leaders of American science saw preparedness as an opportunity to demonstrate the usefulness of scientific research. After a German U-boat sunk the *Lusitania* passenger ship on May 7th, the Secretary of the United States Navy, Josephus Daniels, established the Naval Consulting Board to further the nation's defensive preparedness by developing its submarine detection and aviation capabilities. Determined to marshal "the natural inventive genius of Americans to meet the new conditions of warfare," Daniels established a board of leading American thinkers and industrialists, including Thomas Alva Edison.[7] There were two professional scientists on the Board, Robert S. Woodward and Arthur G. Webster. Both were experts in mechanics, and both served as representatives of the American Mathematical Society (AMS).

When Webster asked why the Board, which was made up almost entirely of representatives from national engineering societies, had not appointed representatives from the American Physical Society, the chief engineer explained that Edison wanted the Board to be "composed of *practical* men who are accustomed to *doing* things, and not *talking* about it." Representatives had been invited from the American

[5] Reinhard Siegmund-Schultze notes that the lack of professional emphasis on applied mathematics in the United States may have seemed out of place in a country known for its rapid industrial progress and inventive practicality. According to Siegmund-Schultze, "Obviously the ties of American mathematicians to the society as a whole were too loose" to counteract their seemingly "paradoxical" fixation on pure mathematics. See Reinhard Siegmund-schultze, "The Late Arrival of Academic Applied Mathematics in the United States: A Paradox, Theses, and Literature," *NTM International Journal of History & Ethics of Natural Sciences, Technology & Medicine* 11, no. 2 (2003): 119.

[6] Kevles, *The Physicists*.

[7] Ibid., 106.

Mathematical Society because "*very few really practical* men are…expert mathematicians," and it would be good to have someone around "who could figure to the 'nth' power, if required."[8] The Naval Consulting Board thus came to reflect a particular conception of Edison's approach to invention: it was helpful to have mathematicians around for specific tasks, but, for the most part, theory-laden science just got in the way.

George Ellery Hale, a leading American astronomer, promoter of American science, and member of the National Academy of Sciences (NAS), had a different idea of how defense research could be orchestrated. Hale thought American scientists, through the Academy, should have a role in national defense.[9] National security, he reasoned, would benefit from some of the nation's most astute minds, and the Academy, in turn, would benefit from closer ties to the federal government, as well as increased recognition and prestige. Since its establishment in 1863, the NAS had not been particularly active in fulfilling its mandate to provide scientific counsel to the United States government.[10] Were it to become more renowned, Hale reasoned, the NAS might be more successful in its appeals for funding and thus more effective in its support of American science. Like other members of the Academy, Hale wanted to ensure that its activities did not become corrupted by partisan politics or special interest groups. "Better to remain passive and pristine," he believed, "than to become active and tainted."[11] Hale did not think that such caution, however, should amount to inaction. Instead, he envisioned an independent body of scientists that preserved the dignified notion of pure scientific research, while also making clear the practical value of science by assisting in matters of national concern. What was going on in Europe was undoubtedly of national concern.

In the aftermath of the sinking of the *Lusitania*, Hale offered privately to President Wilson the services of the Academy. Wilson did not move forward with the offer and proceeded to navigate the crisis without entering the conflict directly. After a German U-boat torpedoed a French passenger steamer ten months later, however, President Wilson delivered an ultimatum to Germany, threatening to cut diplomatic relations if Germany continued to attack non-military ships. The following week, in April 1916, the Academy presented to the White House a resolution offering assistance. Wilson's acceptance of the resolution was kept quiet so as to avoid painting the United States in an overly aggressive, war-ready light. In June, the Academy quietly formed the National Research Council. The Council was meant to bolster

[8] Quoted in Kevles, *The Physicists*, 109. In 1917, E. W. Brown spoke of the Naval Consulting Board's "misconception… as to the functions of mathematicians." See E. W. Brown, "The Relations of Mathematics to the Natural Sciences," Bulletin of the American Mathematical Society 23, no. 5 (1917): 215.

[9] The increasing prevalence of scientific theory in American invention is often attributed, in part, to the role of science in World War I. Alan Gluchoff, for example, quotes from J. S. Ames' 1918 article "The trained man of science in the war" in Alan Gluchoff, "Artillerymen and Mathematicians."

[10] While election to its ranks was a great honor, the Academy had been called into service only four times during the first 15 years of the nineteenth century. See Kevles, *The Physicists.*

[11] Daniel J. Kevles, "George Ellery Hale, the First World War, and the Advancement of Science in America," *Isis* 59, no. 4 (1968): 430.

"national security and welfare" by supporting and coordinating pure and applied research among academic, industrial, and governmental institutions.[12] Hoping for recognition of the Academy's revamped usefulness to the government, Hale convinced Wilson's opponent in the upcoming presidential election to offer his endorsement of the Academy in the name of preparedness, which prompted Wilson to announce the formation of the Council on July 29, 1916. "Preparedness, to be sound and complete," Wilson declared, "must be solidly based on science."[13] Wilson's statement was largely a promotion of Wilson; but to Hale, it was also a promotion of science.

The Council, like the Academy, had been established in light of what Daniel Kevles describes as the scientific community's tradition of "political elitism."[14] According to Kevles, many scientists believed in a righteous commitment to the quest for truth that insulated them, by virtue of being scientists, from any sort of political bias or control. Hale was committed to protecting the Council from the hindrance of governmental oversight by securing funding through private donations and by offering the Council's services to federal agencies without becoming engulfed by them. The government could nominate representatives to the Council, but the Academy retained the power to appoint them.

Hale was proactive in making the Council, which he believed to be "the greatest chance we ever had to advance research in America," a major player in the war effort.[15] Hoping to ensure the Council's involvement, he wrote letters to the Secretary of War that "gave him so much information regarding the Research Council that he had no excuse for forgetting its existence…"[16]

After Germany resumed unrestricted submarine warfare on February 1, 1917, Navy Rear Admiral David W. Taylor immediately instructed the National Research Council to investigate U-boat submarine detection. Later in February, the Council of National Defense, which had been established in August 1916 to coordinate resources for national security, agreed to let the NRC manage its scientific interests. In March, Hale wrote a letter that was likely sent to all NRC committee chairmen, including Chicago mathematician E. H. Moore, who had been appointed Chairman of the Committee on Mathematics.[17] Hale's letter

[12] Kevles, *The Physicists,* 112.
[13] Ibid., 115.
[14] Ibid., 117.
[15] Helen Wright, *Explorer of the Universe: A Biography of George Ellery Hale* (Charlottesville: University of Virginia Press, 1966), 288.
[16] G. E. Hale to C. T. Hutchinson January 16, 1917, Committee on Mathematics, Executive Committee, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.
[17] Yale mathematician and astronomer Ernest William Brown had initially been suggested for the chairmanship of the Committee on Mathematics, but he was passed over because, having been born to English parents in England, he was not a naturalized American citizen. In acknowledging the objection to his serving as chairman, Brown wrote to Hale on April 5, 1917: "But it need made [sic] no difference as far as any work that I can do for the Council is concerned. The mere question of official connection is of no importance to me if it does not prevent my giving assistance." Committee on Mathematics, Executive Committee, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.

explained that, for the time being, all committee work should be focused on national defense.[18] While he admitted that potential contributions from some fields of science may not have been as obvious as from chemistry, physics, and medicine, Hale maintained that there was great need in general for capable investigators to contribute however they could, even if they lacked prior experience in a particular war-related field. To demonstrate his point, Hale provided examples of astronomers who had performed aeronautic calculations and designed range finders to detect Zeppelins. "In the face of war," Hale explained, "every loyal man of science should be willing to drop his present work, wholly or in part, and devote his time and attention to researches on military problems."[19]

As Hale explained in his letter, the first step would be for each scientific committee to generate a list of problems to be solved, which the Military Committee would then rearrange in order of priority. Each chairman was asked to report on the progress of his committee at a meeting held in Washington, D. C. on April 15, 1917. As Moore's report for the Committee on Mathematics explained, "With respect to the general question of Defence [sic], it seems to be evident that we are not in the position of suggesting problems, but that we consider ourselves to be in the position of being able to consider and actively further any problems of a mathematical nature that may be suggested or given to us…"[20] The Committee on Mathematics, Moore declared, was very willing to work with those who might need their services. He also mentioned the impossible burden that had been placed on West Point and Annapolis instructors in their need to train officers for a massive army and navy. With decreased wartime enrollments, college instructors would be able to lend their services, and mathematicians would be especially pleased to do so.

American Mathematicians in War Service

On April 6, 1917, the United States declared war on Germany. Three months later, Brigadier General John J. Pershing requested an army of three million men. One of the challenges of organizing an army that size involved training non-professional soldiers in mathematics-laden fields like artillery and navigation. Yet attempts to equip amateur soldiers with knowledge of these fields revealed gaping deficiencies in young Americans' mathematical backgrounds. The need for basic instruction in trigonometry, algebra, and geometry was great, and many civilian mathematicians stepped in to help. In some cases, Naval Units were formed at colleges and universities where regular faculty members took on the bulk of theoretical instruction. Mathematics courses were also organized through the Student Army Training Corps (SATC), which had been created under the Committee on Education and Special Training

[18] March 1, 1917, Committee on Mathematics, Executive Committee, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.
[19] Ibid. Emphasis in the original.
[20] April 19, 1917, Committee on Mathematics, Executive Committee, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.

of the War Department.[21] In 1918, the War Department published a circular on mathematical instruction, offering guidelines and reminding instructors that their main goal was to make soldiers and that they should refrain from teaching anything other than practical mathematics.[22]

Assuming the narrower definition of mathematics limited to abstract mathematical research, mathematics was largely put on hold during the war. In its broader meaning, however, which included teaching, applications, calculation, administration, and outreach, mathematics was a valuable wartime resource. Like other wartime resources, mathematics required a labor force that had been partially depleted by deployments and was then partially reinforced by women workers. By 1916, forty-nine doctorate degrees in mathematics had been awarded to women in the United States.[23] Yet while these women had been trained by leading American mathematicians in advanced mathematical research, they were often kept out of careers that were conducive to research. Even after earning doctoral degrees, many American women were limited to what was considered "women's work," including full-course-load teaching positions at high schools and women's colleges. Mathematics in its narrower conception—defined by abstract mathematical research—had been constructed as a man's domain, wherein successful women contributors, while recognized, were often written off as notable exceptions. Yet women mathematicians in the early twentieth century were important contributors to American mathematics in its broader conception, which often included less celebrated forms of mathematical labor. As Margaret Rossiter has pointed out, the relationship between the gendering and the valuing of work was reciprocal: uncelebrated work was women's work and women's work was uncelebrated.[24]

In general, American women mathematicians saw more, though not necessarily different, opportunities made available to them during the war. War work for American women mathematicians, as well as other American women scientists, often meant "women's work" in the form of teaching, assisting, and calculating. In particular, the increased demand and diminished supply of mathematics instructors during the war created new teaching opportunities for women mathematicians. In one case, when an Assistant Professor of Mathematics at the University of Nevada was granted leave to serve in the National Army, the vacancy was filled by his wife.[25]

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[21] A letter to the Editor of the American Mathematical Monthly about how to involve more mathematics teachers in training troops claimed that being an instructor for the SATC was "essentially war service." See "Notes," *The American Mathematical Monthly* 25, no. 7 (1918): 328.
[22] Archibald, Dumbaugh, and Kent, "A Mobilized Community."
[23] Judy Green and Jeanne LaDuke, *Pioneering Women in American Mathematics: The Pre-1940 PhD's* (Providence: The American Mathematical Society, 2009).
[24] Margaret W. Rossiter, *Women Scientists in America: Struggles and Strategies to 1940* (Baltimore: Johns Hopkins University Press, 1984).
[25] "Notes and News," *The American Mathematical Monthly* 24, no. 8 (1917): 399.

In the summer of 1918, at the request of the commanding officer of the Naval Reserve School, the Departments of Mathematics at Northwestern University and the University of Chicago offered courses in mathematics for enlisted men. Alice Bache Gould, who had completed doctoral thesis work in geometry under E. H. Moore at the University of Chicago, became an important member of the teaching team that trained the Chicago recruits. Gould taught navigation, in part using a new text she was preparing. Likely because of her lower-rank title and position, she earned 10 percent less than her counterpart, J. W. A. (Jacob William Albert) Young, for a week of teaching.[26]

During her search for war work that would make use of her mathematical training, Gould had been offered a job as a computer in the engineering division of the Army Ordnance Department under Chicago mathematician Forest Ray Moulton. While Gould chose to teach instead, eight other women mathematicians joined Moulton's team studying and calculating the projectile motion of firearms. At least one, Caroline Eustis Seely, had earned a PhD in mathematics.

Ordnance and ballistics were perhaps the most notable fields to which American mathematicians contributed during World War I.[27] In part due to the battling nations' use of long-range and anti-aircraft munitions, the calculation of shell trajectory had become increasingly complicated. In early 1918, Princeton mathematician Oswald Veblen took command of the office of experimental ballistics at the Aberdeen Proving Ground in Maryland, where he worked with and recruited dozens of fellow mathematicians. At Aberdeen, which was one of the last stops in the munitions production process, Veblen and his team collected data from test shots and then used the data to construct range tables, presenting firing distance as a function of variables like barrel angle and wind speed.

The process of computing range tables from firing data was itself a fairly technical task. During the war, Veblen and his men used a computation process that was based on a differential equation model developed in the 1880s by Italian ballistician Francesco Siacci. In Siacci's ballistics, an analysis of mechanical forces was used to determine the "Principle Equation" for the flight of a shell based on accelerations.[28] But determining the position of the shell from the acceleration-based equation required integration, and because the Principle Equation itself was non-integrable, Siacci's main contribution was to determine an approximation for the equation that allowed for integration.

In the summer of 1918, while Veblen and his team were studying ballistics by firing guns, Moulton and his team began work on the mathematical development of ballistics theory from their offices in

[26] Moore to Arnett December 14, 1918, E. H. Moore Papers, Box 3, Folder 19, Special Collections Research Center, The University of Chicago Library.
[27] After the war, leading physicist R. A. Millikan would write, "When it is remembered that the biggest element in the effectiveness of a modern army is its artillery…it will be seen how incalculably valuable the work of the trained physicist and mathematician has proved to be to the practical problems of modern war." See R. A. Millikan, "The New Opportunity in Science," Science 50, no. 1291 (1919): 285–97.
[28] Gluchoff, "Artillerymen and Mathematicians."

Washington, D. C. During the war, Moulton had turned from his prior work on celestial mechanics to the terrestrial mechanics of ballistics. In this new field, he encountered a process for improving mathematical models that involved testing their validity on firing ranges and then tweaking the underlying equations to match the experimental data. Siacci's Principle Equation, for example, included a coefficient, C, that was essentially a "fudge factor" used to account for unknown and undetermined factors and that was adjusted to minimize discrepancies between theoretical and actual trajectories.[29]

Moulton's approach to exterior ballistics was to make improvements to range table calculations that were not based solely on (costly) experimental adjustments, but also on rigorous mathematical ideas. He wanted less guesswork in determining the coefficient C, and he sought mathematically sound justifications for the approximations that enabled integration of the non-integrable Primary Equation. In his attempts to avoid integration approximations, Moulton pursued point-by-point, or numerical, solutions. While numerical integration techniques had been used in ballistics research at the Gâvre proving grounds in France since the late nineteenth century, Moulton was more adamantly concerned with mathematical validity, exploring existence and convergence proofs, for example, as an important part of his work.

In many ways, Moulton and his colleagues' work highlighted the potential disparity between the theory of ballistics and ballistics in practice. Moulton's method was featured after the war in military publications, in textbooks, and, of course, in his own book, *New Methods in Exterior Ballistics*. Yet some critics of the method found it more valuable as a mathematical idea than as an easily usable technique for soldiers with basic training in elementary calculus. Moulton's research helped make the field of ballistics more mathematically sophisticated, though not necessarily more accurate or effective. Similarly, University of Chicago mathematician Gilbert Ames Bliss, who worked under Veblen at Aberdeen, received pushback for his method of numerical integration in ballistics because it involved "auxiliary variables" that lacked any sort of physical interpretation.[30] While Bliss' method had simplified some of the calculations, it also added a new and, for some, opaque layer of mathematical abstraction. James Alexander, a former student of Veblen's at Princeton who worked with Moulton in D. C., offered a tellingly satirical description of the Navy's preference for "simple and inaccurate instead of complicated and inaccurate."[31]

Moulton's work on numerical differential equations was one of the examples of mathematical war work that Moore provided in his official July 1917 letter to Hale. In the same letter, Moore also mentioned the lunar positioning tables, presumably useful for celestial navigation, developed by Ernest William Brown, the publications by Edwin Bidwell Wilson on using differential equations to model the effects of wind gusts hitting an airplane, and George David Birkhoff's study of oceanic magnetic oscillations, which

[29] Gluchoff describes another coefficient, i, that was introduced to account for shell shape and was mockingly referred to as "the coefficient of ignorance." See Alan Gluchoff, "Artillerymen and Mathematicians," 514.
[30] Alan Gluchoff, "Artillerymen and Mathematicians," 536.
[31] Archibald, Dumbaugh, and Kent, "A Mobilized Community," 243.

may have been relevant to submarine detection and defense. Although most American mathematicians were not active researchers in war-related fields prior to 1914, many found ways to put their mathematical skills to work. In addition to those listed by Moore, those who trained troops, and those affiliated with the Army Ordnance Department, American mathematicians participated in the Federal Fuel Administration, the Army Signal Corps, the Naval Experimental Station, the National Advisory Committee for Aeronautics, and the statistical branch of the War Department. Throughout the war, the Mathematical Association of America (MAA) collected diligently and published proudly information about American mathematicians engaged in military teaching, military research, and direct military service. The final list included 178 names along with their academic affiliations and assigned military departments.[32]

The Isolation of American Mathematics: Rhetoric and Historiography

On September 6th, 1917, Earle Raymond Hedrick described to nearly one hundred members of the Mathematical Association of America a hypothetical situation in which an army officer, after losing contact with central command, would have to rely on his knowledge of trigonometry to determine his position and protect the lives of his men. "Ignorance at such a crisis," Hedrick explained, "would be next to treason…"[33]

The intensity of Hedrick's statement likely drew from his concern about the strength and status of mathematics in American education. While Hedrick and his colleagues worked to bring new recruits up to speed in basic mathematics during the war, they bristled at what they perceived to be a "movement against mathematics" in American education. Before widespread education reform in the late-nineteenth and early-twentieth centuries, mathematics, along with Latin and Greek, had been a pillar of Classical education. Yet as progressive education reformers worked to introduce development-centered, versus discipline-centered, learning into the curriculum from one end, and as proponents of vocational training gained ground on the other, traditional subjects like mathematics were forced to justify their continued place in the curriculum. Assertions of the usefulness of mathematics were often at odds with how it was experienced in the classroom, and many argued that a greater emphasis on the applications of mathematics in general education would help foster a more grounded understanding of, a greater appreciation for, and a friendlier attitude toward the subject.

In his address, titled "The Significance of Mathematics," Hedrick attributed a perceived devaluing of mathematics in education and in general to American mathematicians' apparent disregard for applied mathematics.[34] He explained that, while the significance of mathematics was manifold and extended beyond

[32] "Notes and News," *The American Mathematical Monthly* 26, no. 1 (1919): 40-44.
[33] E. R. Hedrick, "The Significance of Mathematics," *The American Mathematical Monthly* 24, no. 9 (1917): 402.
[34] By the early twentieth century, the term "applied mathematics" had come to encompass a range of connecting links between mathematics and other sciences. Applied mathematics was often held in opposition to "pure" mathematics, in which mathematical ideas were explored and developed for their own sake.

its applications, it was in the applications of mathematics, like those recently made apparent through the conduct of war, that the significance of mathematics was most directly "self-evident."[35] American mathematicians, Hedrick believed, ought to pay greater mind to the usefulness of their discipline.

Six weeks prior to Hedrick's speech, Moore had written his "dear Sir" and "dear George" letters to Hale. The examples Moore gave in his formal "dear Sir" letter of mathematicians involved in the war effort, coupled with the apology in his "dear George" letter that American mathematicians had not been more useful, formed a two-part conception of American mathematics that was also attendant in Hedrick's speech: mathematics was useful, but American mathematicians could do more to incorporate its uses into their profession.

In his call for more applied mathematics, Hedrick made clear that he did not mean to undermine the value of pure research, and he explained that he had a "deep interest in the logical and cultural side of mathematics."[36] Yet he found those who would assert the value of mathematics as a cultural achievement to be both myopic and foolishly romantic, and he believed that such sentiment about the beauty and awe-inspiring nature of mathematics should be reserved for specialists.[37] When dealing with the broader public, it would be much more direct and effective to assert the value of mathematics based on more "concrete realities."[38] If American mathematicians continued to focus almost exclusively on formal abstractions, Hedrick warned, "we must expect and we shall deserve public disdain and sincere doubt of our value to humanity."[39]

According to Hedrick, one of the chief goals of the Mathematical Association of America, which was a year and a half old at the time of his speech, should be to ameliorate such public disdain for mathematics and to make obvious its widespread importance. The official purview of the Association, which had been formed in part to support the publication of the *American Mathematical Monthly*, was the development of mathematics education at the collegiate level. But both the Association and its *Monthly* were essentially a place for, as Hedrick explained, "mathematics in its broader meaning," including math education, exposition, and applications, all of which had largely been left out of the development of professional American mathematics.[40] Both the Association and the *Monthly* had been formed to account

[35] Hedrick, "The Significance of Mathematics," 405.
[36] Ibid., 404.
[37] Hedrick may have had in mind addresses like the one he likely heard given by Columbia mathematician Cassius Jackson Keyser to the American Mathematical Society before the start of the war. Keyser offered the assertion that mathematics held higher claims to human regard than the significance of its applications. He explained the difference between pure and applied mathematics as being "much like the difference between one who greets a newborn day because of its glory and one who regards it as a time for doing chores and values its light only as showing the way." Cassius J. Keyser, "The Human Significance of Mathematics," *Science* 42, no. 1089 (1915): 664.
[38] Hedrick, "The Significance of Mathematics," 404.
[39] Ibid.
[40] Ibid., 405.

for mathematical considerations and pursuits that remained outside the purview of the American Mathematical Society as it gradually narrowed from the promotion of interest in mathematics to the support of abstract mathematical research.

As he explained in his speech, Hedrick blamed the relative obscurity of important American mathematicians like Josiah Willard Gibbs and George William Hill on the community's inattention to applied mathematics. "The same may be said," Hedrick continued, "of the essentially mathematical researches of other men still living," at least one of whom was present at the meeting.[41] The point of Hedrick's argument was that American mathematicians needed to help champion the development of applied mathematics, and the Association could help by facilitating the publication of articles and the presentation of results in applied math fields. Such initiatives would also help the development of pure mathematics indirectly by increasing the level of appreciation for mathematics in general among students, the American public, and mathematicians themselves.

When Hedrick, as the retiring president of the Mathematical Association of America, used his platform to discuss the feeble state of applied mathematics in the United States, he was by no means the first American mathematician to do so. Like other scientific communities in the United States, the American mathematics community began to take shape in the late 1800s. To mark the turn of the century, many scientific leaders and communities took stock of the progress they had made and their potential prospects for the future. In an address delivered before the American Mathematical Society in 1902, E. H. Moore, who was then the Society's sixth president and a self-described "pure mathematician," characterized "abstract mathematics" by describing recent work (including his own) in symbolic logic and postulate analysis as it related to mathematicians' growing concern with the foundations of their subject.[42] Moore believed his and his colleagues' focus on abstraction, though praiseworthy, had left a "chasm between pure mathematics and applied mathematics."[43] To help narrow the gap, Moore urged his fellow mathematicians to think outside of their own budding community and to consider the needs of practitioners of neighboring sciences, students of mathematics, and the general public. Moore was asking the American Mathematical Society to play a more active role in reinvigorating applied mathematics in research and education. He believed bringing mathematics and other sciences closer together in education and training would, perhaps with the next generation, bring them closer together at the professional level. Moore gave the title of his speech, "The Foundations of Mathematics," a clever double meaning that alluded to the foundations of mathematics not only as a topic of abstract research but also how the topic itself was related to foundational

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[41] Hedrick, "The Significance of Mathematics," 405.
[42] A group of American mathematicians had become especially interested postulate analysis, which, like other topics in abstract mathematics, were studied separate from any sort of physical grounding or conception. See Eliakim Hastings Moore, "On the Foundations of Mathematics," *Science* 17, no. 428 (1903): 407.
[43] Moore, "On the Foundations of Mathematics," 403.

questions about mathematics as a discipline. Mathematics as a discipline called for bringing new life to applied mathematics, which would benefit mathematics overall, including pure and foundational mathematics, by creating happier students and higher enrollments, resulting in more jobs and greater public support. A similar argument would be made repeatedly by mathematicians before a variety of audiences before, during, and after World War I.

In December 1916, Edwin Bidwell Wilson gave a presentation about mathematical advances in aerodynamics at the annual meeting of the newly formed Mathematical Association of America. Near the end of his address, Wilson referred to the long-standing tradition of mathematical physics, or "mixed mathematics," in England and encouraged American teachers to teach "the good old traditional Cambridge, England, type [of mathematics]… May it not be that we in this country have such a natural bent toward the practical that a diligent cultivation of the British sort of mathematics would find a readier response among our students?"[44] Two days earlier, Ernest William Brown had spoken to the American Mathematical Society about the potential for the further development of applied mathematics in America due to "the natural bent of a nation which has been compelled by its environment to regard most of its affairs from a thoroughly practical point of view…"[45] This common characterization of American interests as "practical" made the prevalence of abstract, perhaps "impractical," mathematical research seem out of place. "There is current all too much of a feeling," Wilson believed, "that only the beautiful general theories of mathematics are worthy the attention of real mathematicians and their students..."[46] Brown seemed to think that reversing this trend would be no easy task and that studying the mathematics used in physical applications had become "repulsive to the pure mathematician, and properly so."[47] Still, he argued, pure mathematicians could encourage their students to explore problems in applied mathematics, and, for their part, leaders in government and industry could create more positions that would encourage young Americans to develop expertise in applied mathematics. Brown mentioned the National Academy of Sciences as "perhaps the most important outside movement affecting the chief objects of the Society…"[48] He was pleased with the Academy's recent efforts to promote cooperation not only among investigators themselves, but also between investigators and those who rely on their technical expertise.

Within Moore's, Brown's, Wilson's, Hedrick's, and other leading mathematicians' calls for more applied mathematics was a particular understanding of their community's own history as well as the broader history of mathematics. Brown, for example, described the "entangling alliance" between mathematics and

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[44] Edwin Bidwell Wilson, "The Mathematics of Aerodynamics," *The American Mathematical Monthly* 25, no. 7 (1918): 297.
[45] E. W. Brown, "The Relations of Mathematics to the Natural Sciences," *Bulletin of the American Mathematical Society* 23, no. 5 (1917): 228.
[46] Wilson, "The Mathematics of Aerodynamics," 296.
[47] Brown, "The Relations of Mathematics to the Natural Sciences," 228.
[48] Ibid., 215.

its role in answering questions about the physical world that preceded the nineteenth-century turn toward abstraction, at which point "mathematics was allowed to progress in its own way."[49] Brown and many of his colleagues understood the growth of their own community in terms of this broader interest in abstract mathematics.[50] For the most part, histories of American mathematics have since echoed this same narrative of early-twentieth-century mathematics defined by growth, professionalization, abstraction, and isolation.

In her article "Mathematical Physics and the Planning of American Mathematics: Ideology and Institutions," Loren Butler Feffer argues that the priorities of the professional American mathematics community in the late nineteenth and early twentieth centuries were set by an "elite collection of leaders" who focused on pure more than applied mathematics and on research more than teaching.[51] While the handful of nineteenth-century American mathematicians who had become known internationally for their work, such as Benjamin Peirce, Josiah Gibbs, George Hill, and Simon Newcomb, had contributed to mathematics that was grounded in the physical world, and while a large portion of the early members of the American Mathematical Society did work in astronomy, physics, engineering, or actuarial science, according to Feffer, "these fields attracted little attention from the next generation of American mathematicians" as they rallied around a focus that was more or less dominated by abstract mathematical research.[52] After Robert Simpson Woodward's retirement as AMS president in 1900, only one president out of the next twenty (E. W. Brown) studied anything other than pure mathematics.[53] In addition, by the early twentieth century, potential contributors to applied mathematics had the option to engage with other newly formed scientific communities, like the American Physical Society and the American Astronomical Society.

Before research had become a priority in American universities, and before American mathematics departments had established solid graduate training programs, American students interested in research-level mathematics traveled to France and Germany, where they found a century's worth of leading ideas in abstract mathematics. As historians of American mathematics have noted, when American students

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[49] Brown, "The Relations of Mathematics to the Natural Sciences," 216.
[50] A notably different story, however, was told by Chicago mathematician Leonard Eugene Dickson in his appeal for departmental funding when he declared that the growth of American mathematics was "due mainly to the increasing appreciation of the value of mathematics as applied to engineering, statistics, actuarial work, ballistics, aeronautics, physics, astronomy, and in less degree to chemistry, biology, and geology." The intended audience and purpose for characterizing the growth of American mathematics likely informed different versions of the story. E. H. Moore Papers, Box 4, Folder 2, Special Collections Research Center, The University of Chicago Library.
[51] Feffer, "Mathematical Physics and the Planning of American Mathematics."
[52] Ibid., 68.
[53] "For the most part," Feffer explains, "American mathematicians welcomed this as evidence they were becoming 'modern.'" See her "Mathematical Physics and the Planning of American Mathematics," 68. When Simon Newcomb addressed the Society in 1894, he apologized for not being "a mathematician in the modern sense." See Simon Newcomb, "Modern Mathematical Thought," Bulletin of the American Mathematical Society 3, no. 4 (1894): 95.

returned to the United States from Europe in the late nineteenth century, they brought with them a penchant for mathematical abstraction.[54] As most historians have recognized, however, the link between the increasing attention to abstract rigor within nineteenth-century European mathematics and the increasing prioritization of abstract topics in professional American mathematics was hardly unequivocal. For one, nineteenth-century mathematics in Europe, while more inward-looking and arcane than a century prior, also continued to develop in relation to other sciences. By the early twentieth century, many European mathematics communities had developed robust programs in both pure and applied mathematics.[55]

For their part, early-twentieth-century elite American mathematicians, as mathematicians, may have seemed detached from the most obvious concerns of American society. Yet as Americans, they were very much concerned with the conflict in Europe as it progressed from hostile and tenuous to deadly and destructive. Like many of their colleagues in the academic community, the majority of American mathematicians were supportive of the war effort. Yet according to Feffer, American mathematicians "… were not immediately recognized as having much value for war work. Young mathematicians were not accorded the same enlistment privileges and deferments as other scientists and engineers, and the National Research Council was slow to find work even for senior men."[56] What is often described in the historiography of American mathematics during World War I is an initial sense of American mathematicians' enthusiastic uselessness, and historians are keen to quote from Oswald Veblen's May 1917 letter to George David Birkhoff in which he wrote, "Thus far I have failed to find any place in which mathematical work is of use in connection with the war. If you run across anything of the sort I wish you would let me know."[57] Veblen would later command the office of experimental ballistics at the Aberdeen Proving Ground in Maryland. He would also become a leading figure in the promotion of American mathematics after the war. According to Feffer, the war had spotlighted the shadowed role of applied mathematics in American science as well as compelled new connections linking professional mathematics to industry, the Federal Government, and leaders of American science.

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[54] Karen Hunger Parshall and David E Rowe, *The Emergence of the American Mathematical Research Community 1876-1900*; Loren Butler Feffer, "Oswald Veblen and the Capitalization of American Mathematics: Raising Money for Research, 1923-1928," *Isis* 89, no. 3 (1998): 474–97; Steve Batterson, *American Mathematics 1890-1913: Catching up to Europe* (Washington, D. C.: Mathematical Association of America, 2017).
[55] The integration of rigorously abstract and physically grounded mathematics was championed around the turn of the twentieth century by German mathematician Felix Klein, who was one of the leading advisors of American mathematicians. While historians credit Klein with training the future leaders of American mathematics in pure research, it remains unclear why Klein's adamant proposal to combine mathematics and physics in both research and education was not built into the professional structure of American mathematics. In many ways, E. H. Moore, who eagerly championed the "laboratory method" of joining mathematics and science in education, did become a proponent of Klein's approach. Yet although Moore occupied an "exalted position within the community," Feffer notes, "his plans for mathematical reform failed." See "Mathematical Physics and the Planning of American Mathematics," 72.
[56] Feffer, "Mathematical Physics and the Planning of American Mathematics," 72.
[57] Quoted in Aubin and Goldstein, "Placing World War I in the History of Mathematics," 4.

"Many New Friends for Pure Science": Mathematics in the Aftermath

On December 27, 1918, six and a half weeks after the November 11th armistice, sixty members of the American Mathematical Society and seventy-three members of the Mathematical Association of America (including many who were members of both) convened at the University of Chicago for a joint meeting. During the session of the American Mathematical Society, research that had continued unabated during the war pertaining to abstract mathematical topics was presented. The joint session of the meeting, however, was "devoted to mathematical problems in connection with the war." Discussion was lively and might have continued had more time been allotted.[58]

The joint session was preceded by an address from the retiring president of the American Mathematical Society, Leonard Eugene Dickson, on "Mathematics in War Perspective." The bulk of Dickson's speech was an overview of education for military purposes in France, England, and the United States, as well as a description of topics in ballistics and navigation. In his introduction, Dickson seemed to echo language from before the United States had entered the war, calling for "preparedness" and the need for highly trained scientists. However, unlike those who had called for preparedness when war had seemed imminent, Dickson spoke of the importance of science in "a future war."[59] He insisted that all potential future soldiers would need a solid understanding of the foundations of science. "Owing to its recognized value as a fundamental part of military education," he explained, "I expressly include mathematics, especially trigonometry and graphical analysis. Let it not again become possible that thousands of young men shall be so seriously handicapped in their army and navy work by lack of adequate preparation in these subjects."[60] Fortunately, he added, such training would also be beneficial to potential future soldiers while they were still citizens, improving their sanity, reliability, and efficiency.

Dickson had likely prepared the majority of his address before the war had ended and then, after hearing news of the armistice, simply framed his discussion of military mathematics and education as a retrospective. Dickson's "lessons learned" sentiment and his call to avoid the challenges of training mathematically ill-equipped young men for the conduct of war was also at hand in the session of the Mathematical Association of America on "Deductions from War Time Experiences with respect to the Teaching of Mathematics." The session featured presentations from mathematics instructors at colleges and universities, predominantly throughout the Midwest, where the Student Army Training Corps had been established. Many of the presenters during this session made reference to an apparent need for math

[58] W. D. Cairns, "Third Annual Meeting of the Mathematical Association of America," *The American Mathematical Monthly* 26, no. 3 (1919): 91–107. A draft program for the meeting had listed Alice Bach Gould's affiliation as the city of Chicago, yet Gould was in fact affiliated with the University of Chicago. Edits to the draft made sure she was correctly listed as an affiliate of the University. Draft program, MAA Mathematical Association of America Records, Dolph Briscoe Center for American History, The University of Texas at Austin, Box 86-14/82, Folder 10.
[59] Dickson, "Mathematics in War Perspective," 289.
[60] Ibid.

educators to focus more on practical applications and less on abstract manipulations. As A. R. Crathorne of the University of Illinois posited, for example, the greatest change in postwar math education might be "…the attitude of the teacher toward practical applications. There seemed to be a general feeling among the instructors that the applied side of mathematical teaching had at least not been over-emphasized."[61] Crathorne thus put lightly what others had harped on decades earlier: the applications of mathematics needed to be more prominent in math education.

The deficiencies of math education notwithstanding, Crathorne also believed that there had "grown up in other departments of the University a better feeling towards the teaching of mathematics and a respect for its usefulness," and he claimed that "several departments requiring mathematics for prerequisites have asked for more mathematics, whereas formerly there was a tendency to hold the mathematics to a minimum."[62] W. B. Ford of the University of Michigan, on the other hand, seemed to sense a continued devaluing of mathematics and to defend the subject in its "idealistic" as opposed to "material" form, at least in the education of younger students. Ford spoke of the continued propensity of American schools to supplant traditional subjects by more practical ones. While traditional subjects, including mathematics, had once been valued for their ability to develop a student's mental discipline, it had become more in vogue to emphasize subjects like economics that claimed both disciplinary and practical value. "These tendencies, which were already well defined before the war began," Ford explained, "will doubtless be intensified in the period lying directly ahead…"[63] Mathematicians would therefore do well to prepare themselves to defend their subject, he advised, and by extension their livelihood. Whether mathematics was increasingly valued, as Crathorne perceived, or would continue to be passed over for other subjects, as Ford feared, seemed to rely on the extent to which it would be defined by its applications.

Following the joint session was a joint dinner at the Quadrangle Club on the evening of the 27th. After dinner, E. H. Moore spoke about the peacetime plans of the National Research Council. Moore perhaps had in mind Hale's response to the pair of letters he'd sent a year and a half earlier, apologizing that the Committee on Mathematics had not yet contributed to the war effort. Hale's response had been full of understanding: "As soon as the war is over [the Mathematics Committee] can perform very valuable services in promoting research in mathematics, but at present we must continue to look for problems in which the Committee can take part."[64] Hale, of course, had a grand vision for the Council that went well beyond its war-related genesis.

[61] Cairns, "Third Annual Meeting of the Mathematical Association of America," 94.
[62] Ibid., 95.
[63] Ibid.
[64] G. E. Hale to E. H. Moore July 25, 1917, Committee on Mathematics, Executive Committee, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.

Starting in the spring of 1918, Hale had sought to establish a permanent, though loose-fitting, connection between the NRC and the federal government. Fortunately, through its cooperation with military, civil, and industrial leaders during the war, the Council had made "many new friends for pure science."[65] And while many scientists were at the time focused on applied, war-related research, Hale also believed that pure science was crucial to national preparedness and well-being. Hoping to continue the Council's federal friendships, Hale wanted Wilson, as well as presidents to come, to continue to cooperate with and appoint representatives to the Council. Instead of a potentially risky appeal to a Democratic, considerably anti-intellectual Congress for a revision of the National Academy of Science's charter, Hale chose to solicit an Executive Order from Wilson, appealing in part to the President's own academic background. In May, Wilson signed Executive Order 2859, perpetuating the National Research Council. Hale was pleased to secure a future for the Council that was free from direct federal financing or oversight.

With a happy lack of federal funding, Hale turned to the Council's newly formed industrial friendships. By the spring of 1919, the Carnegie Corporation had set aside $5,000,000 for the construction of a building to house the NAS and the NRC, AT&T had promised $25,000 annually, and the Rockefeller Foundation had donated $500,000 for the establishment of postdoctoral fellowships in physics and chemistry.[66] The Rockefeller-funded fellowships were specifically intended to cultivate and sustain a mindset for research among young scientists. While many potential investigators had been given a taste for research during their doctoral training, it had often been dampened by teaching-heavy post-graduate appointments, and many seasoned scientists were concerned that young Americans would not become researchers if they lost the momentum for conducting research after completing their degrees. The leadership of the Council had considered establishing an NRC laboratory where young scholars could further their research. But they decided instead to partner with universities across the country, allowing fellowship recipients to conduct postdoctoral research at different institutions without favoring one location. In March 1919, the Council formed a research fellowship board to review applications and administer funding.

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[65] Quoted in Kevles, "George Ellery Hale, the First World War, and the Advancement of Science in America," 432. The war had been an especially explicit demonstration of the power of chemistry, though other sciences, including mathematics, had garnered interest as well. Shortly after the war, E. H. Moore, sent a letter to the president of the University of Chicago, noting "… a marked improvement in the morale as well as in the registrations for our courses through the Calculus." Moore found the uptick in morale and registrations "extremely encouraging" and "doubtless due [in part] to the increased appreciation of Mathematics as well as many other subjects engendered by the war experiences of the country." E. H. Moore to H. P. Judson January 13, 1921, E. H. Moore Papers, Special Collections Research Center, The University of Chicago Library, Box 4, Folder 1.

[66] The NRC research fellowships were a prominent example of how, as Millikan described his September 1919 article, "The New Opportunity in Science," the creation (as opposed to redistribution) of wealth had created opportunities for wealthy Americans to donate their money and to invest in science. "[F]or the first time in history," Millikan claimed, "the world has been waked up by the war to an appreciation of what science can do." See Millikan, "The New Opportunity in Science."

In late fall of 1919, Charles Elwood Mendenhall, the Chairman of the National Research Council Division of Physical Sciences, traveled to Chicago, where he met with University of Chicago mathematician Gilbert Ames Bliss. Mendenhall asked Bliss to discuss with other mathematicians at the upcoming meeting of the western sections of the AMS the potential for assistance from the Council's Division of Physical Sciences in promoting cooperative efforts in pure and applied mathematical research. The Division had allocated funds for committee work, and Mendenhall wanted mathematicians to consider whether or not such work might be useful to them. Bliss agreed to bring up the idea with his colleagues, though his own concern was "the possibility of too much organization and too little scientific work."[67] In general, however, there seemed to be interest among mathematicians in cooperative work, and a resolution was passed at the meeting expressing interest in the Council's suggestion. The Division of Physical Sciences thus went ahead with plans to form a Committee on Cooperation in Mathematical Projects, comprised of Profs. Oswald Veblen (Princeton University), L. E. Dickson (University of Chicago), E. R. Hedrick (University of Missouri), R. C. Archibald (Brown University), and H. S. White (Vassar College). Mendenhall asked the Committee to meet in Washington D. C. on April 26th and 27th.[68]

One of the projects the Committee discussed, and later proposed to the Council, was the establishment of a revolving fund for the publication of books related to mathematics, physics, and astronomy. As the Committee's report to the Council explained, "Without aid of this sort the publication of books that appeal to a limited public is practically impossible under the conditions growing out of the war."[69] The report also mentioned that, due to Germany's support of the publishing firm Teubner, many important books and translations were published in German, which had become a sort of mathematical *lingua franca*. According to the Committee, "It would be a perfectly legitimate nationalistic aim to supplant German by English in this field."[70]

In the year following the armistice, the Division of Physical Sciences of the National Research Council put together a report on "The Status of Applied Mathematics in the United States" that was sent to mathematics departments across the country. "In the opinion of the Division," the report explained, "pure mathematics has not been overemphasized, but applied mathematics has been underemphasized in

[67] G. A. Bliss to C. E. Mendenhall December 17, 1919, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.
[68] Even though the NRC covered the committee members' travel costs, Hedrick told Mendenhall that, because he believed so strongly in the importance of the committee's projects, he would have been happy to pay the necessary expenses out of his own pocket. E. R. Hedrick to C. E. Mendenhall April 15, 1920, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.
[69] Report of Committee on Cooperation in Mathematical Projects April 28, 29, 1920, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.
[70] Ibid.

America."[71] While claiming not to devalue pure mathematics, the Division pointed to an increased—and likely increasing—need in a variety of developing industries for applied mathematicians. Along with the need for applied mathematics in industry, the report also mentioned developments in experimental sciences and the stimulating power of theory and experiment that progress "hand in hand." The Division hoped for "at least a partial return to the earlier methods, by which many of the most important developments of the subject have originated in the study of physical problems, thus maintaining a fresh supply of lines of investigation and produce [sic] closer contact with other branches of science."[72] The report thus echoed much of the rhetoric that had already been voiced within the professional mathematics community.

While the NRC Division of Physical Sciences did not expect active researchers in pure mathematics to go through the trouble of changing course and learning an entirely new field in applied mathematics, the report did encourage all mathematicians to direct their students, especially those "of good ability," toward problems in applied mathematics. To that end, the Division had also requested the sub-committees in physics "to try to formulate some problems in shape for analytical consideration."[73] Such problems, according to a letter from NRC Permanent Secretary Vernon Kellogg to Division Director Charles Mendenhall, could then be suggested to mathematicians who were not at the time active in pure mathematical research without "impairing their armour propre."[74] Kellogg did not think active researchers need be distracted from their work, but others might be looking for something to work on and grateful for suggestions. Yet Kellogg also mentioned a warning issued by Professor Moulton at the recent AMS meeting in St. Louis "against a too ready running off into the field of mathematical physics," which Kellogg interpreted as a warning against thinking such problems constituted low-hanging fruit and would be easily solvable.[75]

Hale had envisioned the National Research Council as an enabling mechanism of cooperation—between scientists in the same field, between scientists in different fields, and between scientists and leaders in government and industry—and much of the work of the Division of Physical Sciences focused accordingly on various forms of cooperation. Perhaps the most significant advantage of cooperation as a strategy for promoting science was the preservation of scientific individualism. Indeed, preserving the autonomy of scientists on their quest for truth was hardly less than a moral imperative for Hale. Fortunately,

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[71] The Status of Applied Mathematics in the United States October 20, 1919, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.
[72] Ibid.
[73] C. E. Mendenhall to Vernon Kellogg January 27, 1920, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.
[74] Vernon Kellogg to C. E. Mendenhall January 29, 1920, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.
[75] Ibid.

he and others believed it was possible for scientists to cooperate without sacrificing their individual practices and ideals. As a product of Hale's commitment to cooperation, the Council was essentially designed as a huge bundle of committees, allowing the committee for a particular science to be devoted to the "pure" form of that science while also pursuing cooperation with other committees. This approach seemed to complement the American Mathematical Society's attitude toward outside engagement, in which mathematics was affiliated—and valued for its affiliation—with the war effort, industry, and other sciences, without changing its mostly abstract form. That the AMS continued to appoint delegates to the Council was likely tied to the Council's promotion of pure mathematics alongside its support for cooperation between mathematics and other sciences.

One of the intended goals of the Council's focus on cooperation was to promote research in areas that sat outside established scientific fields, known as "borderland" science.[76] Mathematical physics, for example, was considered a borderland field. As Glenn Bugos explains, NRC committees needed to "convince pioneering young scientists to plow those borderland fields and get their hands dirty. These committees offered fellowships, grants-in-aid, an appreciative audience, and help with scientific instruments—their equivalent of a moving bonus, forty acres, and a mule."[77] When the NRC Division of Physical Sciences began offering Rockefeller-funded research fellowships in physics and chemistry, representatives of the Division announced that the fellowships were "open to men who wish to work in the borderland between mathematics and either of those subjects."[78]

Yet soon after Oswald Veblen began his tenure as Chairman of the Division in 1923, he convinced the NRC and the Rockefeller Institute of Medical Research to include mathematics on its own—not just as a borderland subject—in the allocation of research fellowships. While Veblen was measuring firing ranges during the war at the Aberdeen Proving Ground, he had also been forming important relationships with government officials and honing his bureaucratic skills. Because the Rockefeller-funded NRC fellowships had been created based on the argument that general research in physics and chemistry could help advance research in medicine, what Veblen needed to do was to convince the Institute that general research in mathematics could help advance research in physics and chemistry, thereby advancing research in medicine.[79]

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[76] According to Loren Butler Feffer, '''Borderland'' was the term of choice used among early 20th-century American scientists to describe work relevant to two or more disciplines." See Feffer, "Mathematical Physics and the Planning of American Mathematics: Ideology and Institutions," 67.

[77] Glenn E. Bugos, "Managing Cooperative Research and Borderland Science in the National Research Council, 1922-1942," *Historical Studies in the Physical and Biological Sciences* 20, no. 1 (1989): 23.

[78] C. E. Mendenhall to Vernon Kellogg January 27, 1920, Committee on Cooperation in Mathematical Projects 1919-1920, Division of Physical Sciences 1919-1939, Archives of the National Academy of Sciences.

[79] When the question of support for astrophysics and astronomy was raised around the same time, Kellogg presumed it would be harder to assert the value of these subjects to medical research. "In medieval times," he explained, "this would not have been so difficult as the stars influenced the stomach, but now-a-days there is less of that sort of

In his appeal to the director of the Rockefeller Institute, Veblen described the interdependence of mathematics and physics, explaining how important new ideas in mathematics had grown from attempts to solve physical problems. On the flip side, however, he explained that when Einstein was developing his general theory of relativity, "It happened that the necessary mathematics was already in existence… Had he been under the necessity of creating the mathematical tools which he used in his gravitation theory, it is more than probable that this theory would have been long delayed and possibly never completed."[80] While some American mathematicians had recently become interested in mathematical physics problems related to relativity and quantum mechanics, Veblen was vying for support for research in pure mathematics on the grounds that the results may perhaps someday be useful.

If the NRC was going to allocate fellowships in mathematics, the question remained as to whether or not it should create a separate fellowship board to do so. Veblen was against the idea of creating a separate board, claiming that the presence of physicists and chemists on the board that also administered fellowships in mathematics would help keep mathematicians closer to, and perhaps more interested in, problems in physics and chemistry. "This sort of broadening of the interests of the mathematicians in this country," he explained, "is very desirable at the present time."[81] By October 1923, Veblen had convinced the necessary representatives of the NRC and the Rockefeller Institute to add mathematics to the fellowship program as part of the renewal of the Institute's funding. While awaiting formal authorization from the Rockefeller Foundation, Veblen informed members of the American Mathematical Society of the likelihood of the addition of a mathematics fellowship. "I think the mathematicians are coming to feel more and more," he reported to Kellogg, "the importance of what the Research Council is doing."[82]

At the same time Veblen was Chairman of the Division of Physical Sciences of the National Research Council, he was also the president of the American Mathematical Society from 1923 to 1924. As the Society sought increasingly to generate interest in its endeavors among non-mathematicians, Veblen played a key role in championing the value of mathematics to those with potentially open ears, minds, and wallets. Veblen helped orchestrate the Society's endowment campaign, for example, which sought much-needed funding from current members, charitable foundations, and math-related industries. Although

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thing…" Vernon Kellogg to G. E. Hale November 24, 1923, Research Fellowship Board in Physics & Chemistry (General) 1920-1923, Fellowships, Administration, NAS-NRC Central File 1914-1918, Archives of the National Academy of Sciences.

[80] "Indeed," Veblen claimed, "it may be added that without the pioneer work of the creators of non-euclidean geometry, the frame of mind in which Einstein approached his problem would not have been possible…" Oswald Veblen to Simon Flexner October 24, 1923, Oswald Veblen Papers, N.R.C. Misc. Corres. Etc. 1921-1924, Box 29, Manuscript Division, Library of Congress.

[81] Oswald Veblen to Simon Flexner October 11, 1923, Oswald Veblen Papers, N.R.C. Misc. Corres. Etc. 1921-1924, Box 29, Manuscript Division, Library of Congress.

[82] Oswald Veblen to Vernon Kellogg October 29, 1923, Oswald Veblen Papers, Subject File: N.R.C. Misc. Corres. Etc. 1921-1924, Box 29, Manuscript Division, Library of Congress.

companies like Bell Telephone Laboratories eventually established their own full-fledged departments of mathematics, academic mathematicians kept a fair distance between their own interests and the interests of industry.[83] The American Mathematical Society remained cloistered, that is, until it needed money, at which point its leaders tried to appeal, mostly unsuccessfully, to the moral responsibility of industrial leaders to mathematics. Because mathematics had been central to the development of industries like those offering insurance and electricity, the reasoning went, those industries owed a debt to mathematics itself.[84] The AMS also tried offering a new form of membership wherein a company, such as General Electric (GE), would pay a "sustaining membership" fee that would provide dues-free membership status to a number of GE employees. Yet when GE employees were asked if they had benefitted at all from the AMS *Bulletin* that was included as part of the company's sustaining membership, the answer was a resounding "no."[85]

In theory, the Society's campaign was meant to be about more than putting its finances in order; it had also been designed as "a campaign of education of the public concerning the basic character of mathematics in our present civilization and the importance of mathematical research in advancing that civilization."[86] The establishment of the Josiah Willard Gibbs lecture series, which was meant to showcase the applications of mathematics to a public audience, was a central part of this overall support-winning scheme. As Veblen explained while introducing the first Gibbs speaker, "It is hoped that the Willard Gibbs Lectures will remind the mathematicians of something that we fear they sometimes forget,—the existence of an outside world."[87]

After the war, at least some mathematicians seemed to receive a constant reminder of the outside world in the form of rising publication costs. In 1923, the Lancaster Press was expected to raise its per page printing fee for the *Transaction of the American Mathematical Society* to $15. Fortunately, the Society was able to secure a contract with a printer in Hamburg, Germany for the equivalent of $3 per page. In October 1924, Veblen petitioned the General Education Board (GEB) of the Rockefeller Foundation for funding to

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[83] According to Reinhard Siegmund-Schultze, "It was simply that much work of this kind did not come to the attention of mathematicians and thus did not influence the character of mathematics as an academic discipline." See Siegmund-Schultze's "The Ideology of Applied Mathematics Within Mathematics in Germany and the U.S. Until the End of World War," *Llull: Revista de La Sociedad Española de Historia de Las Ciencias y de Las Técnicas* 27 (2004): 803.

[84] Feffer, "Oswald Veblen and the Capitalization of American Mathematics: Raising Money for Research, 1923-1928."

[85] Most employee members said that the *Bulletin* contained very little related to the applications of mathematics, and they regretted that they lacked the mathematical training needed to understand most of what was published. Still, many expressed support for the work of the AMS, separate from their own interests. Rowland George Dwight Richardson Papers, Box 22, Folder 21, American Mathematical Society Records, The John Hay Library, Brown University

[86] Council Minutes, Box 12, Folder 91, American Mathematical Society Records, The John Hay Library, Brown University.

[87] R. G. D. Richardson, "The First Josiah Willard Gibbs Lecture," Bulletin of the American Mathematical Society 30, no. 7 (1924): 289-291.

help bring the Society's printing back to the United States. The GEB decided to donate funding for the purpose of supporting American scientific publications to the National Academy of Sciences, from which the AMS secured $3,000 annually, in part by pulling on more than a few patriotic heart strings.[88]

The war itself had engendered high levels of patriotism, and American mathematicians tapped into that spirit as they incorporated the conflict into their narratives extolling the relationship between mathematics and other sciences. In 1924, for example, as mathematicians at the University of Chicago were vying for $2 million in departmental funding, they put together a proposal that discussed the state of modern industrial society made possible by advancements in science as well as asserted the role of mathematics in important scientific achievements. The proposal offered examples of powerful mathematics ranging from Newtonian mechanics to wartime advancements in ballistics. "These are a few only of the instances," the proposal pointed out, "which go to show that higher mathematics and higher mathematicians are not so far removed from the practical affairs of life as is popular believed."[89]

While the authors of the proposal admitted that the applications of mathematics were not the main focus for mathematicians at the University of Chicago, they also declared their belief that mathematics was valuable beyond its remarkable usefulness. And although it was difficult to explain significant mathematical achievements to non-mathematicians, the proposal explained, mathematicians worldwide recognized one another's achievements, which ultimately contributed to the glory and dignity of human life. Leading with the applications of mathematics, especially those that played a part in the war, and then asserting the inherent value of mathematics for its own sake had become a well-used strategy to garner support for all of mathematics, while continuing to prioritize abstract mathematical research. Even after the war, many of the leadership positions in the mathematics community continued to be held by pure mathematicians, whose disciplinary interests may have called for a less isolated community, but whose research interests did not.

Conclusion

Because few major mathematical advancements developed out of efforts to win World War I, the conflict had been largely brushed over in the historiography of mathematics until the past few decades. Since then, scholars have begun to consider the role of World War I in the development of mathematics as a discipline as well as a body of research.[90] The massive, and often haphazard, mobilization of science during the war established the groundwork for the postwar organization of science regarding military,

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[88] Karen Parshall, "'A New Era in the Development of Our Science': The American Mathematical Research Community, 1920-1950," in *A Delicate Balance: Global Perspectives on Innovation and Tradition in the History of Matheatics*, ed. David E Rowe and W. S. Horng (Basel: Springer International Publishing, 2015), 275–308.
[89] Mathematics and Astronomy at the University of Chicago, E. H. Moore Papers, Box 4, Folder 4, Special Collections Research Center, The University of Chicago Library.
[90] Aubin and Goldstein, "Placing World War I in the History of Mathematics."

governmental, and industrial relations. And while the status of American science and the role of science in industry had increased during the early twentieth century, both trends were accelerated during and after World War I, and both meant, to a certain extent, increased opportunity for American mathematics.[91]

Yet both the war itself and the reorganization of science in its aftermath spotlighted an apparent disconnect between American mathematicians' discipline building and research work and between the relevance and rhetoric of American mathematics. According to Loren Butler Feffer, while American mathematicians' "enthusiastic and exclusive" preference for abstract research may have helped promote the autonomy, status, and prestige of their community, the success of their profession was also tied to their role as educators and their place within the larger scientific community.[92] Between the late nineteenth century and the United States' entry into World War I, leaders of the young, but growing, American mathematical research community expressed concern about the lack of outside interest and support for their work. There seemed to be a growing gap between the professional support of "useless" mathematical research and the many uses of mathematics.

When the United States declared war on Germany in 1917, most American mathematicians were active in a field that had become narrowly defined by abstract mathematical research, and some mathematicians like E. H. Moore worried that the mathematics community itself would not be considered useful as a formal wartime resource. Nonetheless, many were quick to put their mathematical training to work, teaching mathematics for military purposes to non-professional soldiers, calculating range tables, modeling aerodynamic forces, managing administrative statistics, and so forth. Ultimately, the war itself became a brutal demonstration of the relevance of science, including mathematics, in human affairs.

After the war, a handful of American mathematicians like Oswald Veblen built bridges between the mathematics community and broader national, industrial, and scientific interests, in part through scientific organizations like the National Research Council. Even still, the rhetoric of professional mathematics continued to depict an isolated community devoted to the august ideal of mathematical abstractions. And though a professional community of applied mathematics would eventually take root in the United States during the second half of the twentieth century, it would remain notably separate from the established community of American mathematical research. American mathematics would continue to tell two stories: one of far-reaching usefulness and another of useless abstractions.

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[91] Kevles, *The Physicists*.
[92] Feffer, "Mathematical Physics and the Planning of American Mathematics," 70.

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