Eliakim Hastings Moore
1862-1932

At the turn of the twentieth century, E H. Moore was one of the three main players in the beginnings of American research mathematics. The other two were J. J. Sylvester and Felix Klein. Moore was the only native-born of the three—in fact he was born in Marietta, Ohio, on January 26, 1862.

He attended old Woodward High School in Cincinnati, Ohio, 1876-1879, which had grown out of Woodward College.* Notable people who had been on the faculty were William Holmes McGuffey (in 1843-1845) and Joseph Ray (1831-1855), author of a famous series of school mathematics texts. In 1892 Moore was invited to form the Department of Mathematics at the new University of Chicago, and retired in 1931. He died in Chicago, December 30, 1932.

Moore grew up in a fertile environment. His father was Rev. David Hastings Moore (B.A. Ohio University 1869, D.D. Ohio Wesleyan 1875, and L.L.D. Mount Union College 1896). He was a Methodist Episcopal Bishop, serving in Shanghai (with jurisdiction over China, Japan, and Korea), president of Cincinnati Wesleyan College, an organizer and first Chancellor of the University of Denver, professor at the University of Colorado, and Lt. Colonel, 125th Ohio Volunteer Infantry during the American Civil War.

Moore's grandfather, also Eliakim Hastings Moore, was a banker, and treasurer and trustee of Ohio University in Athens, and served as a congressman from Ohio. The grandson served as a messenger in Congress one summer.

He married Martha Morris Young of Athens, Ohio, a childhood friend and sister of John Wesley Young who became Professor of Mathematics at Dartmouth College. Young's father was a professor at Ohio U., a colonel in the Civil War, and son of a congressman. She was an instructor in romance languages at Ohio U. and at Denver before marrying Moore and moving to Chicago. A son, a third E. H. Moore, lived in Texas after graduating from Chicago.

Moore became interested in mathematics through a summer job as an assistant to Ormond Stone who was then director of the Cincinnati Observatory (and later founder of the *Annals of Mathematics*). He was encouraged to attend Yale University by two friends, one of which was Horace Taft, brother of William Howard Taft and founder of the Taft School in Connecticut. Moore continued graduate studies at Yale after completing undergraduate studies in 1883, earning a Ph.D. in 1885 under Hubert Anson Newton.

His dissertation was "Extensions of Certain Theorems of Clifford and Cayley in the Geometry of n Dimensions." Newton had four students, the other one with doctoral students was Josiah Gibbs. Newton had studied with Michel Chasles at the Sorbonne, who in turn was a student of Simeon Denis Poisson.

Moore then studied for a year in Germany: in Berlin attending lectures of Kronecker and Weierstrass, and a summer in Göttingen. Moore's original interest was influenced by the British school, but his year in Germany exposed him to a different level of mathematics and introduced him to entirely new topics which influenced him during the rest of his career.

Moore produced 31 doctoral students beginning with Leonard E. Dickson in 1896. The list, below, contains some of the most famous names in twentieth century American mathematics. In turn, many of these produced large numbers of graduates–more than 17,000 mathematical descendants to date, and growing rapidly.

Richard Baker	1910	Thomas McKinney	1905
Raymond Barnard	1926	R. L. Moore (co-advisor)	1905
George Birkhoff	1907	Frederick Owens	1907
Edward Chittenden	1912	Fancisco Perez	1929
Leonard Dickson	1896	Arthur Pitcher	1910
Charles Dines	1915	Ralph Root	1911
William Findlay	1901	Arthur Schweitzer	1916
Meyer Gaba	1914	Herbert Slaught	1898
Vishnu Gokhale	1922	Herman Smith	1926
William Hart	1916	Clarence Van Horn	1923
Theophil Hildebrandt	1910	Oswald Veblen	1903
Mark Ingraham	1924	Mary Wells	1915
Derrick Lehmer	1900	Anna Wheeler	1910
Nels Lennes	1907	Robert Wilson	1923
Harris MacNeish	1909	Yue Wong	1931
		Ernest Zeisler	1922

He convinced the New York Mathematical Society, which had a national reach, to publish the proceedings of the 1893 Congress held at the 1893 Columbian Exhibition in Chicago, to which Felix Klein had been invited. Moore was influential in the founding of the American Mathematical Society, which grew out of the the New York Mathematical

Society in 1893, and he was its First and Second Vice-President 1897-1901, and President 1901-03. He was editor of the AMS *Transactions* 1899-1907. The AMS *E. H. Moore Prize* is awarded for an outstanding research article to have appeared in one of the AMS primary research journals

Moore's work was characterized by careful rigor and abstraction. Moore's initial interest was in algebra and groups, where he proved in 1893 that every finite field is a Galois field. In his work on the foundations of geometry, begun around 1900, he examined the independence of Hilbert's axioms. He reformulated these in terms of points as the only undefined quantities, rather than points, lines and planes. In a 1902 paper he showed that Hilbert's system contained redundant axioms. In 1906 he undertook the foundations of analysis. The Moore-Penrose pseudoinverse, which is used in least squares and projection problems, was independently described by Moore in 1920 and Penrose in 1955.

In his 1902 Retiring President's Address to the AMS, "On the Foundations of Mathematics", Moore promotes a "general point of view [rather than special theories] in what may be called *abstract mathematics*". "General interest in abstract mathematics was aroused by Hilbert's Gauss-Weber Festschrift of 1899." He goes on to talk about independence of postulates.

But he spends much of his address on education at all levels and the pure v. applied mathematics gap, which are issues yet today. Here he also advocates the discovery and laboratory approaches to teaching mathematics and suggested organizing high school algebra, geometry, and physics "into a thoroughly coherent four years' course". He even addresses the English "agitation" to relieve the secondary school teachers from "the burden of a too precise examination system, imposed by the great examination system, ..." Moore's methods soon faded, but the effects continue.

In 1897 he had edited an arithmetic for use in elementary schools, In 1906 Moore wrote a paper on the use of graph paper and the function concept in secondary schools, and proposed that nomography (graphical computation) be emphasized. The latter did not take hold, but the rest had a lasting effect. In 1903-4 he modified the undergraduate instruction at Chicago by introducing the method he called the "laboratory method" in the above address, perhaps influenced by Chicago colleague John Dewey. He taught calculus himself this way. Scheduling problems with the required two-hours per day and the workload soon forced its abandonment; but its influence lives on. The work and teaching of R. L. Moore (the "Moore method" or "Texas Method"), whose 1905 degree was co-advised by E. H. Moore, must have been influenced. (They are not related.)

Arnold Ross, who spent his childhood in Odessa although he was born in Chicago, was told by his Gymnasium teachers there in 1922 that if he went to the University of Chicago, he should study with E. H. Moore. Moore knew that Ross did not have traditional schooling, so he gave Ross special attention. For his first course, Ross attended a Moore graduate course in topology as an undergraduate:

> Moore's teaching was even stronger than our teachers in the Gymnasium. He taught us the beginnings of topology. He never lectured. He would tell us what he conjectured, and we were to prove it. If we had suggestions as to what may be true, we would give them; then we would defend them. It was incredibly exciting. He never paid much attention to the school bell.

Ross got his Ph. D. under L. E. Dickson in 1931 at Chicago, and went on to chair departments at Notre Dame and Ohio State, and established the long-running Ross Summer Mathematics Program for high school students.

Divisions formed in the Chicago department—in particular Herbert Slaught and William Young elected to specialize in education. Ohioan B. F. Finkel, founder of *The American Mathematical Monthly,* spent a couple of summers at Chicago on a graduate fellowship. Chicago gave the *Monthly* some financial support. And Dickson and then Slaught were editors.

Reflecting this early divide between research and teaching, the AMS declined to publish the *Monthly* after it struggled for a few years,. Moore's student Herbert Slaught, who was then an editor of the *Monthly*, was one of the organizers of the Mathematical Association of America in 1915, at Columbus, Ohio. Moore was supportive, but stayed in the background.

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* Personal connection: My great great grandfather, Chauncey Stuntz, taught Physics and Chemistry at Woodward during the time that Moore was there. My great grandparents were also in the class of 1879. And I was at Ohio State when Ross was chair. In fact I was interviewed by him upon my arriving on campus. So we have come full circle.