NATIONAL ACADEMY OF SCIENCES

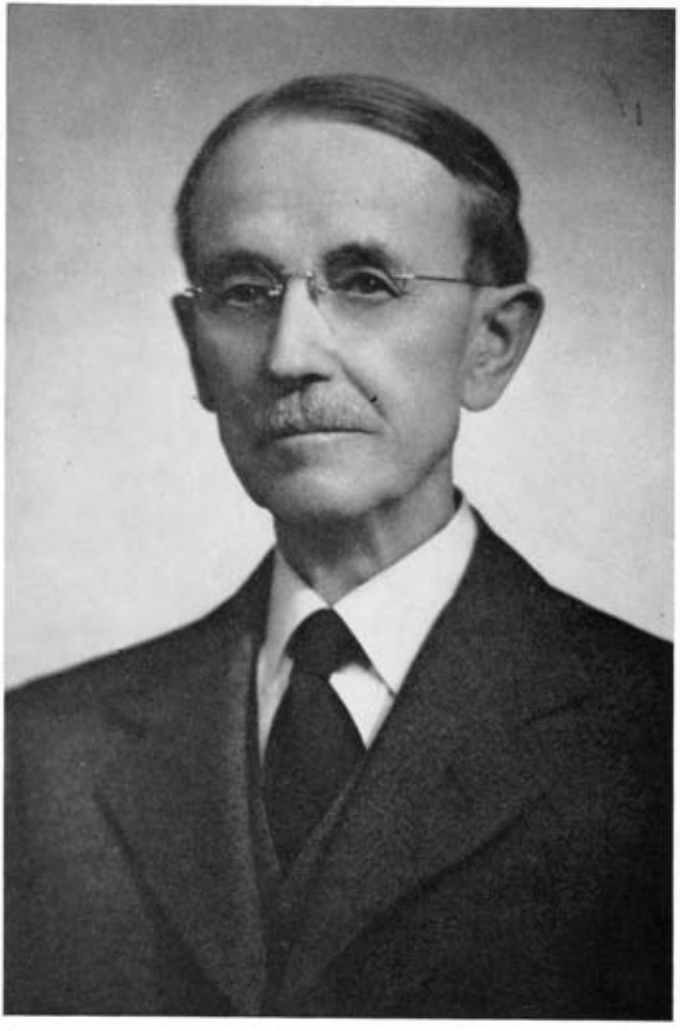
HENRY CREW

1859—1953

A Biographical Memoir by

WILLIAM F. MEGGERS

Biographical Memoir



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HENRY CREW

June 4, 1859—February 17, 1953

BY WILLIAM F. MEGGERS

HENRY CREW was born in Richmond, Jefferson County, Ohio, on June 4, 1859, the morning of the famous frost that killed all the corn in that region! He died in his ninety-third year in Evanston, Illinois, February 17, 1953.

The community about Richmond, which was settled during the first two decades of the nineteenth century, was composed largely of Scotch Presbyterians and Quakers, a frugal and thrifty people, engaged largely in raising wool, grain, and pork, which were shipped to eastern markets by wagon and team.

Richmond College, established in 1835, was a center of liberal and classical education: but from the date when the Panhandle railroad was built and bypassed the town of Richmond, five miles to the north, the educational facilities and the intellectual atmosphere of the place began to diminish.

When Henry Crew became of school age in 1865, the college was decadent and the public schools were in such wretchedly poor condition that his mother moved (in 1872, two years after the death of his father) with him and his two sisters to Wilmington, Clinton County, Ohio, for the sake of the excellent high school and college which this town afforded. A clause in his father's will provided that each of his children was to have a "classical education."

According to autobiographical notes submitted to the Executive Secretary of the National Academy of Sciences, Crew's earliest recollections are a curious combination of what went on in the home life

of a Quaker family in the 1860s and the daily routine of the general store which his father owned and managed next door to their residence. The processes of making butter, soap, sausage, and vinegar, the molding of candles, and the newly invented method of preserving fruit in glass vessels were all matters of intense interest to a small boy. Crew was deeply impressed by what he heard, evening after evening, in his father's store, where old soldiers sat swapping Civil War stories. A large proportion of the young and middle-aged men were still wearing the blue army overcoats. A large part of the education of a boy in Wilmington, Ohio, was obtained during his many visits to the blacksmith's shop, the wagonmaker's shop, the pottery, the tannery, the coal mine, the sawmill, the flour mill, the cooper's shop, the gunsmith's shop, and the carpenter's and tinsmith's shops. The shoemaker and the tailor were valuable personal acquaintances for a boy who had to wind and cover his own baseballs.

Crew learned much more physics unconsciously by harnessing and hitching up horses, by operating a hayfork, by winnowing chaff out of wheat, than he did from *Fourteen Weeks Course in Natural Philosophy,* the first textbook in physics which he studied. To this period, 1865–1870, belongs *The Boys Playbook of Science* by John H. Pepper (London, Routledge, 1866), which his father gave him about 1867 and which he cherished till he died.

Up to his thirteenth year Crew had gotten almost nothing but "mental arithmetic" from the public schools. Reading and writing he had learned from his mother. The result was that, when he went to the Wilmington high school and, later, to Princeton College, he was nearly two years older than the average of his class. In fact, the schools were so poor at Richmond that one year, when he was about ten, his father sent him to a country school three miles out of town. To this he rode on horseback. The following year he was sent to another country school, a mile and a half away, to which he walked.

Every Thursday until he was eleven years of age he was taken from

school at 10:30 A.M. and driven with his parents to the midweek Quaker Meeting, some miles out of town; the journey was made again on Sunday. Many of these meetings were entirely "silent," devoid of inspiration and totally without value to a young boy, save possibly in the practice of obedience and "watchful waiting."

His first serious school work began at Wilmington, Ohio, in the autumn of 1872 and continued to occupy all his time until June of 1878, when he was graduated from high school and took his entrance examinations at Cincinnati for Princeton College. These examinations were conducted by a young teacher of Latin in one of the Cincinnati high schools, Andrew F. West, later Dean of the Graduate School at Princeton University. From his thirteenth to his nineteenth year the studies which appealed to Crew were exclusively concrete subjects, such as human physiology, botany, geology, chemistry, and trigonometry. On the other hand, geometry, algebra, Latin, Greek, and ancient history were exceedingly irksome and uninteresting.

Crew early set out to become a civil engineer. Mechanical engineering was almost unknown and electrical engineering unheard of. But never for a moment did he think of abandoning the goal which his father had set for him in his will, namely, a classical education. Hence, he took three years of Latin and two of Greek so as to enter Princeton, where he was required to take two years more of each of these languages. To all his advisers, including his father, his high school principal, Professor J. H. Grove, and the men at Princeton who maintained the classical curriculum, he was deeply grateful, for, during the next fifty years, scarcely a day passed when he had no occasion to use this fundamental linguistic training in one way or another.

Leisure hours, evenings, and vacations, during these six years, 1872–1878, were spent mainly with young people of his own age, fishing and gardening in the spring, camping and geologizing in summer, nutting in the autumn, hunting quail and rabbits in the winter. Each of these pursuits was generally pervaded and saturated

with some scientific interest, which resulted in a collection of some thousands of fossils and the analysis of some dozens of plants in the flower and vegetable garden.

A few men whom he met socially remained models for him during his entire life. Among them were Judge R. B. Harlan, Colonel A. W. Doan, Benjamin Farquhar, and a near and dear neighbor, George W. Brown.

Crew entered Princeton in the autumn of 1878 (when Woodrow Wilson was a senior). All students were soaked with Latin, Greek, and mathematics during the first two years. A course in the "Doctrine of the Formation of Words in Greek" with Professor S. S. Orvie and one in Anglo-Saxon with Professor T. W. Hunt gave Crew his first firm grasp of the English language.

In the autumn of his junior year (1880–1881) he first met the word *physics* and learned its meaning from a course with Professor C. F. Brackett who used Ganot's text. In his senior year he met his first really great and inspiring teacher, Professor C. A. Young, whose alertness, mastery of his subject, geniality, and courtesy were evident every day during a year's course in general astronomy. In this year, too, he first had the privilege of a laboratory course in physics; this was with Professors Brackett and Magie. Mechanical drawing he took as an extra course, with Professor J. B. McMaster, the historian, whose standards of accuracy left a deep impression upon him.

In June of 1882 Crew was granted (on examination in chemistry, physics, and geology) a fellowship in physics and spent a graduate year in the Princeton laboratory. In the absence of any regular graduate courses in physics, he "browsed in the library, played in the laboratory, and deteriorated intellectually."

In June of 1883 he was awarded another fellowship and went to Helmholtz's laboratory in Berlin for the autumn semester. In a letter to his sister, dated Berlin, November 5, 1883, he wrote: "I have 5 lectures a week from Prof. Helmholtz, the greatest of German physicists, 4 lectures a week from Prof. Kirchhoff on the 'Mathematical Theory of Light,'—Prof. Helmholtz lectures on 'Experimen-

tal (not mathematical) physics.' Then I have 2 lectures a week from Prof. Kayser on 'Optics,' and 2 lessons a week from a tutor in German; making in all 13 hours a week. I yet understand very little of these lectures, though I have caught nearly all that Prof. Kayser says by the aid of his gestures and diagrams." James E. Keeler and W. Wien were also in this class of Kayser's. Before this semester was over, Crew had met Keeler and Dewitt Brace, who told him so much about Henry Rowland that he decided to return to America and take up serious study at The Johns Hopkins University.

In June of 1884 he was granted a fellowship in physics at Johns Hopkins, to which he had gone in the spring as an assistant to Rowland and A. L. Kimball in the experimental part of the determination of the ohm, for which the U. S. Congress had voted Rowland a sum of some $12,000 a year or two earlier. Three years of graduate work were spent in Rowland's laboratory, doing the coefficient of expansion of water, assisting Rowland in his measurement of wave lengths in the solar spectrum, and in the (Doppler) determination of the rotation period of the sun for various heliocentric latitudes. On this last-mentioned piece of work, presented as a thesis, he was awarded the degree of Ph.D. in 1887. He later discovered, however, that the results of this work were vitiated by the very small and imperfect image of the sun with which he worked. Simon Newcomb came to his room several times to see the Doppler displacement of the solar spectrum lines near the equatorial limbs of the sun.

Among the able and inspiring young men in this laboratory at the time were Louis Duncan, A. L. Kimball, J. S. Ames, A. G. Webster, C. T. Hutchinson, and Louis Bell. No one could work in this laboratory untouched by Rowland's originality, clarity, energy, and intellectual honesty. During the academic year 1887–1888 Crew acted as Assistant in Physics at The Johns Hopkins University and conducted two laboratory courses in general physics, one elementary and one more advanced.

The years from 1888 to 1891 were spent as Instructor in Physics, and head of the department, at Haverford College. Here he devised

and, to a certain degree, perfected a method of thermostatic control by use of an electric current-sheet.

The year 1891–1892 was spent at the Lick Observatory where he went, at the request of the Director, to measure the motion in line of sight (Doppler effect) of certain stars and also to see what could be done in the way of photographing stellar spectra by use of a concave grating of deep curvature which Mr. Brashear had given him for the purpose. On reaching the observatory, he found himself on the "no man's land" between two bitter factions. He joined one of these groups (that of S. W. Burnham and E. E. Barnard, his lifelong friends) for one year and then accepted the first appointment offered him, that of a professorship of physics at Northwestern University at Evanston, Illinois. Here he came in the autumn of 1892 with his wife (the former Miss Helen C. Coale of Baltimore, one of the first graduates of Bryn Mawr College, whom he had married during his last year at Haverford) and child.

From 1892 to 1930 Crew was Fayerweather Professor of Physics at Northwestern, but in the summer of 1930 he was granted leave of absence to accept an appointment as Chief of the Division of Basic Sciences at the Century of Progress International Exposition in Chicago, where he spent three and a half years, greatly enjoying his work under Rufus C. Dawes and Major Lenox R. Lohr.

This work consisted of planning and preparing exhibits to fill the huge Hall of Science that proved to be one of the main attractions of the spectacular exposition staged on the Lake Michigan front of Chicago during 1933 and 1934. The exposition was scientifically opened by a beam of light from Arcturus and since that star was then thought to be forty light-years distant, the light energy that "opened" the 1933 exposition had presumedly left Arcturus during the Chicago Columbian Exposition of 1892 and 1893.

The principal theme of the Century of Progress Exposition was the dependence of various industries upon the pure sciences. This was demonstrated to the visitors by showing them the principal phenomena in both fields. The great Hall of Science presented to the

public some of the fundamental facts of the basic sciences (mathematics, physics, chemistry, biology, geology, medicine), leaving the applied sciences to find their illustrations in the pavilions devoted to industry. It had been decided to show phenomena rather than apparatus and to display life processes rather than specimens of animals or plants. Crew was responsible for the entire basic science program, which involved not only the Hall of Science exhibits but also the lectures, symposia, scientific society meetings, and a series of "dollar books" on various sciences. He promptly invited a group of capable young men to take charge of the different sciences. Physics was assigned to Gordon S. Fulcher (an early student of Crew) and J. J. Hopfield, who devised more than 100 exhibits or experiments illustrating physical principles or phenomena. Since Crew insisted that science exhibits be dynamic whenever possible, their design and maintenance required much of his thought and time. He prepared also an interesting 144-page *Official Catalog of Exhibits in the Division of the Basic Sciences.* This was undoubtedly the largest and most successful "science fair" in this country's history because Henry Crew made it so. At the conclusion of the exposition many of the science exhibits were moved to the Chicago Museum of Science and Industry, where they continued to entertain and educate the public.

On September 1, 1933, Crew, in his seventy-fourth year, went on the retired list as Professor Emeritus of Physics at Northwestern University, but his interest and concern for physics continued another sixteen years, during which he reviewed numerous books on physics and prepared biographical sketches and obituaries of many scientists. During this period he translated from Latin into English *The Photismi de Lumine of Maurolycus: A Chapter in Late Medieval Optics,* a treatise by an Italian scholar who lived between 1494 and 1575. This fine translation was published in 1940. Crew planned to trace the knowledge of optics back beyond Maurolycus but he lost heart for this plan after his wife died in 1941.

His four decades of service as Professor of Physics and department head of Northwestern University are marked in the early years by a

series of publications of spectroscopic research and later by a series of textbooks and pedagogical book reviews. His training as a graduate student under Kirchhoff, Kayser, and Rowland naturally inclined Crew toward atomic spectroscopy, and most of his publications between 1888 and 1908 are on this subject. During this period he apparently became aware of defects and deficiencies in the teaching of physics in the United States. This is evidenced by his discussion of the question "What Can Be Done to Make Physics a Better Training for Power?" (*School Review,* 1900) and "Recent Advances in the Teaching of Physics" (*Science,* 1904). In 1899 he wrote his first textbook, *The Elements of Physics,* and in 1902 another, *A Laboratory Manual of Physics.* In 1908 he provided new texts, *General Physics* and *The Principles of Mechanics.* He was an earnest, penetrating student and a dedicated, successful teacher. He modestly disclaimed making any contribution of first-rate importance to knowledge, but considered that his translation of Galileo's *Two New Sciences* (1914) and his book *The Rise of Modern Physics* (1928) were, of his publications, the two most helpful to other students of physics. The latter is certainly a scientific, historical, and literary gem. The temptation to quote two short paragraphs is irresistible:

> In October of 1813, Sir Humphry Davy and his wife made a tour of continental Europe which is not without interest for the history of science. It will be noted that he started on the trip only two years before the close of the Napoleonic wars, spent two winters abroad and did not return until the year of Waterloo. Before leaving London, he had obtained the permission of Napoleon to travel in France; but having reached Paris he was the recipient of many honors and was even elected to honorary membership in the Institut National which, for twenty years following the French Revolution, took the place of the Académie des Sciences.
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> Davy was the guest of the leading scientific men of France and Italy and was often accorded the facilities of their laboratories for his own experimental investigation. At the present time, any such exchange of courtesies between two countries at war is obviously impossible; science no longer ranks, in the estimation of governments or in popular judgment, as merely an intellectual sport. Any investigator in physical science as able and skillful as Davy and coming from the enemy country, would today

have the utmost difficulty in crossing the frontier, and would be more likely to have his name stricken from the rolls of a national academy than to be placed on the honor list. Such a tool has science become in the hands of men who wage war!

In his lectures Crew was a master of exposition and constantly tried to present physics as a living and growing science, filled with human interest. His writings show continual effort to associate things, times, ideas, experiments, the laws of physics, et cetera, not only with the names and dates of famous physicists but also with other human beings and associated historical events. In a paper called "The Problem of the History of Science in the College Curriculum" (1920), he asked, "Is science in America to be forever presented as a set of abstract principles, a set of generalizations, derived, it may be, in the first instance, from experiment or observation, but now formulated in the most impersonal way possible? Or is science to be treated as a distinctly human achievement?"

During many years of historical study, association, and correspondence with scientists, Crew accumulated a large number of photographs of physicists which he used to illustrate his books and to decorate his laboratory and home. When a picture of Rutherford disappeared from the laboratory, Crew wrote the following letter to the student newspaper (*Daily Northwestern,* Jan. 7, 1927) of the University:

"January 3, 1927. To the young man who has the portrait of Sir Ernest Rutherford, recently removed from its place in the Hall of the Physical Laboratory: My dear friend: It was a mere prank, I am sure, for no one who admires, as you do, the fine face of Sir Ernest Rutherford, beaming with honesty and straightforwardness, would want in his collection a portrait not rightly acquired. You know, quite as well as I do, the spirit in which the keen blue eyes of this fearless knight—a man who spent his entire life in hot pursuit of truth—would be constantly looking down upon you. If, therefore, at your first opportunity, you will quietly restore this great Englishman to his proper place, in the good company of his teacher, Sir J. J. Thomson, and of the genial Ampere, you and I will each be happier, and what's more, you may realize anew, and for the rest of your life, the meaning of that freedom which comes with the truth and which it is the aim of every university to confer.

"Furthermore, any feeling of sorrow on the part of Northwestern University, a branch of the nation's service based on integrity and loyalty, will be reversed into pride at your action. Please believe me. Your friend, Henry Crew"

In view of the failure of the picture to make its reappearance, one can only conclude either that the culprit was not a student at Northwestern, or that he could not read!

The above letter and comment are from an address by Professor Richard M. Sutton, recommending Henry Crew as the recipient of the 1941 Oersted Medal for notable contributions to the teaching of physics (*American Journal of Physics,* 10 (1942), 28–32). In his acceptance Crew modestly disclosed the secret of his success as a teacher:

My ideals have always been derived mainly from certain concrete examples; from warm-blooded men and women. I have in mind a well-known remark of Mr. Gilman that the kind of man he wanted, at the head of each department in Johns Hopkins University, was "a student who can also teach." It is only the student-teacher who can at once keep abreast of his subject and, at the same time, be in sympathy with the men in his classes. It is only the student-teacher who can meet the oncoming generation with becoming modesty and also with accurate scholarship. One is here reminded of those two lines from *Faust* with which Boltzmann prefaces his lectures upon Maxwell's electromagnetic theory:

So soll ich dann mit saurem Schweiss
Euch lehren, was ich selbst nicht weiss.

I am wondering whether the best teaching in physics is not *a cooperative form of recreation, supervised by a student who can also teach.* Only in this way is education likely to become a transaction between two warm-blooded individuals, and thus a part of life rather than a mere preparation for help.

Other honors bestowed upon Henry Crew include the Cavaliere, Crown of Italy; and Sc.D. degrees from the University of Michigan in 1914, from Princeton University in 1922, and from Northwestern University in 1937. In 1952 he attended the seventieth anniversary of his Princeton commencement. Crew was a member of the American

Physical Society, founded in 1899, its delegate to the Congress of Physicists in Paris in 1900, its vice president in 1907 and 1908, and its president in 1909–1910. He was also an early member of the Optical Society of America, founded in 1916, and belonged to the American Astronomical Society, the History of Science Society (president, 1930), Association of University Professors (president, 1929), the American Association for the Advancement of Science, the American Academy of Arts and Sciences, the Illinois State Academy of Science (vice president, 1908, president, 1913). the American Philosophical Society, the Chicago Academy of Sciences (vice president, 1916), and the Padua Academy. He was elected to membership in the National Academy of Sciences in 1909. He was associate editor of the *Astrophysical Journal* for half a century.

Although I admired Professor Crew's accomplishments and personality, I had no opportunity to work with or get intimately acquainted with him. With pleasure, I recall meeting him several times at scientific meetings, the first time in October 1929 at a meeting of the Optical Society of America at Cornell University, the second and third times in June 1942 during a Spectroscopy Symposium at the University of Chicago, and the fourth and fifth times in the fall of 1951, when I spoke to spectrochemists in Chicago and to pure spectroscopists in Evanston. He impressed me as a mild-mannered, soft-spoken, kind, and considerate man, mentally keen, alert, and orderly, physically slight of build but constitutionally strong, energetic, and active. In his seventy-fourth year, after he retired from Northwestern University, he took up golf and learned to drive an automobile. He played a good game of golf into his eighties, and could outdo many younger men. Until he reached the age of seventy-four he not only would not own an automobile, let alone drive one, he would hardly accept a ride with anyone. When necessary, he would use taxis, as "they carried insurance against accident to the occupants." But almost immediately after retiring he bought a car and learned to drive.

When I gave a talk, "The Primary Standard of Wave Length,"

at the spectroscopy symposium at the University of Chicago in June 1942, I was surprised to see Professor Crew in the front row of the audience. After the session he told me that he had driven his car from Evanston to South Chicago, through dense morning traffic, just to hear me speak. He was eighty-three years old. When I asked if he would attend the symposium the next day, he replied, "Probably not." However, the following morning, when I reported on "The Spectra of the Rare Earths," Professor Crew occupied the same front seat. In the summer of 1949, when he was ninety years old, he drove his car, with his daughter as "copilot," from Evanston to Dayton and on to his ancestral home in Richmond, Ohio. Whatever he did, he did well.

In autobiographical notes filed with the National Academy of Sciences in 1935 Henry Crew stated that he knew of no printed genealogy of the family, and submitted essential facts as follows:

My paternal grandfather, Henry Crew, after whom I was named, was born in Charles City County, Virginia, on the 6th of August, 1787, and died at Richmond, Ohio, on the 22nd of December, 1856. He was married to Margaret Baily (born at Chadd's Ford, S. E. Pennsylvania) on the 30th of January, 1822. They had four children, James, Benjamin, William H., and Elizabeth. The son William H. (born at Richmond, Ohio, in 1828, died at St. Louis, Michigan in 1870) was my father. My grandfather Crew established his store in Richmond, Ohio, in 1816.

My maternal grandfather was Lemuel Hargrave. He also was born in Charles City County, Virginia. His birthday was the 20th of October, 1799. On the 10th of March, 1829, my grandfather Hargrave married Mary Ann Hubbard. They had four children, one of whom, Deborah Ann, was my mother. She was born in Charles City, Virginia, on the 2nd of July, 1834. Two years later Lemuel Hargrave and his family moved to Mt. Pleasant, Jefferson County, Ohio, where he lived until about 1865 when he moved to Salem, Henry County, Iowa, where he died in 1869.

My mother and father were married in Mt. Pleasant, Iowa, in 1858 and I was born at Richmond, Ohio, in 1859. I have one sister, Caroline L., living and one, Winona B., deceased. My wife and I have three children, Alice H., Mildred, and William H., the first and third of whom are married. Our grandchildren are five in number.

In conclusion, let me say that Henry Crew's son, William H. Crew, is also a physicist, and I am pleased to acknowledge his generous assistance in the preparation of this biographical memoir. He informs us that Caroline Crew died in August 1961 at the age of ninety-six, and that there were twelve great-grandchildren in 1961. Because it is unusual to find three generations of physicists, I mention that Henry Crew's grandson and namesake, Henry Crew III, is also a physicist.

William Crew adds that in June 1949 his father, on his ninetieth birthday, received letters of hearty felicitation and well-wishing from almost all of the older physicists in this country. The son also reports that his father saved volumes of letters from famous physicists and left voluminous personal diaries covering many, many years. He suggests that, although it would be a major task for someone to go through them, they might provide important source material for any historian tracing the development of modern physics out of natural philosophy during the past century.

Finally, for his bibliography Henry Crew, in 1943, supplied the National Academy of Sciences with a list of 90 items, with the statement: "From this list I have omitted a number of unimportant titles, and I am inclined to think the pruning process might well have gone further; but perhaps it is only fair that I should stand by what is here set down." However, a more complete bibliography of 123 articles and 12 books, supplied by his son, is appended because it shows strikingly Professor Henry Crew's transition from research to pedagogy and emphasizes the great efforts he made toward improving physics teaching, the work in which he was most successful and for which he is most admired and honored.

KEY TO ABBREVIATIONS

Am. J. Phys. = American Journal of Physics
Am. Phys. Teacher = American Physics Teacher
Astron. Astrophys. = Astronomy and Astrophysics
Astrophys. J. = Astrophysical Journal
Bull. Am. Assoc. Univ. Professors = Bulletin of the American Association of University Professors
J. Eng. Educ. = Journal of Engineering Education
J. Western Soc. Engrs. = Journal of the Western Society of Engineers
Phil. Mag. = Philosophical Magazine
Phys. Rev. = Physical Review
Proc. Am. Acad. Arts Sci. = Proceedings of the American Academy of Arts and Sciences
School Sci. Math. = School Science and Mathematics
Sci. Mo. = Scientific Monthly
Trans. Illinois State Acad. Sci. = Transactions of the Illinois State Academy of Science

BIBLIOGRAPHY

1888

On the Period of Rotation of the Sun as Determined by the Spectroscope. American Journal of Science (3), 36:151–59.

1889

On the Connection Between Earth Currents and Changes in Solar Activity. Nature, 39:557–58.

Syllabus of Eight Lectures on Electricity. American Society for the Extension of University Teaching.

1891

Ewing's Theory of Induced Magnetism. Journal of the Franklin Institute, 132:1–10.

1892

On a New Method for Obtaining a Constant Temperature. Phil. Mag., 32:89.

Note on the Measurement of Solar Prominences. Astron. Astrophys., 1:90–91.

On the Visible Spectrum of the New Star in Auriga. Astron. Astrophys., 1:231–33.

Note on the Spectrum of the Large Sun Spot Group of February, 1892. Astron. Astrophys., 1:308–10.

Pringsheim on Kirchhoff's Law. Astron. Astrophys., 1:581–87.

An Unusual Sunset. Nature, 46:391.

Daytime Seeing at the Lick Observatory. Nature, 46:465.

Elementary Theory of the Equivalent Focus. American Journal of Photography, 13:298–305; 363–69; 411–18; 460–69.

1893

On the Use of the Concave Grating for the Study of Stellar Spectra. Astron. Astrophys., 2:156–59.

1894

With R. R. Tatnall. On a New Method for Mapping the Spectra of Metals. Phil. Mag., 38:379–86.

1895

With O. H. Basquin. Note on the Spectrum of Carbon. Astrophys. J., 2: 103–5.

With O. H. Basquin. Note on the Magnesium Band at λ 5007. Astrophys. J., 2:100–2.

Normal Spectrum of the Magnesium Arc. Astrophys. J., 2:318–20.

1896

Photographic Map of the Normal Spectrum of the Zinc Arc. Issued by Northwestern University, July.

1898

With O. H. Basquin. A Pocket Handbook of Electroglazed Luxfer Prisms. Chicago, American Luxfer Prism Co. 287 pp.

Laboratory Instructions in Physics—Course A. R. R. Donnelley and Sons. 32 pp. (Printed, not published.)

A Provisional List of Photometric Units. Astrophys. J., 7:299–304.

On the Sources of Luminosity in the Electric Arc. Proc. Am. Acad. Arts Sci., 33:337–49.

On the History of Our Ideas Concerning Illumination. American Architecture and Building News, October 1, 1 p.

On Latitude Variation in a Rigid Earth, as Illustrated by Maxwell's Dynamical Top. Phys. Rev., 6:153–63.

1899

The Elements of Physics. New York, The Macmillan Company. 347 pp.

1900

The Wave Theory of Light (translation of memoirs by Huygens, Young, and Fresnel). New York, American Book Company. 164 pp.

Professor J. J. Thomson's Work on the Structure of the Atom. Astrophys. J., 11:170–74.

What Can Be Done to Make Physics a Better Training for Power? School Review, 8:520–27.

On the Arc Spectra of Some Metals as Influenced by an Atmosphere of Hydrogen. Phil. Mag., 50:497–505.

1902

With R. A. Tatnall. A Laboratory Manual of Physics. New York, The Macmillan Company. 234 pp.

Note on the Wave Length of the Magnesium Line at λ 4481. Astrophys. J., 16:246–48.

With John C. Baker. On the Thermal Development of the Spark Spectrum of Carbon. Proc. Am. Acad. Arts Sci., 38:397–406.

The Function of a Science Club in the University (address). The Northwestern, October, p. 14.

1903

Photographic Map of the Normal Spectrum of the Aluminum Arc. Issued by Northwestern University.

With A. A. Knowlton. Photographic Map of the Normal Spectrum of the Cadmium Arc. Issued by Northwestern University.

Report of Committee on Physics on "Definition of Unit in Physics." North Central Association of Schools and Colleges, April 3.

1904

"Spectroscopy." Article in: *Encyclopedia Americana.* 7 pp.

Review of *Elemente der Vektor-Analyse,* by A. H. Bucherer, Monist, 14:631–33.

Graduate Study. Chapter XXI in *History of Northwestern University,* by Wilde, 9 pp.

Recent Advances in the Teaching of Physics (address). Science, 19:81–88.
On the Conditions Which Govern the Appearance of Spark Lines in Arc Spectra. Astrophys. J., 20:274–84.
Remarks on Standard Wave Lengths. Astrophys. J., 20:313–17.

1905

The Ionic Theory of the Arc and Spark. J. Western Soc. Engrs., February, 19 pp.
With B. J. Spence. Variation of Arc Spectra with the Phase of the Current Producing Them. Astrophys. J., 22:199–203.
A Neglected Point in the Teaching of Elementary Dynamics. School Sci. and Math., 5:331–34.

1906

The Best Preparation for Engineering (six-page circular). Issued by Northwestern University.

1907

Fact and Theory in Spectroscopy (vice-presidential address before Section B of the American Association for the Advancement of Science). Science, 25:1–12.
Engineering at Northwestern University. Northwestern Christian Advocate. July 17.

1908

General Physics. New York, The Macmillan Company. 522 pp. (4th ed., 1927.)
The Principles of Mechanics. New York, Longmans, Green & Co. 295 pp.
The Researches of Professor A. A. Michelson (written on the occasion of his receiving the Nobel Prize). The World Today, February, 3 pp.
Symposium on the Teaching of High School Physics: Part IV. School Sci. Math., 8:722–24.

1909

With Franklin T. Jones. The Elements of Physics. New York, The Macmillan Company. 435 pp.
Force and Torque (lecture demonstration of the monorail car). School Sci. Math., April, pp. 323–31.
Engineering at Northwestern University (speech at dedication of Swift Hall). Northwestern Christian Advocate, May 19, 1 p.

George Washington Hough (obituary). Astrophys. J., 30:68–69.
Albert B. Porter (obituary). Science, 29:962–63.
Review of *Recherches théorétiques et expérimentales sur la constitution des spectres ultraviolets d'étincelles oscillantes,* by Eugène Néculcéa. Astrophys. J., 30:74.
Mass and Inertia. School Sci. Math., 9:864–65.
The Relation of the Sciences to Each Other (after-dinner address). Trans. Illinois State Acad. Sci., 2:100–3.

1910

The Debt of Physics to Metaphysics. Phys. Rev., 31:79–92.
Review of *An Introduction to the Theory of Optics,* by A. Schuster. Science, 32:920–21.

1911

Review of *The Mathematical and Physical Papers of Lord Kelvin: Vol. V.* Astrophys. J., 34:320–22.
Review of *Handbuch der Spectroskopie: Band V,* by H. Kayser. Astrophys. J., 33:87–89.
Review of *Physical Optics,* by R. W. Wood. Science, 34:409–10.
Physical Properties of Radium (part of a symposium). Trans. Illinois State Acad. Sci., 10 pp.
The Voyage of the "Nimrod." Northwestern Christan Advocate, March.
The How and Why of the Flying Machine. Northwestern Christian Advocate, July 5, 4 pp.
The How and Why of Water Waves. Northwestern Christian Advocate, September 20, 5 pp.

1912

Review of *The Teaching of Physics for Purposes of General Education,* by C. Riborg Mann. Educational Review, September, 4 pp.

1913

Review of *Handbuch der Spectroscopie: Band VI,* by H. Kayser. Astrophys. J., 38:126–28.
Review of *Treatise on Light,* by Christian Huygens, trans. by S. P. Thompson. Science, 37:610–11.
Galileo, the Physicist (presidential address, Illinois State Academy of Science). Science, 37:463–70.

1914

With Alfonso de Salvio. Dialogues concerning Two New Sciences, by Galileo (trans.). New York, The Macmillan Company. 300 pp. (3 printings.)

With George V. McCauley. Wavelengths in the Spectrum of the Calcium Arc *in vacuo*. Astrophys. J., 39:29–38.

Review of *Researches in Physical Optics with Especial Reference to the Radiation of Electrons,* by R. W. Wood. Science, 39:25–27.

Review of *Definitions in Physics,* by R. E. Guthe. Science, 39:465–67.

Review of *The Constitution of Matter,* by J. S. Ames. Johns Hopkins Alumni Magazine, March. (Another review of the same book appeared in Astrophys. J., 40:239–40.)

1916

Why Men Should Read Good Books (written for the prisoners in U. S. Penitentiary at Leavenworth). Leavenworth New Era, 3 (No. 41), December.

1917

Review of *Collected Papers on Spectroscopy* by G. D. Living and Sir James Dewar. Astrophys. J., 46:238–40.

1919

The Problem of the Boy in the Swing. Science, 50:139–40.

Site of Evanston's New High School. Evanston News-Index, August 11.

Things That Remain. Alumni Journal of Northwestern University, Sept. 20, pp. 24–25.

1920

Alexander Whyte to Speak in Harris Hall. Evanston News-Index, January.

The Scientific Leadership of the World. Methodist Review, January, pp. 95–102.

The Problem of the History of Science in the College Curriculum. Sci. Mo., 10:475–81.

1921

The Bearing of Recent Research on the Teaching of Elementary Physics (address). School Sci. Math., 21:136–42.

1924

Review of *Bibliographic History of Electricity and Magnetism,* by P. E. Mottelay. Science, 59:258–60.

Review of *Weather Proverbs and Paradoxes,* by W. J. Humphreys. Science, 59:301.

Review of *Time and Timekeepers,* by W. I. Nilham. Phys. Rev., 24:202–4.

With F. R. Lillie. William A. Locy: 1857–1924 (obituary). Science, 60:491–93.

Some Wave Lengths in the Vacuum-arc Spectrum of Titanium. Astrophys. J., 60:108–21.

1926

Ancient and Modern Theories of Light. J. Western Soc. Engrs., 31:455–62.

1928

The Rise of Modern Physics. Baltimore, Williams & Wilkins. 356 pp. (2d ed., 1935.)

Our Debt to the Electricians of the Nineteenth Century (two lectures). J. Eng. Educ., 19:188–219.

What Group of Sciences Does Sigma Xi Represent? Sigma Xi Quarterly, 16:36–40

The New President's Message. Bull. Am. Assoc. Univ. Professors, 14:167–68.

1929

Review of *Theoretical Mechanics* by J. S. Ames and F. D. Murnaghan. Johns Hopkins Alumni Magazine, 17:429–41.

On the Influence of a Hydrogen Atmosphere upon the Arc Spectra of Certain Metals. Phil. Mag., 7:312–16.

The Role of the American Professor (address). Proceedings of the Association of Governing Boards of State Universities and Allied Institutions, November, 6 pp.

1930

With K. K. Smith. Mechanics for Students of Physics and Engineering. New York, The Macmillan Company. 371 pp.

Academic Partnership (presidential address). Bull. Am. Assoc. Univ. Professors, 16:103–11.

Thomas Young's Place in the History of the Wave Theory of Light. Journal of the Optical Society of America, 20: 1–10.

1931

The Basic Sciences at the Chicago Centennial Exposition—1933. Science, 74:94–95. (Written by H. Crew, signed by J. S. Sewell.)

1932

The Exposition of Science (address). Sci. Mo., 35:288–38.

1933

Official Catalog of Exhibits in the Division of Basic Sciences. Chicago, Century of Progress Exposition, 1933. 144 pp.

A Sciencia ua Exposicao de Chicago. Boletim de Uniao Pan-Americana, 35:596–606.

A Century of Science. Review of Reviews, March, 1 p.

1935

Review of *A Source Book of Physics,* by W. F. Magie. Science, 82:63–64.

Professor K. K. Smith, 1887–1935 (obituary). Am. Phys. Teacher, 3:182.

The Dynamo and Motor Rules Again. Am. Phys. Teacher, 3:138.

Biographical Memoir of T. C. Mendenhall, 1841–1924. In: National Academy of Sciences, *Biographical Memoirs,* 16:331–51.

Review of *Noise,* by N. W. McLachlan. Evanston News-Index, October 31.

1936

An Appraisal of the Definitive System of Units. Trans. Illinois State Acad. Sci., 28:217–23.

1937

Review of *The Renaissance of Physics,* by Karl K. Darrow. Science, 85: 243–45.

Concerning Stephen Gray, 1696–1736. Am. Phys. Teacher, 5:233–34.

1938

Charles B. Atwell, 1855–1937 (obituary). Trans. Illinois State Acad. Sci., 31:37–38.

1940

The Photismi de Lumine of Maurolycus: A Chapter in Late Medieval Optics (trans.). New York, The Macmillan Co. 134 pp.

Review of *A Short History of Science,* by W. T. Sedgwick, H. W. Tyler, and R. P. Bigelow. Johns Hopkins Alumni Magazine, 28:100–1.

The Tragedy of Rudolf Diesel. Sci. Mo., 51:512–23.

1941

Heinrich Kayser, 1853–1940 (obituary). Astrophys. J., 94:5–11.

History of Radio (radio talk written for Col. R. R. McCormick). Chicago Tribune, March 23.

1942

Portraits of Famous Physicists: Twelve Biographical Sketches. Scripta Mathematica.

Address of Acceptance of the Oersted Medal. Am. J. Phys., 10:31-32.

Review of *Benjamin Franklin's Experiments,* by I. B. Cohen. Isis, 33:634–36.

Sir Isaac Newton. Sci. Mo., 55:279–84.

Review of *The Methodology of Pierre Duhem,* by A. Lowinger. Journal of Applied Physics, 13:361.

Henry Gordon Gale, 1874–1942 (obituary). Astrophys. J., 97:85–88.

Review of *Ways of the Weather* by W. J. Humphreys. Chicago Naturalist, 5(No. 4).

1943

Galileo, Pioneer in Physics. Sci. Mo., 56:440–46.

Litera Occidit: Spiritus Vivificat. Isis 34:300–1.

1944

Biographical Memoir of Joseph Sweetman Ames, 1864–1943. In: National Academy of Sciences, *Biographical Memoirs,* 23:181–201.

1945

Physical Units. In *Encyclopaedia Britannica.* 5 pp.

Sir Arthur Schuster. *Ibid.*

Sir J. J. Thomson. *Ibid.*

Lord Ernest Rutherford. *Ibid.*

R. A. Millikan. *Ibid.*

S. P. Langley. *Ibid.*

1949

Some Recollections of Henry A. Rowland, 1848–1901. Am. J. Phys., 17:575–77.

1951

Evanston Water Works: Letter to Mayor Ingraham. Evanston Review, September, pp. 22–27.