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BIOGRAPHICAL MEMOIRS

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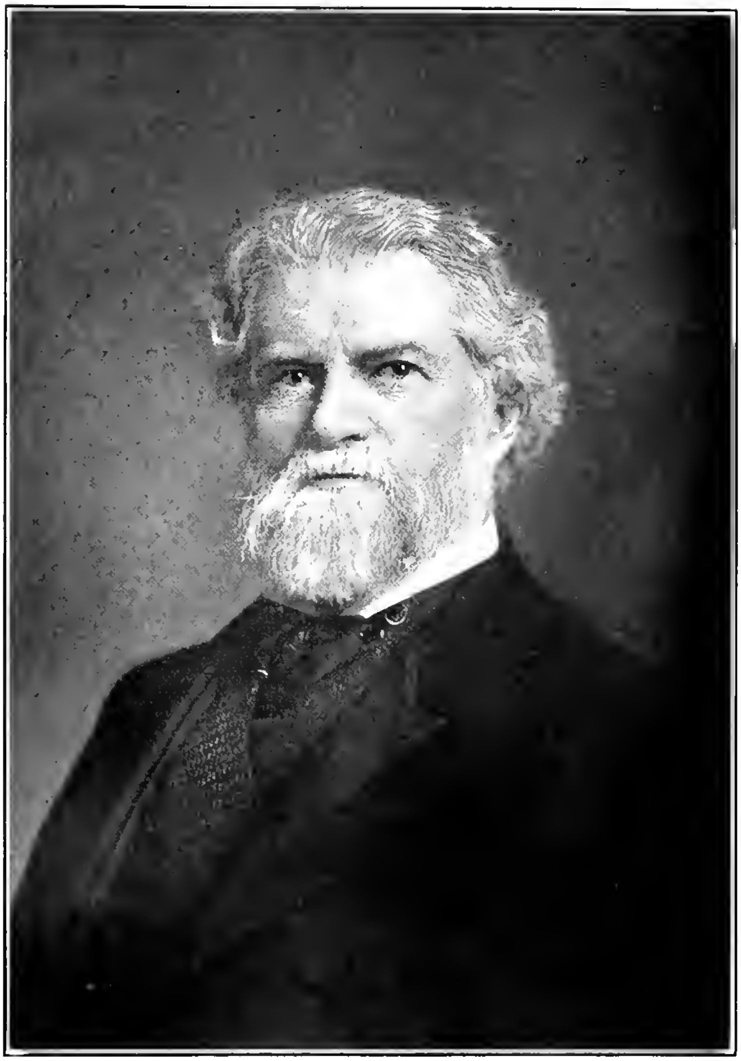
BIOGRAPHICAL MEMOIR SIMON NEWCOMB

1835–1909.

BY

W. W. CAMPBELL.

Presented to the Academy at the Annual Meeting, 1916.



Simon Newcomb

SIMON NEWCOMB.

By W. W. Campbell.

Simon Newcomb's[1] ancestry was chiefly English, and in minor degrees Scotch, French, German, and Irish. His first paternal ancestors to cross the ocean were the family de Vigne. A son of theirs was the first boy of European stock born on Manhattan Island. Simon Newcomb's mother was a descendant of Elder William Brewster and his son Jonathan, who came with the Mayflower company, and of Elder Prince, of Hull, and others who came later. Newcomb's ancestors in every line had crossed the Atlantic long before the American Revolution, and the American descent was almost entirely through New England families. The first identified Newcomb was a sea captain, who married in Boston in 1663. The first Simon Newcomb was born in Massachusetts or Maine about 1666. His descendants formed the habit of naming their eldest sons after him, and except for the fact that his father was a younger son, the astronomer would have been the sixth Simon Newcomb in unbroken lineal descent. His paternal grandfather, Simon Newcomb, who removed to Nova Scotia in 1761, was a stonecutter, but he was credited "with unusual learning and with having at some time taught school;" and he possessed a small collection of books on serious subjects—an algebra, a Euclid, a navigator, The Spectator, etc.—which were destined to influence profoundly the life of our colleague.

The astronomer's father, John Burton Newcomb, was by profession a country schoolteacher. He was a strong character in some ways, and he had the distinction of being an early exponent of the principles of eugenics. After careful study he concluded that a man should marry at the age of 25, and that the wife should have certain temperamental characteristics and be mentally gifted. When John Newcomb "found the age of 25 approaching he began to look about. There was no one in (his village of) Wallace who satisfied the requirements. He therefore set out afoot to discover his ideal." His searches were in vain until they had extended nearly a hundred miles from home and into the neighboring Province of New Brunswick. Hearing the strains of music from a church he went in, and there found his future wife, Emily Prince, in the person of the organist and leader of the singing. Emily's father had migrated from Maine to New Brunswick early in life, where he became a widely known and highly respected citizen of the Province. John Newcomb always "expressed the highest admiration for Emily Newcomb's mental gifts, to which he attributed whatever talents his children might have possessed."

Simon Newcomb, the astronomer, was born on March 12, 1835, at Wallace, on the north coast of Nova Scotia. As the teaching profession in those days was an almost nomadic one, the movings of the family were frequent, and Simon's childhood and boyhood were lived in various parts of Nova Scotia and in Prince Edward Island. Simon was well endowed by nature; he was strong of body, mind, and character. "What we now call school training, the pursuit of fixed studies at stated hours under the constant guidance of a teacher, I (Simon) could scarcely be said to have enjoyed. For the most part, when I attended my father's school at all, I came and went with entire freedom * * * ." Simon was precocious, and he appears to have been born with the conquering power of concentration of mind. Arithmetic was begun at the age of 5, and the study of geography at 6; and at 6½ years of age he was "pretty well through the arithmetic," not including cube root. While his age was still expressed in one digit, his father secured for him an old work on astronomy, concerning which the father late in life wrote to the son: "You were wonderfully taken with it, and read it with avidity. * * * I one evening lectured on astronomy at home; the house was pretty well filled. * * *

[1] Many items in this biography have been taken from Newcomb's autobiographical volume, The Reminiscences of an Astronomer; Houghton, Mifflin & Co., 1903.

you were not quite 10 years old * * *. Almost as soon as I was done you said, 'Father, I think you were wrong in one thing.'"

John Newcomb wrote further to his son, "You were an uncommon child for truth. I never knew you to deviate from it in one instance. * * * You were uncommonly deficient in that sort of courage necessary to perform bodily labor. Until 9 or 10 years of age you made a most pitiful attempt at any sort of bodily or 'handy' work." To understand the local point of view as to manual labor, we should note that the great majority of Newcomb's neighbors were poor. The men and boys worked long hours, tilling the ground, and cutting lumber, wood, and stone for export. The women and girls sheared the sheep, spun the yarn, wove the homespun cloth, and made the clothes.

The father's letter to the son continues:

> I now often impressed upon you the necessity of bodily labor, that you might attain a strong and healthy physical system, so as to be able to stand long hours of study when you came to manhood, for it was evident to me that you would not labor with the hands for a business. On this account, as much as on account of poverty, I hired you out for a large portion of the three years that we lived in Clements.
>
> At 15 you studied Euclid and were enraptured with it. It is a little singular that all this time you never showed any self-esteem, or spoke of getting into employment at some future day, among the learned. The pleasure of intellectual exercise in demonstrating or analyzing a geometrical problem, or solving an algebraic equation, seemed to be your only object. * * *
>
> Your almost intuitive knowledge of geography, navigation, and nautical matters in general caused me to think most ardently of writing to the admiral at Halifax to know if he would give you a place among the midshipmen of the Navy; * * *.

Simon's studies in algebra, in Euclid, and in navigation (from books found in his grandfather's house) were pursued eagerly and without the advice of an instructor. Newcomb says of his studies in geometry: "A new world of thought seemed to be opened. That principles so profound should be reached by methods so simple was astonishing. I was so enraptured that I explained to my brother Thomas, while walking out of doors one day, how the Pythagorean proposition, as it is now called, could be proved from first principles, drawing the necessary diagrams with a pencil on a piece of wood."

At the age of 16 it was necessary for Simon to think of earning a livelihood and to decide upon a trade or profession. He has written of his problem: "The skill required on a farm was above my reach, where efficiency in driving oxen was one of the most valued of accomplishments. I keenly felt my inability to acquire even respectable mediocrity in this branch of the agricultural profession. * * * I had indeed gradually formed, from reading, a vague conception of a different world—a world of light—where dwelt men who wrote books, and people who knew men who wrote books, where lived boys who went to college and devoted themselves to learning, instead of driving oxen. I longed much to get into this world, but no possibility for doing so presented itself. I had no idea that it would be imbued with sympathy for a boy outside of it who wanted to learn."

Circumstances now led Simon to apprentice himself to a physician of Moncton, New Brunswick, who had the reputation of effecting wonderful cures. The contract was to terminate when Simon should reach the age of 21, at which date he was to be a practicing physician. Simon soon found that he was dealing with a dishonest quack who made the apprentice his drudge and gave nothing in recompense. After long consideration, he cut the knot by "running away," on September 13, 1853. Walking more than 50 miles from before daylight till late at night, and more than 30 miles the following day, he arrived in St. John on the evening that the beginning of work on the first railway in New Brunswick was being celebrated. Another week of struggle with the question of a bed by night and a loaf of bread by day brought him across the international boundary line to the village of Calais, in Maine. Here he contracted with the captain of a small sailing vessel for the passage to Salem, 15 miles north of Boston, for all the money Simon had—one or two dollars—and his help on the voyage. The short trip consumed about three weeks. At Salem he was met by his father, who, after the death of Simon's mother at the early age of 37, had sought his fortune in "The States." The father had decided, for some reason, to locate in the eastern part of Maryland; and here, at the beginning of 1854, Simon Newcomb began his distinguished educational career, as the teacher of a country school at Masseys Cross Roads, Kent County. The following year he secured a somewhat better position as teacher of the school in the little town of Sudlersville. Newcomb valued then and later a letter from the trustees of the Sudlersville school, which reads as follows:

> This is to certify that Mr. Simon Newcomb was well qualified to instruct children in the various branches of an English education, and possesses a good moral character. He exhibited a very considerable knowledge of the higher branches of mathematics.
>
> W. J. SUDLER,
> JOHN W. E. SUDLER,
> *Trustees for Primary School No. 4 of Q. A. Co., for the year ending 1855.*
>
> (Dated) SUDLERSVILLE, *November 23, 1855.*

Quoting from Newcomb's Reminiscences: "In 1854 I availed myself of my summer vacation to pay my first visit to the National Capital, little dreaming that it would ever be my home. I went as far as the gate of the observatory, and looked wistfully in, but feared to enter, as I did not know what the rules might be regarding visitors. I speculated upon the possible object of a queer red sandstone building, which seemed so different from anything else, and heard for the first time of the Smithsonian Institution."

While teaching, Newcomb passed every spare hour on such books as he could secure or gain access to. He had, in the meantime, decided that mathematics was the study in which he should specialize, though he did not see clearly how he could turn the results to account.

Newcomb's first published paper is of interest from many points of view. A correspondent of the newspaper, the National Intelligencer, wrote a long letter to refute the Copernican theory of the universe. Newcomb has said of this letter: "It was evidently wholly fallacious, yet so plausible that I feared the belief of the world in the doctrine of Copernicus might suffer a severe shock, and hastened to the rescue by writing a letter over my name, pointing out the fallacies. This was published in the National Intelligencer in 1855."

In 1856 Newcomb was employed as a tutor in the family of a planter residing in Prince Georges County, Md., some 15 or 20 miles from Washington. He frequently rode on horseback to the Capital, which contained much to interest him. The library of the Smithsonian Institution was a great attraction, and there he found Bowditch's translation of Laplace's Méchanique Céleste, a great work of which he had long been dreaming. He secured Prof. Joseph Henry's special permission to take the first volume home. Newcomb dipped into it here and there, but found its formulæ and methods quite beyond his powers at that time.

A little later he had the pleasure of meeting Joseph Henry, who suggested that he might find something to do in the Coast Survey. Newcomb established friendly relations with the chief clerk of the survey, and on one occasion proposed to the clerk a plan for improving the Cavendish method of determining the density of the earth. Later he was received by Mr. J. E. Hilgard, assistant in charge of the survey. An opportunity for service in the Coast Survey did not present itself, but late in the year 1856 Hilgard wrote a letter to Newcomb to say that he had been talking about Newcomb to Prof. Winlock, superintendent of the American Ephemeris and Nautical Almanac, and that it might be possible for Newcomb to obtain employment in the Almanac office. Newcomb had previously bought a copy of the Almanac and had amused himself by computing on a slate the occultations of stars by the moon observable in certain months at San Francisco. The Almanac office was then located in Cambridge, Mass., and about the last day of the year 1856, armed with letters of recommendation from Prof. Henry and Mr. Hilgard, Newcomb started on the tedious journey thither, in the hope that employment would be offered. A few weeks later he was appointed a computer, on trial, at a salary of $30 per month. Newcomb's impressions of Prof. Henry and Mr. Hilgard, and of Prof. Winlock and others employed in the Almanac office, were fully up to his boyhood conception of men of science, and he has written: "I date my birth into the world of sweetness and light on one frosty morning in January, 1857, when I took my seat between two well-known mathematicians (Joseph Winlock and John D. Runkle), before a blazing fire in the office of the 'Nautical Almanac,' at Cambridge, Massachusetts."

Newcomb's assigned duties in the Almanac office required only five hours a day, and he took advantage of the opportunity to enroll himself as a student of mathematics in the Lawrence Scientific School in Harvard College, where he pursued studies under the direction of Prof. Benjamin Peirce. He received the degree of bachelor of science in 1858. During his remaining three years in Cambridge he was on the rolls of Harvard College as a resident graduate.

Newcomb's contributions to mathematical astronomy began shortly following his appointment on the Nautical Almanac. His first paper, On a Method in Dynamics, was dated April 2, 1858, and was published in Gould's Astronomical Journal. Shortly thereafter he decided to investigate the famous and difficult hypothesis that the asteroids owe their origin to the explosion of one and the same antecedent body at some past epoch. If this was the case, then the orbits of the several pieces of the disrupted body passed through a common point at that epoch—the point occupied by the parent body at the instant of disruption. He read a paper at the Springfield meeting of the American Association for the Advancement of Science in 1859 on the changes in the orbit of one asteroid in several hundred thousands of years past. A month later he published similar information for three other asteroids, and in the spring of 1860 the final results of his extensive investigation were published in the Proceedings of the American Academy of Arts and Sciences, under the title, On the Secular Variations and Mutual Relations of the Asteroids. He concluded that, so far as our present theory of motion could show, the asteroids had never passed through a common point, and therefore the hypothesis was not tenable.

The Nautical Almanac office dispatched an expedition, in charge of Simon Newcomb and William Ferrel, to observe the total solar eclipse of July, 1860, at the point where the shadow path crossed the Saskatchewan River, north of Lake Winnipeg. The travel was arduous, and only at the cost of a severe struggle did the birch-bark canoes, propelled by Indians, carry them across Lake Winnipeg and up the Saskatchewan River in time to make hasty preparations for the observations. Unfortunately the sky was completely clouded at the time of the eclipse.

In August, 1861, Dr. B. A. Gould recommended to Newcomb that he apply for the vacant position of professor of mathematics in the United States Navy, for service in the Naval Observatory. The plan did not appeal strongly to Newcomb, as his tastes and talents were along the line of mathematical astronomy, in contradistinction to observational astronomy. Nevertheless, it was desirable to provide for the needs of the future, and he applied. The appointment was made by President Lincoln, and Newcomb reported to Capt. Gilliss, Superintendent of the Naval Observatory, on October 7, 1861. He was assigned to duty as assistant on the transit instrument, under Prof. Yarnall in charge. He and Yarnall alternated in observing right ascensions of the stars—such stars as each "thought best to observe." The mural circle at the other end of the building observed the declinations of such stars as the professor in charge of that instrument chose.

In the year 1863 Newcomb was placed in charge of the mural circle and of the prime vertical transit instrument. He then proposed to Supt. Gilliss that a homogeneity of observing program and method [2] should mark the work of the Naval Observatory, in place of the go-as-you-please policy previously followed by every member of the staff, and the superintendent was pleased to approve and adopt the suggestion. The new transit circle, ordered in Berlin for the Naval Observatory, arrived in 1865, and was placed in Newcomb's charge. He planned with great care a four years' program of "fundamental" observing; that is, a system of observing which rests upon its own foundations, as distinguished from the "differential" method, which assumes the correctness of, and is based upon, the results of earlier observations. He brought this program to completion in 1869. Discussion of the observations revealed, as he had expected, the presence of systematic errors in existing catalogues of star positions, and especially in their right ascensions, to the effect that the assigned right ascensions of the stars in one part of the sky were systematically too great, and in another part of the sky systematically too small. His observing program had been designed originally to detect such errors in the old catalogues and to eliminate them from his own work.

[2] European practice, notably at the Royal Observatory, Greenwich, had suggested this to Newcomb.

In the volumes of Astronomical and Meteorological Observations Made at the United States Naval Observatory, Washington, in the years 1861 to 1870, inclusive, one finds abundant evidence of Newcomb's great energy in using the instruments for which he was responsible, in reducing the observations and in the prompt publication of the results. The same volumes reveal his breadth of view and power, in a half dozen comprehensive papers, on the latitude and longitude of the United States Naval Observatory, on the distance of the sun and the elements which depend upon it, on the new transit instrument (a description), on the positions of fundamental stars deduced from Washington observations made between 1862 and 1867, on the right ascensions of the equatorial fundamental stars and the corrections necessary to reduce the right ascensions of different catalogues to a mean homogeneous system, etc.

Prof. Newcomb was detailed to observe the total eclipses of the sun at Des Moines, Iowa, in June, 1869; at Gibraltar in December, 1870; and at Separation, Wyo., in July, 1878.[3] He was especially interested in determining the relative positions of the sun and moon, as indicated by the times of the contacts of the lunar and solar images, by the durations of the eclipses, and (in Iowa and in Wyoming) by the observed north and south limits of the shadow path. The eclipses at Des Moines and at Separation were successfully observed, but the value of the Gibraltar expedition was largely destroyed by the presence of clouds during the critical parts of the eclipse period.

At about this time Prof. Newcomb realized that the discrepancies between the observed positions of the moon and the positions as predicted in Hansen's tables for the moon had become a serious matter, and at his request it was arranged that he should be relieved from the duty of making observations, and from other observatory work, in order to conduct an investigation of the moon's motion, though at the request of the superintendent he retained his position on the observatory staff. The lunar problem developed into the leading work of his life; it received his best efforts during many of the years 1870 to 1909.

The devoting of the resources of the Naval Observatory to the determination of star positions and to the special needs of the Navy Department led naturally to the neglect of that side of astronomical investigation which requires powerful telescopes. This fact was called to the attention of the superintendent of the observatory by Prof. Newcomb in 1868, and again in 1869, with the recommendation that the observatory procure a refracting telescope as large as the then celebrated maker, Alvan Clark, would undertake to construct. These recommendations led ultimately to the appropriation of $50,000 for the purpose by the Congress of 1870–71. It was decided by Mr. Clark and the observatory authorities that the telescope should be a refractor of 26-inch aperture. Prof. Newcomb tested the object glass in Cambridge in the summer of 1873, and the records show that the first observations made with the telescope finished and mounted in the Naval Observatory were of Neptune's satellite, by Newcomb, on November 20, 1873. He remained in charge of the instrument until May, 1875. In that period he made many measures of the positions of the satellites of Uranus and Neptune, as a basis for determining more accurately the masses of the two planets, in order to facilitate his work of reconstructing the tables of the motions of the planets; many observations of the satellites of Saturn; and a few observations of occultations and of double stars.

Prof. Newcomb was prominently associated with the plans for observing the transits of Venus over the sun in the years 1874 and 1882, to obtain an improved value of the distance between the earth and the sun. He inaugurated the proposal at the April, 1870, meeting of the National Academy of Sciences—the first annual meeting following his election to membership—by reading a paper [4] concerning the coming transits, and by introducing a resolution calling for the appointment of a committee to consider and report upon the subject. This resulted, in 1871, in the establishment of the Transit of Venus Commission, of five members, including Prof. Newcomb and Prof. Harkness. Newcomb was elected secretary of the commission. The commission gave to the subject the serious consideration demanded by its character

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[3] At this time Newcomb was superintendent of the Nautical Almanac and not officially connected with the Naval Observatory, but the expedition was under the auspices of the Observatory and the report upon the observations was addressed to the Superintendent of the Naval Observatory.

[4] On the Mode of Observing the Coming Transits of Venus, *Amer. Jour. Sci. and Arts*, *50*, 74–83, 1870.

and difficulties, and after experiment and trial proposed the following modifications of or additions to the more or less conventional program:

1. The observations should be made with a photographic telescope, of long focus, whose collimation axis should lie in the intersection of a horizontal plane and the plane of the meridian.

2. A plumb line, consisting of very fine wire, should be suspended in front of the photographic plate, and as nearly as possible in contact with it, to form upon the plate a truly vertical line to serve all purposes of orientation.

3. Means should be provided to determine accurately the distance and any changes of distance between the object glass of the telescope and the photographic plate throughout the observation period.

Prof. Newcomb, as secretary and member of the commission, bore a prominent part in the preparation of a series of three papers relating to the transit of Venus in 1874, as a guide and help to the observers, writing the first, On the Application of Photography to the Observation of the Transits of Venus, and the third, On the Corrections to Hansen's Tables of the Moon's Motion, needed in determining the longitudes of isolated observing stations.

Plans for observing the transits of Venus were made also by the astronomers of Great Britain, France, Germany, Denmark, Russia and Italy. Coöperation amongst the parties from the different countries promised to be generally helpful, and with that policy in mind Newcomb accepted an invitation to attend a meeting of the German commission, in Hanover, in 1873. He endeavored to make clear the views of the American commission that valuable results could not be secured by the system of photographing which had been proposed, but the response was that the preparations had been advanced too far to admit of starting on a new plan.

The Congress appropriated a total of $175,000 in the years 1872, 1873, and 1874 to finance the program of the American commission. Expeditions were dispatched to three northern stations, in China, Japan, and Siberia, and to five southern stations. Unfavorable weather prevailed at all of the stations; failure from clouds was not complete at any station, but the value of the observations at every station was impaired. The results for the sun's distance obtained by the commissions from the various countries were disappointing even where the skies were clear. Newcomb was convinced that a better value for the radius of the earth's orbit could be obtained by determining as accurately as possible the velocity of light and the time which light requires to travel from the sun to the earth. He questioned seriously whether our Government would be justified in dispatching parties to observe the transit of Venus in 1882. The astronomers of this country were consulted, but only two negative voices, those of Newcomb and Pickering, were heard. The commission secured an additional appropriation of $85,000, and proceeded with the plans for observing the second transit. Prof. Newcomb conducted the expedition to the Cape of Good Hope, where the sky on the day of the transit was perfect and the observations were made as planned. Clear skies prevailed at about half of the stations—four southern and five northern— and none of the observing parties failed completely.

It was a matter of sincere regret to Prof. Newcomb that the results of the American observations have remained substantially unpublished. A preliminary discussion of some of the observations of 1874 made under the direction of the commission and edited by Newcomb, appeared in 1880; but concerning the 1882 transit, nothing seems to have been published except brief statements in an annual report of the Naval Observatory. Prof. Newcomb, as secretary of the commission, was charged with the duty of reducing the observations and of preparing them for the press. Small appropriations for assistants in this work had been made by the Congress, but in the assignments of the reappropriations there were several slips, apparently beyond Prof. Newcomb's control. The computers were discharged for lack of funds a first time, a second time, and eventually a third time. Shortly thereafter, apparently in 1882, all of the transit of Venus papers and results were turned over to Prof. Harkness, who reported progress during a dozen succeeding years. Prof. Newcomb has recorded the opinion that the work is "in that condition known in household language as 'all done but finishing.' Whether it will ever appear is a question for the future." It is probable that all the men who ever had any responsibility for, or serious knowledge of, the subject have passed away. In one sense, the lack of definite published results is exceedingly unfortunate. In another sense, their non-appearance may not be a serious matter, inasmuch as the transit of Venus method of determining the quantity sought has been superseded by incomparably better methods.

Prof. Newcomb rendered exceedingly valuable service in connection with several of the world's great telescopes. His relations to the Lick Observatory were particularly interesting. Shortly after James Lick had provided for the construction of a telescope "superior to and more powerful than any telescope ever yet made," the president of Mr. Lick's first board of trustees, Mr. D. O. Mills, visited Washington (in the summer of 1874) to confer with the Government astronomers, and chiefly with Prof. Newcomb, as to the kind and size of telescope which the trustees should endeavor to secure. At Mr. Mills's request Newcomb visited the leading European telescope makers, in order to determine whether it was advisable to look beyond the firm of Alvan Clark & Sons in seeking to make a contract. His report to the trustees, bearing the date March 4, 1875, discouraged the trustees from further consideration of European opticians. It was on the occasion of Mr. Mills's first visit to Washington that Prof. Newcomb recommended strongly the advisability of selecting a director for the Lick Observatory, and suggested that Prof. Holden, then Newcomb's assistant on the 26-inch equatorial, might be well qualified. In 1876 Capt. Floyd, the president of Lick's third board of trustees, which finally built the observatory, consulted in Washington with Prof. Newcomb, and it was at the suggestion of Profs. Newcomb and Holden that Mr. Burnham went to Mount Hamilton in 1879 as an expert to test the atmospheric conditions prevailing there. However, this was after Mr. Lick had definitely selected Mount Hamilton as the site of his observatory, and after the county authorities had completed a splendid road to the summit on that condition. It was too late to change the location, but fortunately Burnham's report was enthusiastically favorable.

At Capt. Floyd's request, Profs. Newcomb and Holden suggested plans for the positions and the principal features of the main buildings of the Lick Observatory, and these plans were followed in a general way. Newcomb and Floyd inspected the mounting for the 36-inch Lick refractor in the shops of the builders, Warner & Swasey, Cleveland, Ohio, in 1887. Newcomb continued to take a lively interest in the Lick Observatory and its work to the end of his life.

It is not impossible that the successful construction of the 26-inch Washington telescope was responsible for James Lick's idea and decision to provide for the construction of a larger telescope. Extensive descriptions of the Washington instrument were published in the leading American newspapers at the time of its completion, and an associate of James Lick has told me that he saw scattered about Lick's living room the copies of a large number of American newspapers which contained these descriptions.

When Otto Struve, director of the great Russian observatory at Poulkovo, informed Prof. Newcomb in 1878 that he was arranging with his Government for a grant of money to construct a great refracting telescope, Newcomb called his attention to the ability and success of Alvan Clark & Sons in making large object glasses. Struve's efforts to obtain a suitable object glass from European opticians were fruitless, and he came to the United States in 1879 to make a contract with the Clarks. Prof. Newcomb, as a friend of both parties, took a prominent part in the negotiations. It was chiefly in appreciation of these services that the Czar of Russia, in 1889, presented to Prof. Newcomb a rare vase of jaspar bearing the inscription: "A Monsieur le Professeur Simon Newcomb de la part de l'Observatoire Central Nicolas de Poulkovo 7/19 Août, 1889."

The lunar investigations and tables by Hansen, to which we have referred, published by the British Government in 1857, were based on a few of the Greenwich observations of the moon made between 1750 and 1850. Observations prior to 1750, so far as they seemed to be available, were thought to be too inexact for the purpose. Newcomb considered it very probable that many unpublished observations of occultations of bright stars by the moon prior to 1750 were recorded in astronomers' notebooks on file in the European observatories.

A few occultations, published in the Memoirs of the French Academy and in the Philosophical Transactions, made between the years 1660 and 1700, showed that Hansen's tables, carried back to that period, were much in error, and the importance of making a search for unpublished observations was evident. The solar eclipse of December, 1870, took Newcomb to Gibraltar, and, as soon as the siege of Paris was raised he instituted an exhaustive search for unpublished occultations amongst the records of the Paris Observatory, with results beyond his liveliest expectations. The observations that he wanted had been made in great numbers both at the Paris Observatory and at other points in the city of Paris. The work of copying the observational data, and of familiarizing himself with the methods of the astronomers in making them, consumed six weeks. Newcomb estimates the value of these observations thus: "The material I carried away proved the greatest find I ever made. Three or four years were spent in making all the calculations * * *. Seventy-five years were added, at a single step, to the period during which the history of the moon's motion could be written. Previously this history was supposed to commence with the observations of Bradley, at Greenwich, about 1750; now it was extended back to 1675, and with a less degree of accuracy 30 years further still. Hansen's tables were found to deviate from the truth, in 1675 and subsequent years, to a surprising extent. * * * During the time I was doing this work, Paris was under the reign of the Commune and besieged by the national forces. The studies had to be made within hearing of the besieging guns." The results of the investigations were published[5] by Newcomb in 1878

President Eliot, of Harvard College, offered the directorship of the Harvard College Observatory to Prof. Newcomb in 1875. After due consideration the offer was declined, because, in his opinion, he was better fitted to conduct the work already started in Washington than to direct an observing institution; and there was the further factor that the position of superintendent of the American Ephemeris and the Nautical Almanac would become vacant automatically in two years, and here, as Newcomb expressed it, "would be an unequaled opportunity for carrying on the work in mathematical astronomy I had most at heart." Newcomb has further commented that "no one who knows what the Cambridge Observatory has become under Prof. Pickering can feel that Harvard has any cause to regret my decision."

In due time Prof. Newcomb was appointed Superintendent of the Nautical Almanac. He assumed this duty on September 15, 1877. "The change was one of the happiest of my life. I was now in a position of recognized responsibility, * * * where I could make plans with the assurance of being able to carry them out * * *. The program of work which I mapped out, involved, as one branch of it, a discussion of all the observations of value on the positions of the sun, moon, and planets, and incidentally on the bright fixed stars, made at the leading observatories of the world since 1750. One might almost say it involved repeating, in a space of 10 or 15 years, an important part of the world's work in astronomy for more than a century past. Of course, this was impossible to carry out in all its completeness. In most cases what I was obliged practically to confine myself to was a correction of the reductions already made and published. Still, the job was one with which I do not think any astronomical one ever before attempted by a single person could compare in extent. The number of meridian observations on the sun, Mercury, Venus, and Mars alone numbered 62,030. They were made at the observatories of Greenwich, Paris, Konigsberg, Poulkovo, Cape of Good Hope, but I need not go over the entire list, which numbers 13. The other branches of the work were such as I have already described—the computation of the formulae for the perturbation of the various planets by each other." A fuller and splendid statement of the nature of the great problem, a report of progress made to date, and an outline of plans ahead, were published by Newcomb in September, 1882, in Astronomical Papers of the American Ephemeris and Nautical Almanac, 1, VII–XIV, 1882.

Such enormous tasks could not, of course, be performed by any individual unaided. In the introduction to the volume just referred to Newcomb wrote: "Both Congress and the Navy Department have supplied all the assistance which has been asked for, and a force of from eight to ten computers, some of the highest order of mathematical ability, has been actively employed during the past year, and may, if necessary, be increased in the future." In his

[5] *Researches on the Motion of the Moon. Part I: Reduction and Discussion of Observations of the Moon before 1750. Washington Observations for 1875*, Appendix II, pp. 1-280. 1878.

reminiscences he has written generously of his chief assistants in the work of the Almanac office, and space should be taken for a few quotations:

Perhaps the most eminent and interesting man associated with me during this period was Mr. George W. Hill, who will easily rank as the greatest master of mathematical astronomy during the last quarter of the nineteenth century. * * * The part assigned to Hill was about the most difficult in the whole work—the theory of Jupiter and Saturn Owing to the great mass of these "giant planets," the inequalities of their motion, especially in the case of Saturn, affected by the attraction of Jupiter, are greater than in the case of the other planets. Leverrier failed to attain the necessary exactness in his investigation of their motion.

Hill had done some work on the subject at his home in Nyack Turnpike before I took charge of the office. He now moved to Washington, and seriously began the complicated numerical calculations which his task involved. I urged that he should accept the assistance of less skilled computers; but he declined it from a desire to do the entire work himself. Computers to make the duplicate computations necessary to guard against accidental numerical errors on his part were all that he required. He labored almost incessantly for about 10 years, when he handed in the manuscript of what now forms Volume IV [6] of the Astronomical Papers. * * * And here was perhaps the greatest living master in the highest and most difficult field of astronomy, winning world-wide recognition for his country in the science, and receiving the salary of a department clerk. I never wrestled harder with a superior than I did with Hon. R. W. Thompson, Secretary of the Navy, about 1880, to induce him to raise Mr. Hill's salary from $1,200 to $1,400. It goes without saying that Hill took even less interest in the matter than I did. He did not work for pay, but for the love of science. * * * That I could not secure for him at least the highest official consideration is among the regretful memories of my official life.

Of John Meier he says:

He was the most perfect example of a mathematical machine that I ever had at command.

Of Cleveland Keith:

A man of totally different blood, the best in fact, entered the office shortly before Meier broke down. This was Mr. Cleveland Keith, son of Prof. Reuel Keith, who was one of the professors at the observatory when it was started. His patience and ability led to his gradually taking the place of a foreman in supervising the work pertaining to the reduction of the observations, and the construction of the tables of the planets. Without his help, I fear, I should never have brought the tables to a conclusion.

In 1894 I had succeeded in bringing so much of the work as pertained to the reduction of the observations and the determination of the elements of the planets to a conclusion. So far as the larger planets were concerned, it only remained to construct the necessary tables, which, however, would be a work of several years.

The program was now interrupted by new duties assumed in connection with placing the nautical almanacs of the different nations upon a homogeneous basis, in accordance with plans and decisions made by the heads of the various almanac offices, at a conference in Paris in May, 1896. It later transpired that some of the leading American astronomers were unwilling to approve, adopt, and abide by these decisions, and the full fruits of the plan were not realized in the American Ephemeris. The subject was further complicated by the automatic retirement of Prof. Newcomb on completing his sixty-second year, March 12, 1897. It became a serious question whether he would be able to finish the international program, and also the planetary tables, after his successor should have assumed the duties of the Almanac office. An arrangement was eventually effected under which computers, provided for by a small congressional appropriation, "were not to be prohibited from consulting me in its prosecution."

Speaking of the Nautical Almanac office, Prof. Newcomb has written:

In conducting my office also, the utmost economy was always studied. The increase in the annual appropriations for which I asked was so small that, when I left the office in 1897, they were just about the same as they were back in the fifties, when it was first established. The necessary funds were saved by economical administration. All this was done with a feeling that, after my retirement, the satisfaction with which one could look back on such a policy would be enhanced by a feeling on the part of the representatives of the public that the work I had done must be worthy of having some pains taken to secure its continuance in the same spirit. * * * The work which I most regretted to leave unfinished was that on the motion of the moon. As I have already said, this work is (in 1903) complete to 1750. The computations for carrying it on from 1750 to the present time were perhaps three-fourths done when I had to lay them aside. In 1902, when the Carnegie Institution was organized, it made a grant for supplying me with the computing assistance and other facilities necessary for the work, and the Secretary of the Navy allowed me the use of the old computations. Under such auspices the work was recommenced in March, 1903.

It is a matter for universal congratulation that Prof. Newcomb was able to complete the work of his great program on the motion of the moon, under the patronage of the Carnegie Institution of Washington, and to prepare the results for publication, less than a month before

[6] A New Theory of Jupiter and Saturn, by G. W. Hill.

his death. The monograph containing the results, published in 1913 as Volume IX, Part I, pages 1–249, Astronomical Papers of the American Ephemeris and Nautical Almanac, is entitled Researches on the Motion of the Moon, Part II. Part I had been published in 1878. Newcomb's final views concerning the lunar problems are summarized in his paper dated 1908, December 11, entitled Fluctuations in the Moon's Mean Motion, in *Monthly Notices R. A. S., 69*, 164–169, 1909, from which we quote:

With the aid of my assistant, Dr. Frank E. Ross, I have brought to a completion a study of the moon's mean motion based on observations having an extreme range in time of about 2,600 years. The data of observation are as follows:

1. The eclipses of the moon found in Ptolemy's Almagest, observed between B. C. 720 and A. D. 134.
2. Observations of eclipses by the Arabian astronomers, extending from 829 to 1004.
3. Observations of eclipses of the sun and of occultations of stars by the moon made by Gassendi, Hevelius, and others, from 1620 to 1680.
4. Observations of occultations of stars from 1670 until the present time.

The observations previous to 1750 were all worked up in my Researches on the Motion of the Moon, published in 1878. I have, however, subjected the results to a careful revision, and grouped them in a slightly different way from the former one. From and after 1680 the observations are of a fair degree of precision, but there are frequent gaps during the last half of the eighteenth century. The observations are fairly continuous since 1820.

Taken in connection with the recent exhaustive researches of Brown, which seem to be complete in determining with precision the action of every known mass of matter upon the moon, the present study seems to prove beyond serious doubt the actuality of the large unexplained fluctuations in the moon's mean motion to which I have called attention at various times during the past 40 years. * * *

The feature of most interest is the great fluctuation with a period of between 250 and 300 years. I call this a fluctuation rather than an inequality because, in the absence of any physical cause for its continuance, there is no reason to suppose that it will continue in the future in accordance with the law followed in the past. * * *

I regard these fluctuations as the most enigmatical phenomenon presented by the celestial motions, being so difficult to account for by the action of any known causes, that we can not but suspect them to arise from some action in nature hitherto unknown. * * *

One general result of the present state of things is that we can not draw any precise conclusions from a discussion of the moon's motion in longitude, how refined soever we make it. For example, it is impossible to derive from observation the accurate coefficient of the 18.6-year nodal inequality in longitude, owing to the varying fluctuation.

It is also not possible to predict the future motion of the moon with precision. If we require our ephemerides of the moon's longitudes to be as exact as possible, we must correct the tabular mean longitude from time to time by observations.

It is not possible to give here an adequate impression of the immense labor involved in carrying to completion the programs of lunar and planetary investigations referred to in the preceding pages. In fact, a correct impression can not be gained even at the price of a careful perusal of the voluminous papers describing the results unless the reader himself has dipped into the complexities of gravitational astronomy and has had extensive experience in making astronomical calculations. It means relatively little to say that the work was of herculean and monumental proportions. Some of the investigations are described in the publications of the United States Naval Observatory, in the various astronomical journals, and in special mediums; but the theory and tables of the planetary and lunar motions are contained chiefly in the Astronomical Papers Prepared for the Use of the American Ephemeris and Nautical Almanac, of which eight and one-half large quarto volumes exist. These papers rank amongst the priceless treasures of astronomical literature.

G. W. Hill's theory of the motions of Jupiter and Saturn fills Volume IV, his tables for computing the motions of these planets occupy the first half of Volume VII, and three extensive papers by the same author are in other volumes of the series. Excepting, further, one paper by Safford and two papers by Michelson (on the velocity of light), the remainder of the series is made up of 25 extensive monographs by Newcomb. They treat of solar eclipses; of transits of Mercury and Venus; of a determination of the velocity of light; of the theories of the motions of Mercury, Venus, Earth, Mars, Uranus, and Neptune; of the constants of the orbits of these planets, and tables to assist in computing their future positions; of the mass of Jupiter; of the precession and nutation constants; of the development of the perturbative function; of the motion of the moon, etc. Included also are Newcomb's Catalog of 1098 Standard Stars (their definitive positions and proper motion), prepared to meet his own needs in reducing the already existing observations of the planets and the moon to a homogeneous system, and Newcomb's Catalogue of (1596) Fundamental Stars, reduced to an absolute system, to meet the needs of the almanacs of the different nations.

The need of a more accurate determination of the velocity of light was pointed out by Newcomb in 1867. He brought the subject before the National Academy in 1878, and in response to the academy's favorable report the Congress appropriated $5,000 to defray the expense of the determination. The problem was assigned to Newcomb. He employed Foucault's method, with improvements and refinements. His principal observing stations were at the foot of the Washington Monument and at Fort Myer across the Potomac River. The distance between the mirrors at the two stations was 3,721.21 meters. The observations were conducted in the years 1880–1882, and they led to a concluded velocity of light in vacuo of 299,860 ±30 kilometers per second. Michelson's value, determined at Cleveland in 1882, was 299,853 kilometers per second. The percentage of error in these values is thought to be very small. Newcomb's value of the velocity, combined with Nyren's value of the constant of aberration, 0.″492, led to a corresponding value of 8.″794 for the solar parallax. Unfortunately the many values assigned to the aberration constant by the various investigators differ, for reasons as yet unexplained for the most part, and the related values for the solar parallax are correspondingly uncertain.

A condensed résumé of the investigations of the motions of Mercury, Venus, Earth and Mars, of the masses of these planets, of the constants of precession and nutation, of the solar parallax, of the mass of the moon, etc., was published in 1895 as a supplement to the American Ephemeris, under the title of The Elements of the Four Inner Planets and the Fundamental Constants of Astronomy. This useful volume contains also Newcomb's attempt to account for the outstanding discrepancies[a] of the motions of Mercury, Venus, the Earth and Mars, of which by far the most noteworthy is that concerning the perihelion of Mercury's orbit. He discusses the principal variations that would be produced in the motions of the planets by modifications in, or additions to, the forces normally considered, from the following sources:

1. An assumed nonsphericity of the sun.
2. An assumed intramercurial ring or group of planetoids.
3. The mass of the diffused matter which reflects the zodiacal light.
4. An assumed ring of planetoids between the orbits of Mercury and Venus.
5. A minute deviation of the law of gravitation from the exact inverse squares of the distances.

He concludes, in effect, that all of these assumptions are untenable.

What we may call Newcomb's minor contributions to astronomical knowledge were numerous. We take space to describe a few of them.

Euler's investigation of the motions of the earth had led to the result that if the axis of rotation does not coincide with the axis of the earth's spheroidal figure there must be a minute variation of terrestrial latitudes in a period of 10 months. Several able astronomers searched unsuccessfully for evidence of such a variation in existing observations. Küstner's observations at the Berlin Observatory in the eighties pointed unmistakably to a latitude variation. This led Chandler to institute an exhaustive study of the Greenwich and other observations, which established the existence of minute latitude variations with a principal period of about 14 months. Newcomb retraced Euler's steps, and confirmed his conclusion that an absolutely rigid and nondeformable earth would call for a period of 10 months, but deduced the new result that if the body of the earth were, on the average, only as rigid as steel, then Euler's period would be lengthened to 14 months, and thus be brought into close agreement with observation. Newcomb's investigation supplied, in fact, our first reliable determination of the earth's rigidity and his result has been substantially confirmed by the work of several observers on the tidal deformations of the solid earth and by the extensive series of observations on the transmission of earthquake waves through the earth's deep interior.

[a] At the date of writing this biographical memoir (February, 1916) de Sitter's papers applying Einstein's theory of relativity to this problem had not yet been published. W. W. C.

The published descriptions of the zodiacal light had referred to it as an illumination, lenticular in form, extending east and west from the sun, but said little or nothing concerning the radius of the illumination in the north and south direction. It occurred to Newcomb that the latter constant could be determined by direct observation from a moderately high mountain summit correctly situated as to latitude and possessing transparent sky and unobstructed northern horizon. In the Northern Hemisphere the observations could best be made from points whose latitudes were such that the midnight sun would be only a little more than 18 degrees below the north point of the horizon, as this would eliminate the twilight effect and let the zodiacal illumination extend to its highest practicable altitude. Newcomb endeavored to make these observations from points in the White Mountains in several summers, but failed on account of imperfect atmospheric conditions. On a later trip to Switzerland he ascended the Brienzer Rothorn, altitude 7,700 feet, latitude 47°, with these observations in mind, and he was successful, on the nights of July 26 and 29, 1905. The zodiacal light arch was well seen and unmistakable, and it extended 35° north from the sun. A few years later these observations were repeated and Newcomb's results substantially confirmed by Fath at Mount Hamilton.

Newcomb's great program concerned the solar system, but his interests and contributions extended also to the stellar system. In 1902 he published an important volume on The Stars—A Study of the Universe. Its 20 chapters treat of such subjects as the proper motions of the stars, the parallaxes of the stars, double, triple and multiple star systems, the apparent distribution of the stars in the sky, the distribution of the stars in space, the structure of the Milky Way, the extent of the universe, etc.

Prof. Newcomb found time to write several admirable textbooks on astronomy. His Popular Astronomy, a comprehensive treatise of the fundamental principles of astronomy, issued in 1878, has perhaps never been equaled in merit by any other book aiming to cover approximately the same ground. Notwithstanding the tremendous advances of the past 40 years in astronomical science, the original edition remains a book which all students of astronomy could read with profit and pleasure. It has passed through several editions in this country and it has been translated into half a dozen foreign languages.

An excellent Astronomy for High Schools and Colleges, written by Profs. Newcomb and Holden, passed through several editions. The larger work was abridged for the use of schools.

Newcomb published a volume on Astronomy for Everybody, a Popular Exposition of the Wonders of the Heavens, in 1907, which was very successful. It has been translated into many languages. His Side-Lights on Astronomy and Kindred Fields of Popular Science, which appeared in 1906, reproduces 21 of his principal essays and addresses. His volume, A Compendium of Spherical Astronomy, published in 1906, treats admirably of the subjects which relate to the determination and the reduction of the accurate positions of the stars—precession, nutation, aberration, proper motion, parallax, refraction, systematic errors of star catalogues, etc.

Newcomb possessed the power of writing for the intelligent public. Dozens of his articles on subjects of timely interest, admirably conceived and composed, appeared in Harper's Magazine, The Atlantic Monthly, McClure's Magazine, Popular Science Monthly, etc. He contributed frequently to The Nation, The New York Tribune, The Independent, The Youth's Companion, etc. Short articles and notes from his pen are numerous in Science. He wrote many of the articles on astronomical subjects in the leading encyclopaedias. He made notable addresses on occasions of great astronomical interest, such as the dedication of the Flower Observatory of the University of Pennsylvania, the Yerkes Observatory of the University of Chicago, and the Observatory of Syracuse University.

Newcomb's interest in the progress of mathematics was strong throughout his life. While an assistant on the Nautical Almanac at Cambridge he contributed frequently, especially on the theory and practice of probabilities, to Runkle's Mathematical Monthly during the three years of its existence. He and W. P. C. Bartlett and T. H. Safford were the committee, appointed by the editors, to judge of the solutions offered for problems set by the Monthly, and to award prizes.

An extensive, and what we might call a complete, series of mathematical textbooks for high school and college was written by Newcomb and issued by Henry Holt & Co. in the years 1881–1887. The series included algebras for schools and for colleges, the elements of geometry, the elements of plane and spherical trigonometry, logarithmic and trigonometric tables, the elements of analytics, and the elements of differential and integral calculus. The several editions and reprints through which the books passed are perhaps the best evidence of their success and value.

Prof. Newcomb was appointed professor of mathematics and astronomy in Johns Hopkins University in 1884. He lectured and conducted seminars on astronomy on two days per week until the requirements of the Government service made his resignation necessary, at the end of the year 1893. He was reappointed to the position in 1898 and retained it until 1900, but his duties during this later period were apparently advisory to the students of mathematics and astronomy, as he seems not to have conducted formal courses in these subjects. He was editor of The American Journal of Mathematics, published under the auspices of Johns Hopkins University, during the years 1885–1893 and 1899–1900, and a coeditor in the years 1878–79, 1894–1898 and from 1901 until his death. He was one of the first, and perhaps the first, to receive appointment as lecturer in Johns Hopkins University, in its opening year, 1876. In many of the early years of the university he served as an examiner in mathematics and economics.

That Newcomb's services to Johns Hopkins University were highly valued by the authorities of the institution is clear from the honors conferred upon him. In 1897 he was requested by the faculty and friends of the university to sit for a portrait, to be presented to the university. In 1900 the president of the university wrote, "with grateful recognition of the valued counsel you have given to this university since its organization, the academic council has unanimously recommended to the trustees that you be appointed emeritus professor of mathematics, and the board of trustees with like unanimity approve this recommendation." On February 22, 1901, the Sylvester prize of Johns Hopkins University, a handsome bronze medallion of the late Prof. Sylvester, was awarded in duplicate, the first copy to Lord Kelvin, and the second copy to Prof. Newcomb, "in recognition of his distinction and his service." In February, 1902, at the celebration of the twenty-fifth anniversary of the founding of Johns Hopkins University, the degree of doctor of laws was conferred upon Newcomb "in recognition of his preeminent attainments and important discoveries in science."

Prof. Newcomb was elected president of the American Mathematical Society for two successive terms, serving during the years 1897 and 1898. At the close of the first term he delivered a presidential address on "The Philosophy of Hyperspace."

Prof. Newcomb's contributions to the domain of pure mathematics were limited, necessarily, and the subjects which received his attention were chiefly those which are related more or less intimately to celestial mechanics and probabilities. There could be no question, however, of a great underlying mathematical ability. Prof. Cayley, the eminent mathematician, on presenting the gold medal of the Royal Astronomical Society to Prof. Newcomb in 1874, spoke of a memoir by Newcomb on the Théorie des perturbations de la Lune qui sont dues à l'action des planètes,[7] thus: "The memoir is, from the boldness of the conception and beauty of the result, a very remarkable one, and constitutes an important addition to theoretical dynamics."

In 1895 Newcomb was awarded the Astronomical Journal prize of $400 "For the most thorough discussion of the theory of the rotation of the earth, with reference to the recently discovered variation of latitude."

In 1902 Newcomb was the delegate from the National Academy to the celebration of the centenary of the birth of Abel, in the University of Christiania. The degree of doctor of mathematics was conferred upon him on that occasion. He was one of the vice presidents of the Fourth International Congress of Mathematicians held in Rome in 1908, and one of the nine principal speakers. His interest in the trend of modern mathematical thought and in the improvements of ways and means for teaching mathematics was always keen.

[7] Liouville's Journal, 16, 321-368, 1871.

One of the books which received Newcomb's attention in his school-teaching days was Say's Political Economy, of which he has written: "It was quite a delight to see human affairs treated by scientific methods." His interest in economic questions seems never to have flagged. His writings on the subject are numerous, and many of them have been accorded high rank by leading economists. They inclnde several volumes and a great many magazine articles on timely subjects. In 1865 appeared his first contribution, a volume of 220 pages, entitled A Critical Examination of our Financial Policy during the Southern Rebellion. The A, B, C of Finance, issued in Harper's Half Hour Series, 115 pages, bears the date 1877. His Principles of Political Economy, an extensive treatise of 548 pages, was published in 1885. A Plain Man's Talk on the Labor Question, 195 pages, came out in 1886. His contributions to the North American Review began in 1866 with a thoughtful article on Our Financial Future; and later articles considered such subjects as the let-alone principle in economics, national debts, the standard of value, the principles of taxation, science and government, our antiquated method of electing a President, etc. Other leading journals contain articles on life insurance, the silver question, the organization of labor, schools of political economy, etc. Newcomb was a lecturer on political economy in Harvard College in 1879–80. He was elected president of the Political Economy Club of America in 1887. The first prize, $150, of two "citizenship prizes" offered by the Anthropological Society of Washington, was awarded to Newcomb in 1894 for his essay on The Elements Which Make Up the Most Useful Citizen of the United States. The indications are that if Newcomb had chosen economics for his chief field of endeavor he would have been in the front rank of modern economists.

There were many sides and angles to Newcomb's interests. He was the first president of the American Society for Psychical Research, in 1885–86. His position was not at all that of a believer or devotee, but rather that of the interested observer who wanted to know the truth. His experiences with the American society were apparently in harmony with his opinion of the work of the parent English society: "I could not feel any assurance that the (English) society, with all its diligence, had done more than add to the mass of mistakes, misapprehensions of facts, exaggerations, illusions, tricks, and coincidences, of which human experience is full."

Newcomb wrote instructively for the public on a great variety of subjects: The Mariner's Compass; Can We Make It Rain? The Outlook for the Flying Machine; The Fairyland of Geometry; Why We Need a National University; On Conditions Which Discourage Scientific Work in America; Law and Design in Nature; Evolution and Theology; Science and Immortality; etc. He was inclined to be skeptical as to a practical development of "heavier-than-air" flying machines. He called attention to the fundamental fact that an increase in the dimensions of airplanes would increase the dead weight as the cube, whereas the lifting power would increase only as the square, of the dimensions. Success in developing larger and larger airplanes would demand increasing driving power, other factors being equal, and he did not foresee the recent high development of internal-combustion engines which now fulfill this requirement.

Newcomb also found time to write fiction. He is the author of short stories on The Wreck of the Columbia, and on The End of the World, and of a volume entitled His Wisdom the Defender—a Story, in which airships resembling the Zeppelin type are successfully employed. Newcomb's skepticism as to the airplane did not extend to air vessels involving the balloon principle, in which the lifting power increases as the cube of the dimensions and the resistance increases only as the square. In His Wisdom the Defender, Newcomb makes the hero dominate the earth by means of machines which fly at great heights above the earth and at great speeds, and use his power to disarm the standing armies and navies of the nations. "The greatest day in the history of the world, if I can bring it about, will be that when war shall have ceased forever, armies and navies exist no longer, and universal peace reign over all the nations."

The commanding position in astronomical science attained by Prof. Newcomb is accurately indicated by the long list of honors conferred upon him. In the number and the character of the learned societies in which he held honorary memberships, and in the number of honorary degrees conferred upon him, Newcomb stood alone in America, and in a very small company in the world. He was elected to membership in societies, not including many minor and local societies,[8] as below:

1859: Member American Association for the Advancement of Science. He was made a Fellow in 1874, and was elected president of the American association in 1876. He delivered the presidential address in 1878.

1860: Fellow American Academy of Arts and Sciences.

1869: Member National Academy of Sciences. He was vice president of the academy in 1883–1889, home secretary in 1881–1883, and foreign secretary from 1903 until his death.

1870: Associate Fellow American Academy of Arts and Sciences.

1871: Member Philosophical Society of Washington. He was president of the society for the years 1879, 1880, and 1909.

1872: Foreign Associate Royal Astronomical Society of London.

1873: Member Astronomische Gesellschaft. He was elected a member of the council of the Gesellschaft in 1887.

1874: Corresponding member Paris Academy of Sciences.

1875: Foreign Associate Royal Academy of Sciences, Stockholm.

1875: Corresponding member Imperial Academy of Sciences, Petrograd.

1876: Corresponding member Royal Academy of Sciences, Munich.

1877: Foreign Associate Royal Scientific Society of Upsala, Sweden.

1877: Foreign member Royal Society of London.

1878: Member American Philosophical Society, Philadelphia.

1878: Foreign member Holland Society of Sciences, Haarlem.

1878: Honorary member Cambridge Philosophical Society, England.

1881: Honorary Foreign Fellow Royal Society of Edinburgh.

1881: Foreign member Royal Physiographical Society, Lund, Sweden.

1882: Honorary member Royal Irish Academy, Dublin.

1883: Corresponding member Royal Academy of Sciences, Berlin.

1884: Corresponding member British Association for the Advancement of Science. He was one of the vice presidents of the association in 1904.

1886: Honorary member London Mathematical Association.

1886: Associate Liverpool Astronomical Society.

1887: Honorary member Manchester Literary and Philosophical Society.

1888: Foreign correspondent Royal Society of Sciences, Gottingen.

1891: Honorary member New York Academy of Sciences.

1891: Honorary member Royal Institution of Great Britain.

1891: Honorary Fellow Royal Astronomical Society of Canada.

1891: Foreign Associate Royal Academy of Science, Brussels.

1895: Foreign Associate Institute of France.

1895: Foreign Associate Royal Academy of the Lincei, Rome.

1896: Honorary member Imperial Academy of Sciences, Petrograd.

1896: Officer of the Legion of Honor, France.

1897: Corresponding member Imperial Geographical Society, Petrograd.

1897: Foreign Associate Italian Society of Science, Rome.

1897: Honorary member Royal Society of Arts, London.

1898: Foreign Associate Royal Institute of Science, Letters and Arts, Venice.

1898: Honorary member Royal Academy of Sciences, Amsterdam.

1899: Corresponding member Royal Institute of Science and Letters, Milan.

1899: Foreign correspondent Bureau of Longitudes, Paris.

1901: Honorary member Russian Astronomical Society.

1901: Honorary member Royal Society of New South Wales, Sydney.

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[8] For references to Newcomb's membership in many minor societies and academies I am indebted to Prof. R. C. Archibald's list published in *Tran. Roy. Soc., Canada*, sec. 3, for 1905, p. 79, and to his manuscript extending the list from 1905 to 1909 kindly lent me. (Archibald's list was later published in *Science*, **44**, 871–878, Dec. 22, 1916.)

1902: Honorary member Astronomical Society of Mexico.
1904: Corresponding member Royal Academy of Science, Vienna.
1905: Corresponding member Royal Academy of Science, Turin.
1905: Corresponding member National Institute of Geneva, Switzerland.
1905: Knight of the Order Pour le Mérite for Sciences and Arts, Prussia.
1906: Honorary member Royal Academy of Sciences, Letters and Arts, Padua.
1907: Commander of the Legion of Honor, France.
1907: Honorary Fellow Physical Society, London.
1907: Foreign member Society of Sciences, Christiania.
1907: Foreign member Royal Society of Sciences, Gottingen.

Honorary degrees were conferred upon Prof. Newcomb as follows:

1874: LL. D., Columbian University (now George Washington University), Washington, D. C.

1875: Master of Mathematics and Doctor of Natural Philosophy, University of Leyden, on the third centenary of its founding.

1875: LL. D., Yale College.
1884: LL. D., Harvard College.
1886: Ph. D., University of Heidelberg, on the fifth centenary of its founding.
1887: LL. D., Columbia College, N. Y.
1891: LL. D., Edinburgh University.
1892: Sc. D., Dublin University, on the third centenary of its founding.

1892: Ph. Nat. D., University of Padua on the third centenary of the appointment of Galileo as a professor in the university.

1896: LL. D., Glasgow University.
1896: Sc. D., Cambridge University.
1896: LL. D., Princeton University, on the sesqui-centenary of its founding.
1899: D. C. L., Oxford University.
1900: LL. D., University of Cracow, on the fifth centenary of its founding.
1902: LL. D., Johns Hopkins University, on the twenty-fifth anniversary of its founding.
1902: Math. D., University of Christiania, on the first centenary of the birth of Abel.
1904: LL. D., University of Toronto.

Prof. Newcomb was awarded the following prizes and medals:

1874: The gold medal of the Royal Astronomical Society for his "researches on the orbits of Neptune and Uranus and for his other contributions to mathematical astronomy."

1878: The Huyghens gold medal of the Holland Society of Science, Haarlem, awarded biennially "to the individual who, by his researches and discoveries or inventions during the previous 20 years, had, in the judgment of the society, distinguished himself in an exceptional manner in a particular branch of science."

1890: The Copley medal of the Royal Society for contributions to gravitational astronomy.

1894: The first prize, $150, of two citizenship prizes of the Anthropological Society of Washington, for his essay on "The elements which make up the most useful citizen of the United States."

1895: The Astronomical Journal prize of $400, "For the most thorough discussion of the theory of the rotation of the earth, with reference to the recent discovery of the variation of latitude."

1897: The Schubert prize (900 roubles) of the Imperial Academy of Sciences, Petrograd, for notable advances made in mathematical astronomy.

1897: The Bruce gold medal of the Astronomical Society of the Pacific, in recognition of his services to astronomy—the first award of the medal.

1901: The Sylvester prize of Johns Hopkins University, a bronze medallion of Prof. Sylvester, "In recognition of his distinction and his service."

Many items of services rendered or honors received, additional to or in amplification of foregoing references, should be mentioned.

Newcomb was a member of the National Academy committee to arrange the program of observations for the total solar eclipse of May, 1883. He was one of the academy's three delegates to the Wiesbaden Conference of 1899 which led to the organization of the International Association of Academies. He was the academy's delegate to the meeting of the Council of the International Association of Academies held in London in 1903. He was a member of the academy committee on weights, measures, and coinage. He was a member of the academy committee which the Government authorities had requested to consider a report "upon the surveys of a scientific character made under the auspices of the War and Interior Departments and the Land Office." He was chairman of the academy advisory committee on meteorology, appointed in 1881. He was a member of the academy committee, appointed in 1886, to consider and report on the work of the scientific bureaus of the Government, with the view of securing greater efficiency and economy of administration. He was a member of the academy committee, in 1884, to assist the customs department in arriving at the correct interpretation of the expression, "philosophical and scientific apparatus, instruments, and preparations."

Newcomb was one of the three members of the National Academy named in the will of Prof. J. C. Watson to administer, with the academy's approval, the income of the Watson Fund, in which service he was active from 1881 until his death. He was chairman of the board of trustees of the Watson Fund from 1887 to 1909. In this interval the Watson Fund supported various minor researches and financed the laborious and highly skilled investigations on the motions of the Watson asteroids made by Prof. Leuschner; and the Watson gold medal of the academy was awarded to B. A. Gould (1887), Edward Schönfeld (1889), Arthur Auwers (1891), S. C. Chandler (1894), and Sir David Gill (1899).[9] This list of medalists is conspicuous by the absence of Newcomb's name; a regrettable omission, presumably due to the fact that he was chairman of the board of trustees, which governed the making of the awards.

Newcomb was president of the American Association for the Advancement of Science, in 1877. He was the first president of the Astronomical and Astrophysical Society of America (now the American Astronomical Society), founded in 1899, and was reelected president annually until 1905, when he requested and insisted on relief from the duty. He was president of the International Congress of Arts and Science at the Universal Exposition, held at St. Louis in 1904, where he delivered the introductory address, at the opening session, on The Evolution of the Scientific Investigator. His influence was potent in the selection of the great number of speakers from this and other countries who were invited to address the St. Louis congress, and he made a special trip to Europe in 1893 to secure the coöperation of the leading European men of science. He was elected a member of the board of overseers of Harvard University for the period 1906–1912. His portrait was painted in 1887, in compliance with the request of the Czar of Russia, for placing in the gallery of famous astronomers, in the Poulkovo Observatory. The University of Tokyo, in 1888, presented him with a pair of bronze vases of great beauty and value. He was elected one of the eight foreign associates of the Paris Academy of Sciences in 1895, to succeed von Helmholtz, Benjamin Franklin having been the only other native American to hold this appointment. He was a member of the first advisory committee on astronomy in the Carnegie Institution, in 1902–3, and thereafter a research associate in the institution. Grants of money in support of his researches on the moon were made each year by the institution. Newcomb was the first to receive the Bruce gold medal of the Astronomical Society of the Pacific, in 1897. The rules of award make this medal international in character; the directors of six observatories, Berlin,* Greenwich, Harvard, Lick, Paris, and Yerkes, nominate a limited number of astronomers worthy to receive the medal, and the directors of the society must select the nominee from this list. The president of the society, in awarding the first medal, said, "One name stood forward so prominently in the nominations from the heads of six leading observatories of the world that the directors of this society could but set the seal of their approval upon the verdict of his peers and award the first Bruce medal to Prof. Simon Newcomb."

[9] Note added in 1917: The sixth award of the Watson medal was made in 1917, to A. O. Leuschner.

*Cordoba was substituted for Berlin in 1919.

On August 4, 1863, Prof. Newcomb married Miss Mary Caroline Hassler, daughter of Dr. C. A. Hassler, United States Navy, and granddaughter of Ferdinand R. Hassler, the founder and first superintendent of the United States Coast Survey. Their life was a happy one in all respects. Mrs. Newcomb was able and constant in thoughtfulness for his comfort, health, and happiness, and the remarkably strong individuality of each was thoroughly respected by the other. Mrs. Newcomb is cheered by three surviving daughters, the oldest of whom, Dr. Anita Newcomb McGee, was Acting Assistant Surgeon, United States Army, in charge of the Army Nurse Corps in the Spanish War and until 1901.

Prof. Newcomb became aware several months before his death that his days were numbered, and his remaining energies were devoted to the completion of his investigations of the motion of the moon. He died in Washington on July 11, 1909. His funeral was attended by many who were prominent in science and government, including the President of the United States and representatives of foreign governments. He was buried with military honors in the National Cemetery at Arlington, on the south side of the Potomac River, directly opposite the city of Washington. His chief monument consists of his contributions to astronomical science. An outline of his publications, prepared [10] by Prof. R. C. Archibald, is contained in the following article.

Newcomb's more striking qualities were well described, as below, by the late William Alvord, president of the Astronomical Society of the Pacific, in awarding the Bruce gold medal of the society to him. Alvord was a member of James Lick's first board of trustees, and his acquaintance with Newcomb began in 1874 when the latter was first consulted by the trustees:

> The basis of Prof. Newcomb's character is intellectual and moral honesty pushed to the highest degree. He loves truth and detests shams. He has, as it were, a veritable passion for justice—whether in personal relations or in civil matters. The circumstances of his career have made him ruggedly independent in thought and speech. The excellent quality of his mind is that of a philosopher, rather than that of a mathematician or an astronomer merely. * * * In his treatment of all questions it is the philosophical habit of his mind which is the most remarkable and the most valuable. * * * With all these qualities there is a note of practicality in his methods of work which has stood him in good stead and enabled him to complete vast labors which another man scarcely less gifted might not have been able to bring to a termination. * * * It is due to this faculty that the enormous task of revising the elements of the orbits of the major planets and of tabulating them in convenient forms has been carried through to completion in a comparatively short time. * * * This gigantic task would have been above even his power had it not been for this practicality * * *.

Newcomb's work, driven by untiring energy and guided by philosophic intelligence for more than a half century, placed him at the head of his profession in America, and gave him membership in a small class of the most productive astronomers of all countries and all centuries. His influence upon the development of the science was exerted by speech and by letter as well as by published paper and volume. It was potent with beginners and assistants as well as with veterans and directors. It was applied with singleness of purpose, and solely in the interest of the science. Those who discussed astronomy with Newcomb had the impression of obtaining astronomy in the abstract, impersonal and disembodied, and on that account his scientific associates often failed to understand his personality. A survey of Newcomb's activities leads to the view that he was intellectually a giant.

What we may call Newcomb's personal interests made of him a charming friend to many people in many States and countries. He was a lover of travel. Mountain climbing in Switzerland enticed him successfully up to within a year of his death. He read history and other literature extensively. He could recite page after page of poetry. His wide and varied reading, combined with accurate memory and universal interest, made his conversation virile and enlightening. His lamented death brought a sense of severe loss to personal friends as well as to scientific colleagues.

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[10] Publication of this biographic sketch has been delayed, pending the completion of the bibliography.

SIMON NEWCOMB

1835–1909

BIBLIOGRAPHY OF HIS LIFE AND WORK

BY

RAYMOND CLARE ARCHIBALD

1924

CONTENTS.

INTRODUCTORY.

Simon Newcomb was one of the most notable scientists that America has ever produced and no other among her men of research has ever achieved such general recognition of eminence. In 1916 the writer published a paper[1] which was designed to contain a complete record of Newcomb's diplomas, medals, decorations, certificates of membership, and other honors. In the following pages an attempt is made to bring together references to sources of information concerning his life and work.

The references to sources in the case of his life are grouped under the headings: "Majora" (the more important material), "Minora" (material which though of lesser importance seemed worthy of listing), "Portraits-Published Photographs" (reproductions of 16 photographs taken at various times during 50 years), and "Portraits-Paintings" (to be found in public and private places).

As to sources regarding Simon Newcomb's work, it has been the intention to indicate all of his books, pamphlets, memoirs, reports, magazine articles, letters to newspapers or periodicals, reported addresses, etc.—in short, everything in print which he has written or spoken.[2] It has further been the endeavor to make mention of everything published in every edition and every language. For example, in the case of his Popular Astronomy, first published in New York in 1878, there are listed 15 American editions or reprints, 3 English, 7 German, 1 Norwegian, and 1 Russian. Many of the items may appear trivial from some points of view. But in the case of a man so highly honored everything he wrought has interest in indicating his sympathies, his habits of mind and methods of work, and the development of his career.

In order more clearly to indicate different lines of Simon Newcomb's activity, the titles have been rather roughly grouped under the four headings "Astronomy," "Mathematics," "Economics," and "Miscellaneous," but many titles under "Astronomy" might be classed also under "Mathematics" and "Miscellaneous," while some titles under "Mathematics" or "Miscellaneous" might come under "Astronomy" also. There are 541 titles in all.[3]

The most extensive previously published bibliography of Simon Newcomb's work was the one by the writer which appeared in the *Transactions of the Royal Society of Canada* for 1905. Some 370 titles were there listed. In the present work this list has been radically revised and amplified, and more than 160 new titles have been added. While it is known that even the resulting list is not complete, especially in connection with anonymous editorials, reviews, and notes in *The Evening Post*, *The Nation*, and *Science*, nevertheless it is believed that the approximation to completeness is a good one. Checks have been made with all the English, French, and German bibliographic works, and with the Library of Congress catalog, but there were scores of titles not to be found in any of these sources.

The authorship of a very large number of anonymous notes, reviews, and editorials was determined by consulting the editorial file of *The Nation* and the index volumes of the *Atlantic Monthly* and of the *North American Review*.

At one time it was intended to list *all* the more important reviews of Simon Newcomb's publications, but this plan was abandoned in favor of listing only those which had been noticed in connection with the main inquiry.

Occasional notes, explanatory of the titles, or containing additional information which would appear to be of interest for one reason or another, have been added to the titles.

As mathematical editor of *Science*, 1895–1903, and as associate editor or editor in chief of the *American Journal of Mathematics* between 1878 and 1909, much of Simon Newcomb's scientific work was unsigned and will never be known.

In the preparation of the material for the following pages it is the writer's duty and privilege to acknowledge the enthusiastic and able cooperation of Simon Newcomb's daughter, Dr. Anita Newcomb McGee.

Brown University, April, 1923. R. C. A.

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[1] *Science*, n. s., vol. 44 (Dec. 22, 1916): 871-878.
[2] No attempt has been made to list all articles quoted in such a periodical as *The Literary Digest*.
[3] Observation records as in *Astronomische Nachrichten*, vols. 69, 70, 71, 86, and 90, have not been listed.

ABBREVIATIONS.

Amer. Acad. Proc.	*Proceedings of the American Academy of Arts and Sciences*, Boston, Mass.
Amer. Assoc. Proc	*Proceedings of the American Association for the Advancement of Science.*
Amer. Jl. Math	*American Journal of Mathematics*, Baltimore.
Amer. Jl. Sci.	*Silliman's American Journal of Science and Arts*, New Haven, Conn.
Amer. Math. Mo	*American Mathematical Monthly.*
Astr. Jl	*Gould's Astronomical Journal*, Cambridge, Mass.
Astr. Nach.	*Astrononomische Nachrichten*, Kiel.
Astr. Papers	*Astronomical papers prepared for the use of the American Ephemeris and Nautical Almanac.*
Astrophysical Jl	*Astrophysical Journal*, Chicago, Ill.
Bull. Amer. Math. Soc.	*Bulletin of the American Mathematical Society*, New York.
Bull. N. Y. Math. Soc	*Bulletin of the New York Mathematical Society.*
Bull. Phil. Soc. Wash	*Bulletin of the Philosophical Society of Washington.*
Crelle's Jl	*Journal für die reine und angewandte Mathematik*, Berlin.
Comptes Rendus	*Comptes rendus de l'Académie des Sciences de l'Institut de France*, Paris.
Educ. Rev	*Educational Review*, New York.
Jl	*Journal.*
Mag	*Magazine.*
Math. Mo. (Runkle's)	*Mathematical Monthly*, Runkle's, Cambridge, Mass.
Mem. Amer. Acad	*Memoirs of the American Academy of Arts and Sciences.*
Mem. Nat. Acad. Sci.	*Memoirs of the National Academy of Sciences*, Washington.
Mo	*Monthly.*
Mo. Notices R. Astr. Soc	*Monthly Notices of the Royal Astronomical Society*, London.
N. Amer. Rev	*North American Review*, New York.
n. s	*new series.*
Nat. Educ. Assoc. Proc.	*Proceedings of the National Education Association.*
Phil. Mag	*Philosophical Magazine*, London.
Phil. Trans. R. Soc.	*Philosophical Transactions of the Royal Society*, London.
Pop. Astr	*Popular Astronomy*, Northfield, Minn.
Pop. Sci. Mo	*Popular Science Monthly.*
Pop. Sci. Mo. Suppl	*Popular Science Monthly, Supplement.*
Publ. Astr. and Astrophysical Soc. of America.	*Publications of the Astronomical and Astrophysical Society of America*, Ann Arbor, Mich.
Q. Jl. Econ	*Quarterly Journal of Political Economy.*
s.	*series.*
Sci. Amer. Suppl	*Scientific American Suppiement*, New York.
Sid. Mess	*Siderial Messenger*, Northfield, Minn., and Cincinnati, Ohio.
Smithsonian Contribs. Kn.	*Smithsonian Contributions to Knowledge*, Washington, D. C.
Smithsonian Misc. Coll	*Smithsonian Miscellaneous Collections*, Washington, D. C.
Sirius	*Sirius, Zeitschrift für populäre Astronomie*, Leipzig.
Vierteljahrsschrift Astr. Gesell.	*Vierteljahrsschrift der Astronomischen Gesellschaft*, Leipzig.
Wash. Obs.	*U. S. Naval Observatory, Washington Observations*, Washington, D. C.

Section I.

LIFE.

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   Forum, vol. 11 (Apr., 1891): 183–191.
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Paris, Gauthier-Villars, 1899.
References to S. Newcomb: pp. 127, 151, 208–211, 218, 220, 224, 258. Portrait facing p. 210.

68. W. DRYSDALE. Helps for ambitious boys.
New York, T. Y. Crowell Co., 1899. Portrait and note opposite p. 420.

69. Anonymous. Simon Newcomb. Geboren 12 März 1835 in Wallace (Neuschottland).
Mutter Erde, Berlin, vol. 2 (Aug., 1899): 377–378. (Portrait.)

70. L. BRENNER.
Astronomische Rundschau, Sussinpiccola, Austria, vol. 3 (no. 25, 1901): 160–161. Portrait.

71. J. H. BROWN, editor. Lamb's Biographical Dictionary of the United States.
Boston, Federal Book Co., vol. 5 (1903). (Woodcut portrait.)

72. F. C. BEACH, etc., editors. Encyclopaedia Americana.
New York and Chicago, American Book Co., vol. 11 (1904). (Full page portrait.)

73. R. JOHNSON and J. H. BROWN, editors. Twentieth Century Biographical Dictionary of Notable Americans.
Boston, The Biographical Society, vol. 8 (1904).

74. B. J. LOSSING. Harper's Encyclopaedia of United States History.
New York, Harpers, vol. 6 (1905): 443. (Portrait.)

75. H. MACPHERSON, Jr. A Century's Progress in Astronomy.
Edinburgh and London, Blackwood, 1906.
Many references to S. Newcomb.

76. Anonymous. American star gazers are the best.
Washington Herald (Sept. 1, 1907): 5 cols.

77. M. MCNEILL. Some great American scientists, III. Simon Newcomb.
Chautauquan, vol. 48 (Nov., 1907): 394–403. (Portrait.)

78. J. B. MORROW.
Washington Post (Nov. 1, 1908): 3 cols.

79. J. T. FARIS. Winning their way: Boys who learned self-help.
New York, Stokes, [1909].
Simon Newcomb: pp. 75–81.

80. J. H. HYSLOP. Professor Newcomb and occultism.
Jl. Amer. Soc. Psychical Research, vol. 3 (May, 1909): 255–289.
Cf. Section V, no. 144.

81. S. H. BORGLUM. Some impressions of Simon Newcomb.
Independent, vol. 67 (July 22, 1909): 183–5.
Not accurate: several misunderstandings.

82. Anonymous. The scientific work of the late Prof. Simon Newcomb.
Scientific American, vol. 101 (July 24, 1909): 59.

83. Anonymous. An American scholar.
Outlook, vol. 92 (July 24, 1909): 667–668.
Editorial.

84. W. T. LYNN. Professor Newcomb.
Jl. Brit. Astr. Assoc., London, vol. 19 (July 30, 1909): 402–403.

85. A. E. BOSTWICK. Simon Newcomb: America's foremost astronomer.
Amer. Review of Reviews, vol. 40 (Aug., 1909): 170–174. (Portrait.)

86. Anonymous. The death of Simon Newcomb.
Pop. Sci. Mo., vol. 74 (Aug., 1909): 204–206. (Portrait.)

87. Anonymous. About Simon Newcomb and the fun he had.
Life, vol. 54 (Aug. 5, 1909): 174–175.
Good character sketch; evidently written by one who knew him well.

88. Anonymous. Professor Newcomb and Father Höll.
America, New York, vol. 1 (Aug. 7, 1909): 465.
Editorial.

89. Anonymous.
Economic Jl., London, vol. 19 (Sept., 1909): 493.

90. Anonymous. The greatest astronomer of our time.
Current Literature, vol. 47 (Sept., 1909): 326–328. (Portrait.)
Quotes from *Scientific American*, *Cosmos*, *Knowledge* and *Nature*.

91. B. BAILLAUD. Simon Newcomb.
Revue générale des sciences, Paris, vol. 20 (Sept. 15, 1909): 725–727.

92. Anonymous. Simon Newcomb.
L'Enseignement Mathématique, Geneva, vol. 11 (Oct., 1909): 403–404.

93. T. T. ⊙ [Simon Newcomb; in annual report of the Council, April, 1910.]
Manchester Phil. Soc. Proc., vol. 54 (1910): xxxi-xxxv.

94. D. S. JORDAN. The permanent wealth of the nation.
Independent, vol. 68 (June 16, 1910): 1329–1332.
Commencement address, using the life of Simon Newcomb as part of his text.

95. Mrs. S. N. MERRICK. John and Simon Newcomb, the story of a father and son.
McClure's Mag., vol. 35 (Oct., 1910): 677–687. (Six portraits of S. Newcomb at different periods of life.)
More accurate presentation of these facts is found in the Reminiscences (see no. 14 of this Section). The author was S. Newcomb's sister.

96. R. RATHBUN. Notes on the bequest to the National Museum.
Smithsonian Institution Report for 1910, Wash. Govt. Print. Off. (1911): 45.

97. G. H. HAMILTON. Simon Newcomb, in J. J. Conway's Footprints of Famous Americans in Paris.
London: John Lane, 1912, pp. 220–223.

98. A. N. McGEE. Simon Newcomb on flying.
New York Times (Apr. 20, 1919), section 3, p. 2, col. 8.

PORTRAITS—PUBLISHED PHOTOGRAPHS.

1858. Aged 23:
Reproduced in *McClure's Mag.*, vol. 35 (Oct., 1910): 680.

1862. Aged 27:
Reproduced in *McClure's Mag.*, vol. 35 (Oct., 1910): 680.
This entry, and others that follow, correct statements made in this article.

1863, fall. Aged 28: Photograph with Mrs. Newcomb, shortly after their marriage.
Reproduced in *McClure's Mag.*, vol. 35 (Oct., 1910): 685.

1871. Aged 34:
Reproduced in *McClure's Mag.*, vol. 35 (Oct., 1910): 681.

1879, Dec. Aged 44:
Reproduced in *McClure's Mag.*, vol. 35 (Oct., 1910): 681.

1879, Dec., 16. Aged 44: Photograph by Wm. Klauser, New York.
Reproduced in *Eclectic Mag.*, vol. 94 (April, 1880): opposite page 385. (Steel engraving by J. J. Cade of New York.)
Also in *Harper's Mag.*, vol. 62 (March, 1881): 550. (Woodcut.)
Also in nos. 55 and 56 above.

1884, Aug. Aged 49: Photograph by W. C. Taylor, Philadelphia, Pa.
Reproduced in *Harper's Weekly*, vol. 28 (Sept. 27, 1884): 630.
Also in no. 74 above.

1887, spring. Aged 52: Photograph by Bachrach, Baltimore.
Reproduced in *Harper's Weekly*, vol. 38 (Dec. 1, 1894): 1144.
Also in *Amer. Math. Mo.*, vol. 1 (Aug., 1894): frontispiece.
Also in nos. 3, 7, and 62 above.

1895. Aged 60: Photograph by Rice, Washington, D. C.
Reproduced in *New England Mag.*, vol. 18 (Aug., 1898): 647; also vol. 21 (Nov., 1899): 264 (in an article on American economists of the day).
Also in *Harper's Weekly*, vol. 53 (July 17, 1909), p. 6 of the issue.
Also in no. 29 above.

1896. Aged 61: Photograph by Bachrach, Baltimore.

Reproduced in *Amer. Review of Reviews*, vol. 25 (Apr., 1902): 430; also vol. 30 (Sept., 1904): 323; also vol. 40 (Aug., 1909): 170.

Also in no. 45.

1897, Aug. or Sept. Aged 62: Photograph by A. D. Wyatt, Brattleboro, Vt.

Reproduced in *Harper's Weekly*, vol. 43 (Nov. 25, 1899): 1184.

Also in *Publs. Astron. and Astrophysical Society of America*, vol. 1 (1910): frontispiece.

Also in nos. 11, 12, 26, 30, 31, 38, 42, 69, and 77 above; also no. 216 (ed. by G. Iles) of Section II.

1903. Aged 68: Bachrach, Baltimore and Washington, D. C.

In nos. 14, 72, and 86 above.

1907, May 4. Aged 72: Photograph taken by F. S. Archenhold in Washington, D. C.

Reproduced in *Weltall*, Berlin, vol. 10 (Aug. 15, 1910): opposite page 322; no. 44 above.

1907, Aug. 7. Aged 72: Photograph taken by Mr. C. A. Chant, of Toronto, at the Lick Observatory.

Reproduced with, "Note regarding the portrait of Professor Newcomb" in *Jl. Roy. Astr. Soc. Can.*, vol. 3 (July–Aug., 1909): 312–313.

1909, Mar. Aged 74: Photograph by Harris and Ewing, Washington, D. C.

Reproduced in *Outlook*, vol. 92 (July 24, 1909): 757.

1909, Mar. Aged 74: Another photograph (taken same day) by Harris and Ewing, Washington, D. C.

Reproduced in *Sci. Amer.*, vol. 101 (July 24, 1909): 53.

Also in no. 90 above.

The portraits in nos. 67 and 71 above have not been identified.

PORTRAITS—PAINTINGS.

1. By E. F. Miller, of Washington, D. C., 1882.

   Property of S. Newcomb's daughter, Mrs. Josepha Whitney, 227 Church Street, New Haven, Conn.

2. By Julius Ulke, of Washington, 1887.

   Portrait ordered by the Russian Government for the gallery of famous astronomers at the Imperial Observatory of Poulkovo. Simon Newcomb is the only representative of America in the gallery.

3. By R. G. Hardie, of Boston, 1897.

   Portrait ordered by colleagues and friends and presented to Johns Hopkins University.

   Reproduced in *New England Mag.*, n. s. vol. 19 (Sept., 1898): 10.

   Reproduced (from a photo of the painting, by A. D. Wyatt, of Brattleboro, Vt.) in the *Amer. Jl. Math.*, vol. 21 (Jan., 1899): frontispiece.

4. By C. H. L. Macdonald, of Washington, D. C., painted about 1899.

   Property of Mrs. Josepha Whitney.

5. By C. H. L. Macdonald, of Washington, D. C., copied from no. 4 in the fall of 1909, with reference also to the Wyatt photograph of 1897.

   Portrait ordered by friends and presented to the American Philosophical Society for their rooms in Philadelphia, Pa.

6. By C. H. L. Macdonald, of Washington, D. C., copy of no. 5.

   In the National Museum, Washington. Loaned by Dr. Anita N. McGee.

7. By C. H. L. Macdonald, of Washington, D. C., another copy of no. 5.

   Property of S. Newcomb's daughter, Mrs. F. A. Wilson, Pelham, N. Y.

8. By C. H. L. Macdonald, of Washington, another copy of no. 5 on a smaller scale.

   Property of S. Newcomb's granddaughter, Mrs. David M. Willis, Fairfax, Marin Co., Calif.

9. By H. F. Waltman, of New York City, painted about 1906.

   Property of the Cosmos Club, Washington, D. C. The picture is 17 x 14 inches in size.

There is also a crayon portrait made in 1880 or 1881 by Dr. Anita N. McGee from Klauser's photograph of 1879. It is now in her possession in Washington.

Finally there is a medallion of Simon Newcomb in the science panel of one of two bronze doors for the west entrance of the United States Capitol. These doors were designed and modeled by Professor Louis Amateis in 1910. At present they are in the vestibule of the New National Museum.

SECTION II.

ASTRONOMY.

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1. Velocity of meteors. Motion of bodies impelled by a single center of force.

The National Intelligencer, Washington (May 26, 1855), col. 2.

A letter dated Sudlersville, Md., May 19, 1855, in reply to a letter of May 5, by G. W. Eveleth.

"When in Maryland I read an elaborate attempt to refute the Copernican system of astronomy, and was quite surprised after waiting some days or weeks to find that no one ventured to point out the writer's fallacies. Fearing that sound knowledge was in danger, I at length ventured in a reply which in due time appeared over my name in The Intelligencer . . . It provoked two pleasing attentions—a book from Col. J. J. Abert, of the topographical engineers, and a letter and a pamphlet from Prof. J. Lawrence Smith." Quotation from no. 169 of this bibliography, below.

2. Elements and ephemeris of the fifty-fourth asteroid, by S. Newcomb and T. H. Safford.

Astr. Jl., vol. 5 (Oct. 16, 1858): 162.

3. Elliptic elements of comet, 1858, V.

Astr. Jl., vol. 5 (Dec. 20, 1858): 178.

4. On the secular variations of the eccentricities and perihelia of the asteroids Vesta, Metis, Hygea, and Parthenope.

Astr. Jl., vol. 6 (Nov. 25, 1859): 65–67.

5. Comparison of the lunar ephemeris in the American Ephemeris and Nautical Almanac, with Greenwich Observations.

Astr. Jl., vol. 6 (Nov. 25 and Dec. 7, 1859): 67–69: 175–176.

First communication dated Oct. 13, 1859.

6. Note on an inequality of long period between the planets Mars and Juno.

Astr. Jl., vol. 6 (Dec. 21, 1859): 80.

7. On the secular variations of the eccentricities and perihelia of certain of the asteroids.

Amer. Assoc. Proc., Cambridge, 1859, vol. 13 (1860): 158–162.

8. On the secular variations and mutual relations of the orbits of the asteroids.

Mem. Amer. Acad., n. s., vol. 5 (1860): 123–152.

9. A review of *Popular Astronomy* by O. M. Mitchell.

Atlantic Monthly, New York, vol. 6 (July, 1860): 117–119.

Anonymous.

10. On the supposed intra-mercurial planets.

Astr. Jl., vol. 6 (Nov. 13, 1860): 162–163.

11. On some illusions and other phenomena attendant on vision through colored media.

Amer. Jl. Sci., vol. 21 (May, 1861): 418–419.

12. Modern theoretical astronomy.

N. Amer. Rev., vol. 93 (Oct., 1861): 367–390.

Anonymous.

13. Smith's Illustrated Astronomy, designed for the use of the public or common schools in the United States ... by Asa Smith ... Revised and improved from Notes and Manuscripts of New Discoveries which have been made to the present date (1860), furnished by Prof. Newcomb, of the astronomical department at Cambridge, Mass.

Boston, Chase and Nichols, 1862, Sm. 4to. 79 pp.

The preface to this revised edition states that it had run through fifteen editions since its publication. There were Spanish and Portuguese editions of this work; the *American Catalogue of Books in Print and for sale July 1, 1876*, lists them as offered for sale by D. Appleton & Co. Whether or not these are translations of the 1860 (or later) edition could not be determined. In the Library of Congress the latest Spanish edition is *Astronomia illustrada de Smith* ... published in New York by Daniel Burgess & Co., in 1853. In the library of the British Museum there is not only a Spanish edition of 1857 but also a French edition published at Strasbourg in 1854.

Another edition, Boston, S. F. Nichols, 1866, 4to, 79 pp.

14. On Dr. Lehmann's new determination of the Gaussian constant K.

Astr. Nach., vol. 57 (Feb. 22, 1862): cols. 65–68.

Remarks on this by Lehmann, vol. 60, col. 289.

15. Determination of the law of distribution of the nodes and perihelia of the small planets between Mars and Jupiter.

Astr. Nach., vol. 58 (Sept. 25, 1862): cols. 209–220.

16. Longitude of Washington as derived from moon calculations observed at the Royal Observatory, Greenwich, and the United States Observatory, Washington, during the years, 1846–1860, inclusive.
Wash. Obs., Appendix A (1862): xliii–li.

17. On Kowalski's theory of Neptune.
Mo. Notices R. Astr. Soc., vol. 25 (1865): 45–47.

18. Investigation of the latitude and longitude of the United States Naval Observatory, Washington, and of the declinations of certain circumpolar stars.
Wash. Obs., 1864 (1866), pp. xxxix–xlvii.

18A. On the latitude and longitude of the United States Naval Observatory, Washington, and the declinations of certain circumpolar stars.
[Washington, 1866?], 9 pp., and cover title. [Appendix to the introduction to *Wash. Obs.*, 1864].

19. An investigation of the orbit of Neptune, with general tables of its motion.
Washington, Smithsonian Institution, January, 1866, 6+111 pp.
Also in *Smithsonian Contribs. Kn.*, vol. 15, art. 2
Smithsonian Institution publication no. 199.

20. Measures of the Companion of Sirius made at the United States Naval Observatory, Washington, 1866, with a note on the identity with the disturbing body indicated by theory.
Astr. Nach., vol. 66 (May 4, 1866): cols. 381–384.
A small part of the communication is by C. H. Davis.

21. Schreiben des Herrn Prof. Simon Newcomb an den Herausgeber.
Astr. Nach., vol. 67 (Sept. 6, 1866): cols. 347–348.
Letter, dated Washington, July 24, 1866, correcting a statement of Dr. Oppolzer's in regard to Leverrier's Solar Tables.

22. Observations of the later asteroids made at the United States Naval Observatory, Washington, with the great transit circle of Pistor & Martins.
Astr. Nach., vol. 67 (Sept. 12, 1866): cols. 363–367.

23. Description of the transit circle of the United States Naval Observatory.
Wash. Obs., 1865, app. 1 (1867): 47 pp.+8 pls.

23A. Description of the transit circle of the United States Naval Observatory, with an investigation of its constants.
Washington, Govt. print. off., 1867. 3+50 pp., 8 folding pls.

24. An investigation of the distance of the sun and of the elements which depend upon it.
Washington Obs., 1865, app. 2 (1867): 29 pp.

24A. An investigation of the distance of the sun and of the elements which depend upon it, from the observations of Mars made during the opposition of 1862, and from other sources.
Washington, Govt. print. off., 1867. 29 pp.

25. The United States Naval Observatory.
N. Amer. Rev., vol. 105 (Oct., 1867): 382–393.
Anonymous.

26. Sur la parallaxe du soleil.
Comptes Rendus, vol. 65 (Nov. 25, 1867).
Letter dated United States Observatory, Washington, Oct. 31, 1867, to M. Delaunay.

27. Observations and discussions on the meteoric showers of November, 1867, U. S. Naval Observatory, Washington. [Reports by S. Newcomb, W. Harkness, and J. R. E. Eastman.]
Washington, Govt. print. off., 1867, 40 pp., 3 maps.
S. Newcomb's report, pp. 5–12; map A by S. Newcomb and W. Harkness.

28. Meteoric showers.
N. Amer. Rev., vol. 107 (July, 1868): 38–50.
This is in the form of a combined review of (1) *Observations and Discussions on the meteoric showers of November Meteors of 1867* by the United States Naval Observatory [no. 27]; (2) *Meteoric Astronomy* by D. Kirkwood; and (3) *A Treatise on Meteorology* by E. Loomis.

29. On Hansen's theory of the physical constitution of the moon.
    Amer. Assoc. Proc., vol. 17 (1868): 167–171.
    Also (abridged) in *Amer. Jl. Sci.*, 2 s. vol. 46 (Nov., 1868): 376–378.
    Also (abridged) in *Phil. Mag.*, 4 s. vol. 37 (Jan., 1869): 32–35.
30. Comparison de la théorie de la lune de M. Delaunay avec celle de M. Hansen.
    Comptes Rendus, vol. 46 (June 15, 1868): 1197–1200.
31. Remarks on Mr. Stone's rediscussion of the transit of Venus, 1769 [a criticism of Mr. Stone's interpretation of Chappe's observations of egress in 1769].
    Mo. Notices R. Astr. Soc., vol. 29 (1868): 6–7.
32. Comparison of the actual and probable distribution in longitude of the nodes and perihelion of 105 small planets.
    Astr. Nach., vol. 73 (Mar. 15, 1869): cols. 278–288.
33. On the observing of corona, etc., during a total eclipse.
    Amer. Jl. Sci., 2 s., vol. 47 (May, 1869): 413–415.
34. Note on the theory of aberration.
    Astr. Nach., vol. 74 (Aug. 2, 1869): cols. 237–240.
35. Report on observations of the total eclipse of the sun, Aug. 7, 1869. Conducted under the direction of Commodore B. F. Sands.
    Washington, Govt. print. off. (1869): 214 pp.
    Also in *Wash. Obs.*, 1867, app. 2 (1870).
    Reports from ten scientists; S. Newcomb's report, pp. 5-22.
36. Positions of fundamental stars deduced from observations made at the U. S. Naval Observatory between the years 1862 and 1867.
    Wash. Obs., 1867 app. 3 (1870) 46 pp.
    Also Washington, Govt. print. off., 1870, 46 pp.
37. Aperçu d'une méthode directe et facile pour effectuer le developpement de la fonction perturbative et de ses coefficients differentiels.
    Comptes Rendus, vol. 70 (Feb. 21, 1870): 385–388.
38. On the mode of observing the coming transits of Venus.
    Amer. Jl. Sci., vol. 50 (July, 1870): 74–83.
    Read before the National Academy of Sciences. April 13, 1870. The substance of the paper was also published in *Nature*, London, vol. 2 (Aug. 25, 1870): 343-345.
39. Sur les inégalités de la lune dues à l'action des planètes.
    Comptes Rendus, vol. 71 (Aug. 22, 1870): 384–386.
40. Sur la manière d'observer le prochain passage de Venus, par M. S. Newcomb: note de M. Faye.
    Comptes Rendus, vol. 71 (Sept. 12, 1870): 413.
41. Considerations on the apparent inequalities of long period in the mean motion of the moon.
    Amer. Jl. Sci., 2 s. vol. 50 (Sept., 1870): 183–194.
    Read before the National Academy, April 13, 1870.
42. On a very accurate method of determining the relative positions of the centers of the sun and moon during a nearly central eclipse of the sun.
    Astr. Nach., vol. 76 (Oct. 27, 1870): cols. 365–368.
43. Théorie des perturbations de la lune qui sont dues à l'action des planètes.
    Comptes Rendus, vol. 72 (Apr. 3, 1871): 403–406.
44. Review of P. A. Secchi's *Le Soleil* ... and R. A. Proctor's *The Sun* ...
    Nature, London, vol. 4 (May 18, 1871): 41–43.
45. Review of P. A. Secchi's *Le Soleil* ...
    Nature, London, vol. 4 (June 29, 1871): 160.
    Reply by Newcomb to a complaint of R. Proctor in a letter, dated May 18, on the review. Proctor replies to this letter, making interesting statements about Newcomb, *Nature*, London, vol. 4 (July 6, 1871): 183.
46. Phenomena of contact.
    Nature, London, vol. 4 (Sept. 28, 1871): 423.
47. The solar parallax.
    Nature, London, vol. 4 (Nov. 23, 1871): 160.
    Letter dated Oct. 23, 1871.

48. Reports on observations of the total solar eclipse of December 22, 1870 [at Gibraltar].
Washington, Govt. print. off., 1871, 132 pp.
Also in *Wash. Obs.*, 1869, app. 1 (1872).
S. Newcomb's report, pp. 5-24, is one of five.

49. Memoir ... on the lunar theory.
Mo. Notices R. Astr. Soc. vol. 31 (suppl. no., 1871): 265–268.

50. Théorie des perturbations de la lune qui sont dues à l'action des planètes.
Journal de mathématicques pures et appliquées, s. 2, vol. 14, (Nov., 1871): 321–368.

51. Schreiben des Herrn Professor S. Newcomb an den Herausgeber.
Astr. Nach., vol. 79 (May 17, 1872): cols. 245–246.
Letter dated April 1, 1872, calling attention to the favorable opportunity for determining the mass of Jupiter, which is afforded by its small planet Polybymnia.

52. On the application of photography to the observation of the transits of Venus.
Washington, Govt. print. off., 1872, pt. 1 (1872): 14–25.
One of a number of "Papers" published by the commission on the transit of Venus, Dec. 9, 1874.

52A. Zum Venusdurchgang. Auszug aus Prof. Newcombs Artikel.
Photographische Mittheilungen, Berlin, vol. 10 (1874): 18–21; 128–132.
Translation of most of pages 14-21.

53. On the right ascensions of the equatorial fundamental stars, and the corrections necessary to reduce the right ascension of different catalogues to a mean homogeneous system.
Washington, Govt. print. off., 1872, 73 pp.
Also in *Wash. Obs.*, 1870, app. 3 (1873).

54. New tables of Uranus.
Mo. Notices R. Astr. Soc., vol. 32 (June, 1872): 308.
Letter dated Washington, May 16, 1872.

55. Note sur un théorème de mécanique céleste.
Comptes Rendus, vol. 75 (Dec., 1872): 1750–1753.

56. A mode of testing the motion of a clock pendulum.
Astr. Nach., vol. 81 (May 22, 1873): cols. 319–320.

57. Chronometer tests.
Nature, London, vol. 8 (June 19, 1873): 150.

58. An investigation of the orbit of Uranus, with general tables of its motion.
Washington, Smithsonian Institution, October, 1873, 7+288 pp.
Also in *Smithsonian Contribs. Kn.*, vol. 9, art. 4, 1874.
Smithsonian Institution publication no. 262. "For which and the tables of Neptune, Newcomb was awarded a gold medal by the Royal Astronomical Society of Great Britain, on Feb. 13, 1874." Work on these tables was begun as early as 1859.

59. Proctor on the moon.
Nation, New York, vol. 17 (Oct. 23, 1873): 274–275.
Anonymous review.

60. The story of a telescope.
Scribner's Monthly (now *Century Mag.*), vol. 7 (Nov., 1873): 44–55.

61. [Expedition toward the North Pole by Capt. Hall. Instructions on astronomical observations.]
Smithsonian Report, 1871 (1873): 367–368.

62. Instructions for observing the transit of Venus, December 8–9, 1874. Prepared by the Commission authorized by Congress and printed for the use of the observing parties by authority of the Hon. Secretary of the Navy.
Washington, Govt. print. off., 1874, 28 pp.
Written by S. Newcomb as secretary of the Commission.

63. [Lockyer's *Contribution to Solar Physics*.]
Nation, New York, vol. 18 (Mar. 19, 1874): 192–193.
Anonymous review.

64. [Note on Hansen.]
Nation, New York, vol. 18 (Apr. 9, 1874): 237
Anonymous.

65. [Note on Proctor.]
Nation, New York, vol. 18 (Apr. 16, 1874): 251–252.
Anonymous.

66. [Review of Proctor's *The Universe and the Coming Transits* and *The Expanse of Heaven.*]
Nation, New York, vol. 18 (June 4, 1874): 368.
Anonymous.

67. On the possible variability of the earth's axial rotation, as investigated by Mr. Glasenapp.
Amer. Jl. Sci., 3. s. (Sept., 1874): 161–170.

68. On the possible periodic changes of the sun's apparent diameter, by Simon Newcomb and Edward S. Holden.
Amer. Jl. Sci., vol. 8 (Oct., 1874): 268–277.

68A. Russian translation (abridged). [The diameter of the sun and his temperature.]
Tehnickesky Sbornik vést. promyšl, St. Petersburg and Moscow, vol. 19 (1874): 191.

69. Some talks of an astronomer.
Harper's Mag., vol. 49 (Oct., 1874): 693–707 and (Nov., 1874): 825–841.

70. On the present state of M. Delaunay's investigation on the lunar theory.
Mo. Notices R. Astr. Soc., vol. 35 (Nov., 1874): 62.
From a letter to Warren de La Rue, Esq.

71. The coming transit of Venus.
Harper's Mag., vol. 50 (Dec., 1874): 25–35.

72. On the general integrals of planetary motion.
Washington, Smithsonian Institution, December, 1874. 7+31 pp.
Also in Smithsonian Contribs. Kn., vol. 21, art. 3.
Smithsonian Institution publication no. 281.

73. [Note on the transit of Venus.]
Nation, New York, vol. 19 (Dec. 17, 1874): 399.
Anonymous.

74. The Uranian and Neptunian systems, investigated with the 26-inch equatorial of the United States Naval observatory.
Wash. Obs., 1873, app. 1 (1875).
Also Washington, Govt. print. off., 1875. 74 pp.

75. [Review of Proctor's *Transit of Venus.*]
Nation, New York, vol. 20 (Apr. 1, 1875): 230.
Anonymous.

76. On the transit of Venus.
New York Tribune (Apr. 23, 1875): 2, col. 2.
Paper read before the National Academy of Sciences, Washington, Apr. 21, 1874.

77. Remarks on the observations of the late transit of Venus.
Amer. Jl. Sci., 3 s., vol. 9 (April, 1875): 388–391.

78. Recent works on astronomy.
Nation, New York, vol. 20 (May 20, 1875): 349–50.
Anonymous review of Drayson's *Cause of the Supposed Proper Motion of the Fixed Stars*, J. Rambosson's *Astronomy*, and A. Searle's *Outlines of Astronomy*.

79. Notes on the position of the equinoxes.
Mo. Notices R. Astr. Soc., vol. 35 (1875): 404–405.

80. Astronomy's needs.
New York Tribune (July 21, 1875): 2, cols. 1–2.
A letter dated, Washington, July 16, 1875.

81. Investigation of corrections to Hansen's tables of the moon, with tables for their application.
Washington, Govt. print. off., 1876. 51 pp.
Part III of papers published by the Commission on the transit of Venus.

82. On a hitherto unnoticed inequality in the longitude of the moon.
Mo. Notices R. Astr. Soc., vol. 36 (June, 1876): 358–361.
Read before the Royal Astronomical Society, June 9, 1876. Reported in the *Astronomical Register*, London, vol. 14 (July, 1876): 152–154.

83. Recent astronomical progress.
N. Amer. Rev., vol. 98 (July, 1876): 86–112.

84. Suggestions respecting a school of practical astronomy. Extract from a lecture delivered before the Johns Hopkins University, December 18, 1876.
Baltimore, Johns Hopkins University, 1876. 4 pp.
A few copies were struck off for the Trustees.

85. On observations of contacts of the limb of Venus or Mercury with that of the sun.
Mo. Notices R. Astr. Soc., vol. 37 (March 9, 1877): 237–241.
Dated Washington, 1877, February 22.

86. Note on the new inequalities in the moon's longitude, pointed out by Mr. Neison.
Mo. Notices R. Astr. Soc., vol. 37 (June 8, 1877): 428–430.

87. Details about the moons of Mars.
New York Tribune (Aug. 23, 1877).
Letter dated Washington, Aug. 22, 1877. Extract from this letter in *Nature*, London, vol. 16 (Sept. 6, 1877): 398.

88. [Elements of the Mars satellites.]
Astr. Nach., vol. 90 (Sept. 15, 1877): cols. 275–276.
In a letter from John Rodgers.

89. The discovery of the satellites of Mars.
Nature, London, vol. 16 (Sept. 27, 1877): 456–457; cf. also pp. 398 (no. 91 of this section).

90. [Note on le Verrier.]
Nation, New York, vol. 25 (Sept. 27, 1877): 198.
Anonymous.

91. The satellites of Mars.
The Observatory, London, vol. 1 (Oct. 20, 1877): 213–214.
Letter dated Washington, Aug. 22, 1877.

92. On the mean motion of the moon.
Amer. Jl. Sci., 3 s. vol. 14 (Nov., 1877): 401–410.
Also a summary in *The English Mechanic*, London, vol. 26 (Jan. 4, 1878): 400.

93. New elements of Iphegenia (107), etc., communicated by Simon Newcomb.
Astr. Nach., vol. 91 (Nov. 28, 1877): cols. 107–108.

94. *Astronomy* by R. S. Ball ... specially revised for America by S. Newcomb.
New York, H. Holt & Company, 1878, 13+ 154 pp.
Of the series: Handbooks for students and general readers.

95. Corrections to Hansen's tables of the moon, prepared and printed for the use of the American Ephemeris and Nautical Almanac.
Washington, Govt. print. off., 1878. [3] pp.
Signed: Simon Newcomb.

96. Reduction of the constants of precession found by Bessel, Struve, and Nyrén, to a common equinox.
Vierteljahrsschrift Astr. Gesell., vol. 13 (1878): 107–110.

97. Instructions for observing the transit of Mercury, May 5-6, 1878.
Washington, 1878. 8 pp. diagrs., plates.
Also in *Wash. Obs.*, 1876, app. 2 (1878).

98. Popular astromony.
New York, Harper Bros., 1878. 16+566 pp. + 5 maps of stars.
Second ed., 1879, 18+572 pp. + maps of stars. Third ed., 1880. Fourth ed. revised, 1882, 18+577 pp. (Reprinted, 1883.) Fifth ed., 1886, 18+578 pp. Sixth ed., 1890. Seventh ed., New York, American Book Co. [1893]. 18+578 pp. (preface dated Mar., 1892). Eighth ed., 1896, 18+578 pp. Small editions were manufactured in 1909, 1910, 1911, 1912, and 1918.
Beginning with 1880 a "School Edition" was issued in America; since 1882 there has been no other "school" edition. The work is still in demand; between January 1, 1908, and December 31, 1921, 1125 copies were sold.
London, MacMillan, 1878, 566 pp. Exactly same as Harper's first edition with the exception of the title page. Second ed., 1883, 580 pp. (preface dated July, 1882). Second ed. revised [July], 1910, 600 pp.
Of the English edition 3,500 copies have been sold.

98A. German translation—Populäre Astronomie, von Sim. Newcomb, Astronom in Washington. Deutsche vermehrte Ausgabe, bearbeitet durch Rud. Engelmann.
Leipzig, Verlag von Wilhelm Engelmann, 1881, 16+742 pp.
Zweite vermehrte Auflage, herausgegeben von Dr. H. C. Vogel, 1892, 20+748 pp. Dritte Auflage [thoroughly revised], 1905, 10+748 pp. Vierte Auflage in Gemeinschaft mit den Herren Eberhard, Ludendorff, Schwarzschild, herausgegeben von P. Kempf, 1911, 16+722 pp. Fünfte Auflage, 1914, 12+835 pp. Sechste Auflage, in Gemeinschaft mit den Herren Eberhard, Freundlich, Kohlschütter, herausgegeben von H. Ludendorff, 1921, 12+889 pp. Siebente Auflage, 1922, 14+902 pp.
An English translation of the seventh edition is in course of preparation.

98B. Norwegian translation—Omrids af astronomin. Efter S. Newcombs Populære Astronomi ved Sophus Tromholt. Udgivet af Selskabet for folkeoplysningens Fremme som første Tellægohefte til Folkvennen for 1887. (Outline of Astronomy. According to [that is, abridged from] S. Newcomb's Popular Astronomy, by Sophus Tromholt. Published by the Society for the Advancement of Popular Education as the first supplementary part to *Folkvennen* for 1887.)

Kristiania, Grondahl & Sons, Bogtrykkeri, 1887, 16 mo. 339 pp. + 1 plate.

98C. Russian translation—Astronomīīā v obshcheponīātnom izlozheniī, dopolnennaīā G. Fogelem, s. 195 ris. (Astronomy in popular presentation, supplemented by G. Fogel, with 195 charts and illustrations.) [From the second German edition by N. S. Drenteln.]

St. Petersburg, 1896.

Cajori, in his *History of Mathematics in the United States*, and the author of the sketch of Newcomb in the *New York Tribune* (compare nos. 4 and 63 in Section 1 of this bibliography), state that there was a French edition of the Popular Astronomy. This is not the case.

99. The *American Ephemeris and Nautical Almanac* for the year 1881. First edition. Edited with preface by Simon Newcomb.

Washington, Bureau of Equipment, 1878.

The *Almanacs* for the years 1882–1900 were published in a similar manner, 1879–1897.

The preface of the last volume, prepared under Newcomb's supervision, was by W. Harkness, who in 1897 succeeded S. Newcomb as director of the Nautical Almanac and senior professor of mathematics, U. S. Navy.

100. Report of the secretary of the navy [including Reports of Superintendent of Nautical Almanac].

Washington, Govt. print. off. (1878): 162–164; (1879): 127–129; (1880): 122–129; (1881): 236–237; (1882): 132–134; (1883): 270–273; (1884): 160–162; (1885): 116–118; (1886): 244–245; (1887): 226–229; (1888): 180–182; (1889): 432–433; (1890): 105–107; (1891): 132–134; (1892): 141–142; (1893): 164–166; (1894): 171–175; (1895): 114–116.

Most of S. Newcomb's report published in 1887 was reprinted in *Astr. Nach.*, vol. 119 (June 25, 1888), cols. 221–224.

101. Researches on the motion of the moon made at the United States Naval Observatory, Washington. Part I—Reduction and discussions of observations of the moon before 1750.

Washington, 1878, 280 pp.

Also in *Wash. Obs.*, 1875 (1878), Appendix 2.

"Engaged on this memoir for six years." *Nature*, 1878. Part II was published posthumously in 1912; see there (no. 317).

102. "Astronomy," "Galaxy," "Gravitation" "Probability, Theory of, or calculus of probability."

In *Johnson's New Universal Cyclopaedia*, edited by F. A. P. Barnard, A. Guyot, etc., 4 vols.

New York, A. J. Johnson's Son, 1878.

See also nos. 179 and 258 of this Section.

103. A manufactured comet.

Harper's Mag., New York, vol. 57 (June, 1878): 139–141.

104. Lockyer's *Star-gazing Past and Present.*

Nation, New York, vol. 27 (July 11, 1878): 29.

Anonymous review.

105. Elcipses of the sun.

Princeton Rev., vol. 2 (Nov., 1878): 848–864.

106. Note on the tidal force.

Science Observer, Boston, vol. 2 (Nov., 1878): 25.

Letter, dated Washington, Nov. 19, 1878, replying to Mr. Arnold's criticism of the explanation of two tides a day in Newcomb's Popular Astronomy.

107. On the recurrence of solar eclipses, with tables of eclipses from B. C. 700 to A. D. 2300.

Washington, Bureau of navigation, Navy dept., 1879, 55 pp.

Also in *Astr. Papers*, 1882, vol. 1, pt. 1 (1879).

"A considerable part of this work of constructing the tables [was] performed by John Meier." Preface.

107A. On the present state of the theories of the celestial motions.
Sid. Mess., vol. 2 (1883): 11–17, 33–39.
Reprint of the introduction to no. 107.

108. The Nautical Almanac.
Proc. U. S. Naval Inst., vol. 5 (1879): 33–49.
Read before the U. S. Naval Institute, Jan. 30, 1879.
Also in Side-Lights on Astronomy (1906): 191–215; see no. 300 in this section.

109. *Six Months in Ascension*, by Mrs. David Gill.
Nation, New York, vol. 28 (Feb. 13, 1879): 121–122.
Anonymous review.

110. Astronomy for Schools and Colleges, by Simon Newcomb and Edward S. Holden.
New York, Henry Holt & Co., Oct., 1879, 11+512 pp. Second ed., "revised for students and general readers," 1880. Third ed., "revised for high schools and colleges," 1880. Fourth ed., revised, 1883 12+512. Fifth ed. 1885. Sixth ed., 1887, 12+512 pp. There were other reprints or editions in 1888 (100 of the 1,300 in this edition were destroyed by fire), 1893, 1897, 1902, 1907. In all 11,825 copies were printed.
"American Science Series." With the publication in 1883 of Astronomy (American Science Series, Shorter Course) (no. 136) this work was called Astronomy (American Science Series, Advanced Course).

111. Note on the correction of the mean longitude of Hansen's lunar tables.
Mo. Notices R. Astr. Soc., vol. 40 (Dec., 1879): 81–82.

112. Observations at Separation, Wyoming, in "Reports on the Total Solar Eclipse of 1878, July 29."
Washington (1880): 99–116.
Also in *Wash. Obs.*, 1876, app. 3 (1880).

113. Observations of the transit of Venus, Dec. 8–9, 1874, made and reduced under the direction of the Commission created by Congress. Part I—General discussion of results.
Washington, Govt. print. off., 1880, 157 pp.

114. A transformation of Hansen's lunar theory, compared with the theory of Delaunay, by S. Newcomb and J. Meier.
Astr. Papers, vol. 1, 1882, pt. 2 (1880): 57–107.

115. Request for observations of Polyhymnia.
Astr. Nach., vol. 96 (Jan. 1, 1880): cols. 191–192.
Dated Washington, Nov. 28, 1879.

116. Sketch of the life of Prof. Otto W. Struve.
Pop. Sci. Mo., vol. 17 (June, 1880): 263–264.

117. A method of developing the perturbative function of planetary motion.
Amer. Jl. Math., vol. 3 (Sept., 1880): 193–209.

118. [Note on J. C. Watson.]
Nation, New York, vol. 31 (Dec. 2, 1880): 393.
Anonymous.

119. Apparent right ascensions additional time stars, 1881–84, with mean additional time stars, 1881–84, with mean places for 1884.
Washington, 1881. 61 pp.

120. [E. S. Holden's *Sir William Herschel.*]
Nation, New York, vol. 32 (Feb. 17, 1881): 118–119.
Anonymous review.

121. [Note on a comet.]
Nation, New York, vol. 32 (June 30, 1881): 450.
Anonymous.

122. Astronomical observatories.
N. Amer. Rev., vol. 133 (Aug. 1881): 196–203.
Also in *Nature*, London, vol. 26 (Aug. 3, 1882): 326–329.
Also in *The Observatory*, London, vol. 5 (Sept., 1882): 247–253.

123. Catalogue of 1098 standard clock and zodiacal stars, prepared under the direction of Simon Newcomb.
Astr. papers., vol. 1, 1882, pt. 4 (1882): 147–314.

124. Discussion and results of observations on transits of Mercury, from 1677 to 1881.
Astr. Papers, vol. 1, 1882, pt. 6 (1882): 363–487.
Reviewed in *The Observatory*, London, vol. 6 (May 1, 1883): 143–149.

125. An eclipse of the moon.
Science for All, edited by Robert Brown, London, Paris, and New York, Cassell & Co., vol. 5 (1882): 1–8.

126. Instructions for observing the transit of Venus, December 6, 1882, prepared by the commission authorized by Congress and printed for the use of the observing parties.
Washington, Govt. print. off., 1882, 50 pp.+4 maps.
Actually written by S. Newcomb as secretary of the commission.

127. A small telescope and what to see with it.
Harper's Mag., vol. 64 (March, 1882): 523–536.
Also in Side-Lights on Astronomy (1906): 76–105, as "Making and using a telescope"; see no. 300 of this Section.

128. Remarks on the instructions for observing the transit of Venus formulated by the Paris International Conference [in Oct. 1881].
Mo. Notices R. Astr. Soc., vol. 42 (April 14, 1882): 275–281.
Also in *Astr. Register*, London, vol. 20 (April, 1882): 103–105.

129. Probable times of the four contacts in the coming transit (Dec., 1882) of Venus.
Astr. Nach., vol. 103 (Sept. 14, 1882): cols. 111–112.
Dated Washington, Aug. 28, 1882.
Also in *The Observatory*, London, vol. 5, (Nov., 1882): 313–314.

130. Formulæ and tables for expressing corrections to the geocentric place of a planet in terms of symbolic corrections to the elements of the orbits of the earth and planet. By Simon Newcomb, assisted by John Meier.
Astr. Papers, vol. 2, 1891, pt. 2 (1883): 1–48.

131. "The Moon," in *Encyclopædia Britannica*, 9th ed., 25 vols.
London & Edinburgh, A. & C. Black, vol. 16 (1883): 798–803.
For articles in later editions of the *Britannica* see nos. 271 and 316. No attempt has been made to list American pirated forms of the ninth edition of the *Britannica*.

132. The transit of Venus.
Astr. Register, vol. 21 (Jan., 1883): 26–30.

133. Solar parallax.
Astr. Register, vol. 21 (Jan., 1883): 32–33.
Report of a paper presented at meeting of the Royal Astronomical Society.

134. On Hell's alleged falsification of his observations of the transit of Venus in 1769.
Mo. Notices R. Astr. Soc., vol. 43 (May 11, 1883): 371–381.
Reference may be given to a sketch of Maximilian Hell or Höll (1720–1792) in the *Catholic Encyclopaedia*, New York, Appleton, vol. 7 (1910). See also this bibliography, Sections I, no. 88, and II, no. 257.

135. The apparent inequality of the mean motion of the moon.
The Observatory, London, vol. 6 (Aug., 1883): 243–244.
Letter dated Neuchâtel, Switzerland, July 11, 1883.

136. Astronomy (American Science Series, Shorter Course), by Simon Newcomb and Edward S. Holden.
New York, Holt, Oct., 1883, 10+338 pp.
Second ed. revised and enlarged, 1884. 10+352 pp. The other editions or reprints appeared in 1885, 1887 (450 copies of the 2,480 in this edition were destroyed by fire), 1889, 1890, 1892, 1896, 1907. In all 13,605 copies were printed. In 1892 the series title was changed to (American Science Series, Briefer Course). The preface states: "The present treatise is a condensed edition of the Astronomy [no. 110] of the American Science Series."

136A. Elementary Astronomy by E. S. Holden.
New York, Holt, 1899, 15–446 pp.
This work is condensed from the two volumes listed above in nos. 110 and 136. The number of copies sold was 562.

137. Remarks on the published corrections to Hansen's lunar tables.
Astr. Nach., vol. 107 (Dec. 4, 1883): cols. 269–270.

138. Development of the perturbative function and its derivatives in sines and cosines of multiples of the eccentric anomaly and in powers of the eccentricities and inclinations.
Astr. Papers, 1891, vol. 3, pt. 1 (1884): 1–200.

139. On the motion of Hyperion—a new case in celestial mechanics.
Astr. Papers, vol. 3, 1891, pt. 3 (1884): 345–371.

140. Report to the Secretary of the Navy on recent improvements in astronomical instruments.
Washington, Govt. print. off., 1884, 27 pp.
Reprinted, in part, under the title: (1) "Astronomical clocks," in *Sid. Mess.*, vol. 3 (1884): 206–208; (2) "New method of mounting reflectors," in *Science*, vol. 3 (Mar. 14, 1889): 320–321; (3) "The great Vienna telescope," *Science*, vol. 3 (Mar. 28, 1884): 380–381.

141. Questions respecting Mr. Stone's theory of changes in the mean solar day.
Mo. Notices R. Astr. Soc., vol. 44 (Mar., 1884): 234–235.

142. Remarks on the value of the secular acceleration of the moon's motion derived from observation.
Mo. Notices R. Astr. Soc., vol. 44 (Mar., 1884): 236–237.

143. Recent determinations of stellar parallax.
Science, Cambridge, vol. 3 (Apr. 11, 1884): 456–457.

144. Note on Mr. Stone's explanation of the error of Hansen's lunar tables.
Mo. Notices R. Astr. Soc., vol. 44 (June 13, 1881): 381–383.
This article is followed in the same issue by "Answers to Prof. Newcomb's questions on the changes in the adopted unit of mean time," by E. J. Stone.

145. Sur le mouvement d'Hyperion.
Comptes Rendus, vol. 99 (Sept. 22. 1884): 499–502.

146. Remarks on the theory of the relations between the mean motions of the planets.
Astr. Nach., vol. 110 (Sept. 29, 1884): cols. 1–4.

147. Measures of the velocity of light, made under direction of the Secretary of the Navy during the years 1880–'82.
Astr. Papers, vol. 2, 1891, pt. 3 (1885): 107–230+7 plates. "Introduction" reprinted in *Sid. Mess.*, vol. 5 (Jan. and Feb., 1886): 15–18, 68–73.
Immediately following this memoir, in the same volume of *Astr. Papers*, was A. A. Michelson's memoir "Supplementary measures of the velocities of white and colored light in air, water, and carbon disulphide," with an "Introductory note" (p. 235) by Simon Newcomb.

148. On the proposed change of the astronomical day.
Mo. Notices R. Astr. Soc., vol. 45 (Jan. 9, 1885): 122–123.

491. The Lick Observatory of California.
Harper's Mag., vol. 70 (Feb., 1885): 399–406.

150. [Letter in appendix to a "Report of the Committee of the American Meteorological Society on Standard Time"].
Proc. Amer. Meteorological Society, New York, vol. 5 (May, 1885): 57–62.
Letter dated Dec. 6, 1884, and addressed to W. E. Chandler, Secretary of the Navy.

151–152. (1) [Remarks on the proposed change of the astronomical day]; (2) [Remarks on the progress of work on the planetary theories.]
Vierteljahrsschrift der Astr. Gesell., vol. 20 (Oct., 1885): 228–229, 236–237.

153. [Letter to President F. A. P. Barnard, chairman of the committee of the National Academy of Sciences, replying to his inquiries about conditions at the U. S. Naval Observatory, in the appendix of the report of the National Academy of Sciences to the Secretary of the Navy on the advisability of building a new Naval Observatory.]
Washington, Govt. print. off., Feb. 10, 1886. Senate, 49th Congress, 1st session.
Executive Document No. 67. Letter dated Washington, D. C., November 17, 1885.

154. Popular astronomy.
Science, New York, vol. 7 (Apr. 30, 1886): 392.
Letter concerning similarity of passages in R. S. Ball's *The Story of the Heavens* on the one hand, and the previously published Young's *The Sun*, and Newcomb's *Popular Astronomy* on the other.

155. Red sunsets and volcanic eruptions.
Nature, London, vol. 34 (Aug. 12, 1886): 340.

156. Alvan Clark.
Nation, New York, vol. 45 (Aug. 25, 1887): 149–150.
Anonymous editorial.

157. The place of astronomy among the sciences—an address delivered at the dedication of the new observatory of the University of Syracuse, N. Y., Nov. 18, 1887.
Sid. Mess., vol. 7 (Jan., 1888): 14–20; (Feb., 1888): 65–73.

158. New tables of the planets.
Astr. Nach., vol. 119 (June 25, 1888): cols. 221–223.

159. On the mutual action of the satellites of Saturn.
Astr. Jl. vol. 8 (Oct. 2, 1888): 105–106.

160. Note on the satellite of Neptune.
Astr. Jl., vol. 8 (Dec. 17, 1888): 143.
Dated Washington, Dec. 2, 1888.

161. Discussion of observations of the transit of Venus in 1761 and 1769.
Astr. Papers, vol. 2, 1891, pt. 5 (1890): 259–405.

162. Comparison of the right ascensions of clock stars in the Greenwich ten-year catalogue for 1880, with fundamental catalogues of the American Ephemeris, and of the Astronomische Gesellschaft.
Mo. Notices R. Astr. Soc., vol. 50 (June 13, 1890): 473–481.

163. Discussion of the north polar distances, observed with the Greenwich and Washington transit circles with determinations of the constant of nutation.
Astr. Papers, vol. 2, 1891, pt. 6 (1891): 407–490.

164. The Johns Hopkins University of Baltimore. The needs of the astronomical department.
[Baltimore] 1891. 2 pp.
Printed for private use only.

165. [Letter of acceptance of honorary membership.]
Trans. of the Astr. and Phys. Soc. of Toronto, vol. 2 (1891): 42–43.

166. Periodic perturbations of the longitudes and radii vectores of the four inner planets of the first order as to the masses.
Astr. Papers, 1891, vol. 3, pt. 5 (1891): 395–574.

167. Lockyer's *Meteoritic Hypothesis*.
Nation, New York, vol. 52 (Jan. 1, 1891): 14–15.
Anonymous review.

168. [J. Scheiner's *Die Spectralanalyse der Gestirne*.]
Nation, New York, vol. 52 (Mar. 5, 1891): 206.
Anonymous review.

169. Formative influences.
Forum, vol. 11 (Apr., 1891): 183–191.
Autobiographical sketch dealing with S. Newcomb's life to the beginning of his scientific career.

170. Ferrel's early astronomical work.
Amer. Meteorological Jl., vol. 8 (Dec., 1891): 337–339.
Read at a meeting of the N. E. Meteorological Soc. Oct., 1891.

171. On the periodic variation of latitude and the observations with the Washington prime-vertical transit.
Astr. Jl., vol. 11 (Dec. 23, 1891): 81–82.

172. Perturbations of the four inner planets.
Bull. N. Y. Math. Soc., vol. 1 (Feb., 1892): 120–122.
Review by "S. N." of *Astr. Papers*, vol. 3, last part.

173. Our national observatory.
The Evening Post, New York (Feb. 13, 1892).

174. On the dynamics of the earth's rotation, with respect to the periodic variations of latitude.
Mo. Notices R. Astr. Soc., vol. 52 (Mar. 11, 1892): 336–341.

175. Results of the observations of α Lyrae, made during the years 1862–67, with the prime-vertical transit of the U. S. Naval Observatory.
Astr. Jl., vol. 11 (Apr. 28, 1892): 182–183.

176. On the law and the period of the variation of terrestrial latitudes.
Astr. Nach., vol. 130 (June 18, 1892): cols. 1–6.
Dated, Aix-les-Bains, Savoie, June 1, 1892.

177. Remarks on Mr. Chandler's law of variation of terrestrial latitudes.
Astr. Jl., vol. 12 (July 22, 1892): 49–50.

178. Observations of the solar eclipse of 1892, October 20, made at the Johns Hopkins University, Baltimore.
Astr. Jl., vol. 12 (Dec. 9, 1892): 141; vol. 13 (Mar. 9, 1893): 24.

179. "Algebra," "Algol," "Almanac," "Almucantar," "Altazimuth," "Analysis," "Angle," "Asteroids," "Astronomy," "Binary system," "Calculus," "Collimation," "Collimator," "Comets," "Composition of forces," "Curves," "Eclipse," "Ecliptic," "Energy," "Energy, conservation of," "Equation," "Falling bodies," "Fluxions," "Functions," "Geodesy," "Geometry," "Horizon," "Imaginary quantities," "Incommensurables," "Infinities and infinitesimals," "Interpolation," "Jupiter," "Light," "Limits," "Logarithms," "Magic squares," "Mars," "Mathematics," "Mercury," "Moon," "Nebular hypothesis," "Observatory," "Occultations," "Orbit," "Parallax," "Perturbations," "Photometry," "Planet," "Precession of the equinoxes," "Probability," "Progression," "Ptolemaic system," "Quadrature of the circle," "Quaternions," "Saturn," "Series," "Solar parallax," "Solar system," "Stars," "Sun," "Telescope," "Time," "Transit," "Transits of Venus and Mercury," "Trigonometry," "Trilinear coordinates," "Twilight," "Universe," "Venus," "Vulcan," "Year," "Zodiacal light," in *Johnson's Universal Cyclopædia* [later *Universal Cyclopedia and Atlas*], 8 volumes.
New York, A. A. Johnson Co., 1893–1895.
S. Newcomb was the "Associate editor" for "astronomy and mathematics" in connection with this work. See also nos. 102 and 258 in this Section.

180. On the lunar equation in the heliocentric motion of the earth.
Astr. Nach., vol. 132 (Mar. 8, 1893): cols. 161–164.
Dated Washington, Jan. 1, 1893.

180X[1]. [Letter dated June 21, 1893, to the Secretary of the Navy, and a testimonial to Dr. J. Morrison dated May 1, 1886].
Astronomy and Astrophysics, Northfield, Minn., vol. 12 (Aug. and Oct., 1893): 665, 760.
Compare no 61 of Section 1.

181. A development of the perturbative function in cosines and multiples of the mean anomalies and of angles between the perihelia and common node and in powers of the eccentricities and mutual inclinations.
Astr. Papers, vol. 5, 1895, pt. 1 (1894): 1–48.

182. Inequalities of long period stars and of the second order as to the masses in the mean longitudes of the four inner planets.
Astr. Papers, vol. 5, 1895, pt. 2 (1894): 49–96.

183. Theory of the inequalities in the motion of the moon produced by the action of the planets.
Astr. Papers, vol. 5, 1895, pt. 3 (1894): 97–295.

184. Secular variations of the orbits of the four inner planets.
Astr. Papers, 1895, vol. 5, pt. 4 (1894): 297–378.

185. Considerations on the best methods of determining the positions of the planets by observation.
Astr. Jl., vol. 13 (Feb. 10, 1894): 191–192.

186. Remarks on Mr. Stone's proposed corrections to the measure of time since 1864.
Mo. Notices R. Astr. Soc., vol. 54 (Mar. 9, 1894): 286–288.

187. Two questions on Mr. Stone's proposed correction in the measure of time.
Mo. Notices R. Astr. Soc., vol. 54 (May 11, 1894): 408.
"Reply to Professor Newcomb's two questions" by Mr. Stone, pp. 409–412.

188. On the elements of (33) Polyhymnia and the mass of Jupiter.
Astr. Nach., vol. 136 (Aug. 29, 1894): cols. 129–134.
Dated Washington, June 1, 1894. Compare no. 205, below.

189. Reorganization of the Naval Observatory.
The Evening Post, New York, vol. 93. (Sept. 26, 1894): 6, cols. 4–5.
Also in *Nation*, New York, vol. 29 (Sept. 27, 1894): 228.
Anonymous editorial.

[1] This number is used because the title was inserted in galley proof.

190. Note on accounting for the secular variations of the orbits of Venus and Mercury.
Astr. Jl., vol. 14 (Oct. 1, 1894): 117–118.

191. Note on Mr. Stone's theory of the measure of time.
Mo. Notices R. Astr. Soc., vol. 55 (Nov. 9, 1894): 3.

192. The world's debt to astronomy.
Chautauquan, vol. 20 (Dec., 1894): 286–291.
Also in Side-lights on Astronomy (1906): 216–226; see no. 300 in this Section.

193. Sur les variations séculaire des orbites des quatre planètes intérieures.
Comptes Rendus, vol. 119 (Dec. 10, 1894): 983–986.

194. A very popular astronomer.
Nation, New York, vol. 59 (Dec. 20, 1894): 469.
Anonymous review of Flammarion's *Popular Astronomy* translated into English by J. E. Gore.

195. On the mass of Jupiter and the orbit of Polyhymnia.
Astr. Papers, vol. 5, 1895, pt. 5 (1895): 379–449.

196. Tables of the motion of the earth on its axis around the sun.
Astr. Papers, vol. 6, 1898, pt. 1 (1895): 7–169.

197. Tables of the heliocentric motion of Mercury.
Astr. Papers, vol. 6, 1898, pt. 2 (1895): 171–270.

198. Tables of the heliocentric motion of Venus.
Astr. Papers, vol. 6, 1898, pt. 3 (1895): 271–382.

199. Tables of Jupiter, by G. W. Hill, with prefatory note by Simon Newcomb
Astr. Papers, vol. 7, pt. 1 (1895):

200. The elements of the four inner planets and the fundamental constants of astronomy. Supplement to the *American Ephemeris and Nautical Almanac* for 1897.
Washington, Gov't print. off., 1895. 9+202 pp.
Preface dated Jan. 7, 1895.
Reviewed in *Mo. Notices R. Astr. Soc.*, vol. 56 (Feb., 1896): 267–272.
Reviewed by F. W. Dyson in *The Observatory*, vol. 18 (May, 1895): 202–205.

201. On the principal fundamental constants of astronomy.
Astr. Jl., vol. 14 (Jan. 31, 1895): 185–189.

202. Note on the solar parallax as derived from the observed parallactic inequality of the moon.
Astr. Jl., vol. 15 (Oct. 16, 1895): 167–168.

203. On the value of the precessional constant.
Astr. Jl., vol. 15 (Nov. 23, 1895): 185–188.

204. Conférence internationale des étoiles fondamentales de 1896. Procès-verbaux.
Paris [Bureau des Longitudes], 1896. 90 pp.
In this report of the discussion and conclusions of this important conference, held in Paris, May 18–21, and in which Bauschinger, Newcomb, Backlund, Downing, Gill, Loewy, Tisserand, and Faye participated, S. N. took the most prominent part, and his remarks appear on practically every page of the discussion.

205. Elements of (33) Polyhymnia.
Astr. Nach., vol. 139 (Jan. 21, 1896): cols. 271–272.
Dated Washington, Jan., 1896. Compare no. 188, above.

206. On Boss's system of declinations and on that of the Astronomische Gesellschaft.
Astr. Jl., vol. 16 (Feb. 3, 1896): 33–36.

207. American judgment of American astronomy.
Science, New York, n. s., vol. 3 (Feb. 21, 1896): 284–286.

208. On the variation of personal equation with the magnitude of the star observed.
Astr. Jl., vol. 16 (Mar. 21, 1896): 65–67.

209. The influence of atmospheric and oceanic currents upon terrestrial latitudes.
Astr. Jl., vol. 16 (Apr. 6, 1896): 81–82.
Also in *Nature*, London, vol. 53 (Apr. 30, 1896): 618–619.
Also in *Sci. Amer. Suppl.*, vol. 42 (July 4, 1896): 17098–17099.

210. Note sur les passages observés de Mercure sur le disque du soleil et sur la question de l'existence des inégalités à longue période dans la longitude moyenne de la lune, dont la cause est encore inconnue, et dans la rotation de la terre sur son axe.
Comptes Rendus, vol. 122 (June 1, 1896): 1235–1239.

211. On the solar motion as a gauge of stellar distances. First paper.
Astr. Jl., vol. 17 (Dec. 10, 1896): 41–44.
Last sentence: "I hope soon, in a second paper, to treat the subject more fully by a modified method." This "second paper" does not seem to have been published, although the subject was treated elsewhere (e. g. nos. 216, 217, 221).

212. "Astronomy," "Photography, Astronomical," "Telescope," in *New American Supplement to the Encyclopædia Britannica* edited . . . [by] D. O. Kellog, 5 vols.
New York and Chicago, The Werner Co., 1897.

213. A new determination of the precessional constant with the resulting precessional motions.
Astr. Papers, vol. 8, pt. 1 (1897): 1–76.

214. Note on the foregoing article [this is, Nyrén's determination of constant aberration at Pulkova.]
Astr. Jl., vol. 17 (Feb. 19, 1897): 90.

215. An ambitious paradoxer.
Science, New York, n. s., vol. 5 (Mar. 5, 1897): 400.
Letter concerning Stephen H. Emmens, author of The *Argentaurum Papers*, part I.

216. The problems of astronomy. An address at the dedication of the Flower Observatory at the University of Pennsylvania, May 12, 1897.
Lancaster, Pa., The New Era Printing Co., 1897, 20 pp.
Also in *Science*, New York, vol. 5 (May 21, 1897): 777–785.
An extract of this, entitled "The extent of the Universe," appeared in *Current Lit.*, vol. 22 (Dec., 1897): 560. An extract, entitled "Professor Newcomb on the distances of the stars," appeared in *Nature*, London, vol. 56 (June 10, 1897): 139–140.
Also in *Smithsonian Report*, 1896 (1898): 83–92.
Also in Side-Lights on Astronomy, under the title "The evolution of astronomical knowledge" (1906): 258–273; see no. 300 in this Section.
Also in the series Little Masterpieces of Science, edited by George Iles: *The Skies and the Earth*, by R. A. Proctor, S. Newcomb, C. Young, T. A. Huxley, G. Iles, C. Lyell, S. Shaler.
New York, Doubleday, Page & Co. (1902): 33–52.
The frontispiece of the volume is a portrait of Newcomb, and there is a brief biographical note.

216A. German translation—Die Probleme der Astronomie.
Himmel und Erde, Berlin, vol. 10 (Nov., 1897): 74–79 (Dec., 1897): 126–135.
Also in *Naturwissenschaftliche Rundschau*, vol. 12 (Aug. 14, 1897): 413–416; (Aug. 21, 1897): 429–431.

217. Solar motion and stellar distances.
The Observatory, London, no. 254 (June, 1897): 247–248.
A letter to the editor dated May 17, 1897, and referring to the May number, in which was "an appreciative notice of a paper of mine On the Solar Motion as a Gauge of Stellar Distances" (no. 211).

218. A new determination of the precessional motion.
Astr. Jl., vol. 17 (June 11 and July 2, 1897): 161–167, 184.
Reprinted in pamphlet form.

219. Reasons for the adoption of new values of the precessional motions; a reply to the remarks of Boss in *A. J.* 410.
Astr. Jl., vol. 18 (Sept. 27, 1897): 33–35.

220. Aspects of American astronomy.
Pop. Astr., vol. 5 (Nov., 1897): 351–367.
Also in *Science*, New York, vol. 6 (Nov. 12, 1897): 709–721.
Also in *Astrophysical Jl.*, vol. 6 (Nov., 1897): 289–309.
Also in *Smithsonian Report*, 1897 (1898): 85–99.
Also in Side-lights on Astronomy (1906): 274–299; see no. 300 in this Section.
Also in *Business Administration* [a textbook of La Salle Extension University, Chicago], edited by M. La Follette, W. M. Handy, and C. Higgins. Chicago, DeBower-Chapline Co., vol. 7 (1909): 67–83.
An address delivered at the University of Chicago, Oct. 22, 1897, in connection with the dedication of the Yerkes Observatory.

221. The solar motion as a gauge of stellar distance.
Astrophysical Jl., vol. 6 (Dec., 1897): 441.
Under "Proceedings of the conference held at the Yerkes Observatory, October 18–21, 1897." Cf. no. 211.
Also in *Publ. Astr. and Astrophysical Soc. of America*, vol. 1 (1910): 27–28.

222. Catalogue of the fundamental stars for the epochs 1875 and 1900 reduced to an absolute system. Prepared by and under the direction of Simon Newcomb.
Astr. Papers, vol. 8, pt. 2 (1898): 77–403.
Preface by Wm. Harkness, dated Mar. 1, 1899.
Introduction by Simon Newcomb, dated May 16, 1898.
Notes and errata by W. G. Thackeray are given in *Mo. Notices R. Astr. Soc.*, vol. 63 (Nov., 1902): 38.

223. Remarks on the precessional motion: a rejoinder.
Astr. Jl., vol. 18 (Feb. 2, 1898): 137–139.

224. Note on the value of the aberration constant derived from Küstner's observations of 1884–85.
Astr. Jl., vol. 18 (Mar. 1, 1898): 165.
Followed, pages 165–166, by a "Note by the editor."

225. Note on Mr. G. W. Hill's "Observations" in *A. J.* 428. [The principal element of precession.]
Astr. Jl., vol. 18 (Mar. 1, 1898): 166.

226. Recent astronomical progress.
Forum, vol. 25 (Mar., 1898): 109–119.

227. Remarks on Prof. Boss's third paper on the precessional motion, *A. J.* 430.
Astr. Jl., vol. 19 (Apr. 14, 1898): 2–3.

228. Tables on the heliocentric motion of Mars.
Astr. Papers, vol. 6, 1898, pt. 4 (1898): 383–586.
Preface to volume dated Washington, May 13, 1898.
Concerning certain errors in these tables, see *Mo. Notices R. Astr. Soc.*, vol. 70 (1910): 654.

229. Sur les formules de nutation basées sur les décisions de la conférence de 1896.
Bull. Astronomique, vol. 15 (July, 1898): 241–246.

230. Reminiscences of an astronomer.
Atlantic Mo., vol. 82 (Aug., 1898): 244–253; (Sept., 1898): 384–393; (Oct., 1898): 519–526. See also no. 282.

231. An unusual aurora.
Science, New York, vol. 8 (Sept. 23, 1898): 410–411.
Letter dated Harpers Ferry, W. Va., Sept. 12, 1898.

232. Usefulness of the planet *DQ* for determining the solar parallax.
Astr. Jl., vol. 19 (Nov. 22, 1898): 147–148.

233. Statement of the theoretical laws of the polar motion.
Astr. Jl., vol. 19 (Dec. 29, 1898): 158–159.
Also in *The Observatory*, London, vol. 12 (Mar., 1899): 115–117.

234. Tables of the heliocentric motion of Uranus.
Astr. Papers, vol. 7, pt. 3 (1899): 287–416.
Preface dated Dec. 1, 1898.

235. Tables of the heliocentric motion of Neptune.
Astr. Papers, vol. 7, pt. 4 (1899): 417–471.

236. Note on the relation of the photographic and visual magnitudes of the stars.
Astr. Nach., vol. 148 (Feb. 10, 1899): cols. 285–286.
Dated Washington, Nov., 1898.

237. On the limitation of the period during which special perturbations can be used in planetary theory.
Astr. Nach., vol. 148 (Mar. 1, 1899): cols. 321–324.
Dated Washington, Dec., 1898.

238. Some points relating to the solar motion and the mean parallax of stars of different orders of magnitude.
Astr. Jl., vol. 20 (Mar. 8, 1899): 1–6.

239. Notes on the problem of the sun's mean temperature.
Astr. Jl., vol. 20 (Mar. 23, 1899): 15.

240. A national observatory.
Science, New York, vol. 9 (Mar. 31, 1899): 465–467.
Anonymous editorial.
Also a letter, page 468, signed by S. Newcomb discussing this question.

241. The unsolved problems of astronomy.
McClure's Mag., vol. 13 (Jnly, 1899): 248–259.
Also in Side-Lights on Astronomy (1906): 1–17; see no. 300 of this Section.
Quoted in *About the Bible, Being a Collection of Extracts from the Writings of Eminent Biblical Scholars and Scientists of Europe and America*, compiled by C. L. Hammond, New York, Cooke & Frye (1900): 33–35; with note about author and quotation about his work from Loewy's article (Section I, no. 12).

242. Professor S. Newcomb at the Royal Astronomical Society.
The Observatory, London, vol. 22 (July, 1899): 256–257.
Also in *Pop. Astr.*, vol. 7 (Aug., 1899): 392–393.
Report of an address delivered June 9, 1899.

243. The terrestrial gegenschein.
Nature, London, vol. 60 (Oct. 5, 1899): 544.
A letter.

244. The solar motion.
The Observatory, London, vol. 22 (Dec. 1899): 443.
Letter dated Washington, Nov. 13, 1899.

245. How the planets are weighed.
McClure's Mag., vol. 14 (Jan., 1900): 290–292.
Also in Side-Lights on Astronomy (1906): 133–139; see no. 300 of this Section.

246. On the distribution of the mean motions of the minor planets.
Astr. Jl., vol. 20 (Feb. 12, 1900): 165–166.

247. A chat about the stars.
The Youth's Companion, Boston, vol. 74 (Feb. 15, 1900): 76–77.
Portrait.

248. Feasibility of determining the solar parallax by observations of *Eros* at the coming opposition, 1900–01.
Astr. Jl., vol. 20 (Apr. 9, 1900): 189–191.

249. Report of the Watson Trustees on the award of the Watson Medal to David Gill.
Science, New York, vol. 11 (May 11, 1900): 721–726.

250. Suggested observations of shadow bands and other unexplained irregularities of light to be made by the members of the National Geographic Society during the eclipse [of the sun].
[Washington (?)] May 18, 1900. 1p.

251. The coming eclipse.
The Evening Post, New York (May 19, 1900).

252. Plans of American eclipse parties.
Astrophysical Jl., vol. 11 (May, 1900): 314–317.
Also in *Proc. and Trans. of the R. Astr. Soc. of Canada* vol. 5 (1900): xix.
Circular letter in connection with the eclipse May 28, 1900, signed by S. Newcomb, chairman of the Eclipse Committee of the Astronomical and Astrophysical Society of America, and others.

253. The coming total eclipse of the sun.
McClure's Mag., New York, vol. 15 (May, 1900): 45–53.

254. Chapters on the stars.
Pop. Sci. Mo., vol. 57 (July, 1900): 227–239; (Aug.): 376–389; (Sept.): 500–516; (Oct.): 638–659; vol. 58 (Nov.): 3–27; (Dec.): 130–147; (Jan., 1901): 307–323; (Feb.): 413–428; (Mar.): 449–466.
The articles were collected, revised, and expanded in book form, no 254B.
Reviewed in *Publ. Astr. Soc. of the Pacific*, vol. 13 (1901); 99–114.

254A. French translations—"Les étoiles variables" [October article], and "Etude du ciel étoilé" [February article].
Ciel et Terre, Brussels, vol. 22 (Aug. 16 and Sept. 1, 1901): 281–290, 305–317; and vol. 23 (Feb. 1, Mar. 15, 1903): 561–574, 592–599.

254B. The Stars: A Study of the Universe.
New York, Putnam, 1901, 11+333 pp.
Reprinted Feb., 1902, June, 1902, Sept., 1904, Oct., 1906, Aug., 1908. This last edition has on title page: New York, G. P. Putnam's Sons, London, J. Murray, 1908. Up to Feb., 1922, 3,520 copies of the work had been sold.
No. 9 in The Science Series, ed. by J. M. Cattell and F. E. Beddard.
London, Murray, Nov., 1901. Second ed. in The Progressive Science Series, London, Murray [Mar.], 1902.
Reviewed in *Nation*, New York, vol. 73 (Nov. 21, 1901): 403.
Reviewed by E. Anding in *Vierteljahrsschrift der Astr. Gesell.*, vol. 37 (1902): 328–348.
Reviewed by H. R. H. in *The Observatory*, London, vol. 25 (Feb., 1902): 96–98.
Reviewed by R. A. Gregory in *Nature*, London, vol. 65 (Mar. 13, 1902): Suppl. viii–x.
Reviewed by W. W. Campbell in *Publ. Astr. Soc. Pacific*, vol. 14 (Apr., 1902): 51–53.
Reviewed in *Spectator*, vol. 88 (May 31, 1902): 846–847.
Reviewed in *Athenaeum*, vol. 1 (May 31, 1902): 694.

254C. Dutch translation—De sterren. Een studie over het heelal door Simon Newcomb. Vertaald met goedvinden van den schrijver, onder toezicht en met een voorwoord van H. G. van de Sande Bakhuyzen.
Leiden, A. W. Sijthoff [1903]. 12+284 pp.

254D. Japanese translation—[Study of the Universe, Stars and Planets, Astronomy. Ichinohe Naozo, translator.]
Tokyo, Shokwa Bo., Nov., 1906, 362 pp.
"Author's note to the Japanese edition" in English.
Portrait reproduced from: Reminescences of an Astronomer (1903); see no. 282 of this Section.

255. The scientific work of the National Geographic Society's eclipse expedition to Norfolk, Va.
Nat. Geogr. Mag., vol. 11 (Aug., 1900): 321-324.

256. Elements of Astronomy.
New York, American Book Co., Oct., 1900. 240 pp
This book has been reprinted eleven times, since 1907, in 1909, 1910, 1911, and 1918. From January 1, 1908, to December 31, 1921, 5,765 copies were sold.
Reviewed in *Nation*, New York, vol. 72 (Feb. 7, 1901): 116.

257. An astronomer's friendship.
Atlantic Mo., vol. 86 (Nov., 1900): 688-693.
Also in Side-lights on Astronomy (1906): 227-235 under the title "An astronomical friendship"; see no. 300 of this section.
The subject of the article is Father Hell; see no. 134.

257A. German translation—Eine Ehrenrettung nach hundert Jahren. *Wissenschaftliche Beilage zur Germania*, no. 16 (1901): 125-127.

258. "Acceleration," "Algebra," "Algol," "Almanac," "Almucantur," "Altazimuth," "Analysis," "Angle," "Asteroids," "Astronomy," "Aurora," "Binary system," "Calculus," "Collimation," "Collimator," "Comets," "Composition of forces," "Curves," "Eclipse," "Energy," "Equation," "Falling bodies," "Fluxions," "Functions," "Geodesy," "Geometry," "Imaginary quantities," "Incommensurables," "Infinites," "Interpolation," "Jupiter," "Light," "Limits," "Logarithms," "Magic squares," "Mars," "Mathematics," "Mercury," "Moon," "Nebular hypothesis," "Observatory," "Occulations," "Orbit," "Parallax," "Perturbations," "Photometry," "Planet," "Precession of the equinoxes." "Probability," "Progression," "Ptolemaic system," "Quadrature of the circle," "Quaternions," "Saturn," "Series," "Solar parallax," "Solar system," "Stars," "Sun," "Telescope," "Time," "Transit," "Transits of Venus," "Trigonometry," "Trilinear coordinates," "Twilight," "Universe," "Venus," "Vulcan," "Year," "Zodiacal light," in *Universal Cyclopedia and Atlas*, newly revised and enlarged. 12 vols.
New York, Appleton, 1901.
S. Newcomb was the "Associate editor" in "astronomy and mathematics" for this new edition as well as for the older work listed as no. 179 in this Section.

259. On the period of the solar spots.
Astrophysical Jl., vol. 13 (Jan., 1901): 1-14.

260. The naval observatory report.
Science, New York, n. s., vol. 13 (Jan. 4, 1901): 1-5.
Anonymous editorial.

261. A notable official report.
Science, New York, n. s., vol. 13 (Jan. 11, 1901): 41-45.
Anonymous editorial.

262. The century's advance in astronomical science.
The Evening Post, New York, Jan. 12, 1901.
Reprinted in *The 19th Century. A Review of Progress during the past One Hundred Years in the Chief Departments of Human Activity*, New York, G. P. Putnam's Sons, 1901, pp. 323-335.

263. On the use of statements of ancient solar eclipses for correcting the elements of the moon's motion, with special reference to Prof. Ginzel's *Spezieller Kanon der Finsternisse*.
Astr. Nach., vol. 154 (Jan. 25, 1901): cols. 197–202.
Dated, Washington, Dec. 5, 1900.

264. Position of the equinox and the values of other elements derived from recent Greenwich and Washington observations of the sun.
Astr. Jl., vol. 21 (May 21, 1901): 141–142.

265. Recent astronomical discoveries.
New York Times (June 16, 1901).

266. A study of the limiting magnitudes of the Cape photographic Durchmusterung.
Astr. Jl., vol. 21 (June 28, 1901): 153–155.

267. La période des taches solaires.
Paris Bull. Soc. Astr. de France, vol. 15 (Aug., 1901): 355–357.

268. On the Cordoba Durchmusterung and some conclusions derived from it.
Astr. Jl., vol. 22 (Sept. 18, 1901): 21–26.

269. An asteroid orbit of great eccentricity [signed by Edward C. Pickering].
Harvard College Observatory Circular, no. 63 (Nov. 19, 1901): 2 pp.
Professor Pickering states that S. Newcomb determined the orbit as given on page 2.
Reprinted as: New Planet 1901 HN.
Astr. Nach., vol. 157 (Dec. 30, 1901): cols. 225–226.

270. A rude attempt to determine the total light of all the stars.
Astrophysical Jl., vol. 14 (Dec. 1901): 297–312.

271. "Astronomy," "Eclipse," "Moon," "Sun," "Telescope," in *Encylopædia Britannica*, 10th ed., 11 vols.
London, Edinburgh, and New York, 1902.
See also nos. 131 and 316.

272. Remarks on certain determinations of the constant of aberration by the U. S. Coast and Geodetic Survey.
Astr. Jl., vol. 22 (Mar. 20, 1902): 114–115.

273. The problem of the universe. A discussion of the results of modern science which relate to the extent and structure of the universe.
International Mo., Burlington, Vt., vol. 5 (Apr., 1902): 395–417.
Also as "The Structure of the Universe" in Side-Lights on Astronomy (1906): 31–59; see no. 300 of this Section.

274. What the astronomers are doing.
Harper's Mag., New York, vol. 105 (July, 1902): 246–249.
Also in Side-Lights on Astronomy (1906): 106–119; see no. 300 of this Section.

275. On the statistical relations among the parallaxes and the proper motions of the stars.
Astr. Jl., vol. 22 (Oct. 1902): 165–169.
Dated Maloja, Engadine, Oct. 15, 1902.

276. Are other worlds inhabited?
The Youth's Companion, Boston, vol. 76 (Dec. 11, 1902): 639–640.

277. Astronomy for Everybody; a Popular Exposition of the Wonders of the Heavens.
New York, McClure, Phillips & Co., Dec. 1902. 15+333 pp.
"The present work grew out of articles contributed to *McClure's Magazine* [nos. 241, 245, 253] a few years since on the unsolved problems of astronomy, total eclipses of the sun and other subjects." Preface.
In the Science for Everybody Series.
In the fall of 1910, 5,000 copies of this work had been sold in America alone. In 1918–19, 500 copies of this work were sold to the American Library Association for the use of the U. S. Army overseas. It is the "best seller" of all books listed in this Section. Doubleday Page is now the publisher.
London, Isbister & Co., June, 1903, 15+341 pp. With an introduction by Sir Robert S. Ball. Cheap ed., London, 1907, 16+341 pp.; other reprints in London by I. Pitman & Sons, 1919 and 1923.
Reviewed *Nation*, New York, vol. 76 (Feb. 26, 1903): 172.
Reviewed *Athenaeum*, London, vol. 2 (Aug. 1, 1903): 261.
Reviewed *Nature*, London, vol. 69 (Nov. 26, 1903): 75–76.
Reviewed *The Observatory*, London, vol. 26 (Oct., 1903): 394–396.

277A. Russian translation—Astronomiîa dlîa vsiekh Per. s Angl., s predisl. A. Orbinskago (Astronomy for Everybody—Translation from the English, with an introduction, by A. Orbinskij.)
Odessa, "Technik," 1905. 14+285 pp.
Second edition, 1911. 20+288 pp.

277B. German translation—Simon Newcomb's Astronomie für Jedermann—Eine allgemeinverständliche Darstellung der Erscheinungen des Himmels. Nach der Übersetzung von F. Gläser, bearbeitet von R. Schorr und K. Graff.
Jena, Verlag von Gustav Fischer, 1907, 8+364 pp.
Zweite Auflage, Jena, 1910, 10+366 pp.+6 maps. Dritte Auflage, 1920, 12+385 pp. Vierte Auflage, 1921, 8+409 pp., mit 1 Titelbild, 3 Tafeln, 3 Sternkarten und 89 Abbildungen.

277C. Bohemian translation—S. Newcombova Astronomie pro Každého. Se svolením spisovatelovým volně přeložil Dr. Bohuslav Mašek.
Prague, J. Otto, 1909, 391 pp. + 5 plates (Portrait).
Česká Knihovna zábavy a poučení. Vydává Ústřední spolek českých professorů. Pořádá František Bílý. Číslo 25. Translation of the London edition.

277D. Swedish translation—Newcomb Astronomi för Alla, en populär framställning av himmelsföreteelserna. Svensk bearbetning av Östen Bergstrand.
Stockholm, A. Bonnier, [1909], 10+308 pp.
"Vetenskap och Bildning ...," Band II. There were 3,000 copies in this edition, which was prepared for use as a textbook in the high-schools.

278. [Length of the tropical year.]
[*Annals of the Central Chamber for Weights and Measures* (Russian)], St. Petersburg, vol. 5 (1903): 84–88.
Letter from Prof. Newcomb, translated into Russian, by F. Blumbach.

279. The universe as an organism. [Report of an address before the Astronomical and Astrophysical Society of America, Dec. 29, 1902.]
Science, New York, n. s. vol. 17 (Jan. 23, 1903): 121–129.
Also in *Sci. Amer. Suppl.*, vol. 55 (Feb. 21, 1903): 22694–22696.
Also in Side-Lights on Astronomy (1906): 300–311; see no. 300 of this Section.

279A. French translation. L'univers comme organisme.
Revue Scientifique, Paris, 4 s., vol. 19 (Mar. 14, 1903): 321–326.

279B. German translation (abridged). Das Weltall als einheitlicher Organismus.
Astronomische Rundschau, Lussinpiccolo, Austria, vol. 5, no. 44 (1903): 113–119.

280. Present state and needs of astronomical research.
Carnegie Institution of Washington, Year Book, No. 1, 1902 (Jan. 1903): 147–152.
Dated Washington, Oct. 8, 1902.
Appendix E to Report of advisory committee on astronomy, submitted by Simon Newcomb *et al.*, pages 87–104.

281. On the desirableness of a reinvestigation of the problems growing out of the mean motion of the moon.
Mo. Notices R. Astr. Soc., vol. 63 (Mar. 13, 1903): 316–324.

282. The Reminiscences of an Astronomer.
Boston, Houghton, Mifflin & Co. [Oct.], 1903, 12+424 pp.
See also no. 230 of this Section, and no. 14 of Section I.

283. [*The Moon Considered as a Planet*, by James Nasmyth and James Carpenter.]
Nation, New York, vol. 77 (Nov. 5, 1903): 368–369.
Anonymous review.

284. The new problems of the universe.
Harper's Mag., vol. 107 (Nov., 1903): 872–876.
Also in Side-Lights on Astronomy (1906): 18–30; see no. 300 in this Section.

285. On the apparent extent of the illumination surrounding a new star on the hypothesis that it is reflected light.
Astr. Jl., vol. 23 (Nov. 25, 1903): 212.

286. "Asteroids," "Astronomy," "Astronomy: History," "Astronomy: Practical," "Astronomy: Theoretical," "Aurora Borealis," "Clock," "Geodesy," "Gravitation," "Horizon," "Mercury," "Parallax," "Refraction," "Saturn," "Scintillation," "Solar System," "Stars," "Sun," "Time," "Time: Measurement of," "Transits," "Universe," in *Encyclopedia Americana*, 22 volumes.
New York, *Scientific American*, 1904.
S. Newcomb was the "department and advisory editor" in astronomy for this work. In the 1920 edition of this *Encyclopedia* (in 30 volumes) the articles "Clock," "Gravitation," "Time," "Time: Measurement of" are unsigned; the article "Mercury" is signed by Eric Doolittle alone, and the articles "Horizon," "Parallax," "Refraction," "Scintillation," "Solar System," and "Transits" by Simon Newcomb alone; the others are signed by Newcomb with the added statement "Revised by Eric Doolittle."

287. Wallace on life in the universe.
Nation, New York, vol. 78 (Jan. 14, 1904): 34–35.
Anonymous review.

288. [Note on Pickering and photographs of the moon.]
Nation, New York, vol. 78 (Jan. 28, 1904): 71.
Anonymous.

289. Stars variable and compound.
Good Words, Edinburgh, vol. 45 (Mar., 1904): 217–219.

290. Remarks on the determination of the parallactic inequality of the moon.
Mo. Notices R. Astr. Soc., vol. 64 (May, 1904): 570–571.
Dated, Washington, May 11, 1904.

291. On the position of the galactic and other principal planes toward which the stars tend to crowd.
Carnegie Institution of Washington Contributions to Stellar Statistics, Washington (June, 1904), 32 pp.
First paper. Publication No. 10. "Contribution to stellar statistics," first paper.

292. The extent of the universe.
Harper's Mag., vol. 109 (Oct., 1904): 795–801.
Also in Side-Lights on Astronomy (1906): 60–65; see no. 300 in this Section.
Also in *Scientific papers; physics, chemistry, astronomy, geology, with introductions, notes, and illustrations.* New York, P. F. Collier & Son, vol. 30 (1910): 323–326.

293. On the eclipse of Agathocles.
Mo. Notices R. Astr. Soc., vol. 65 (Dec. 9, 1904): 181–183.
Also in *Pop. Astr.*, vol. 13 (Apr., 1905): 199–201.

294. Aufforderung betr. Beobachtungen von Sternbedeckungen.
Astr. Nach., vol. 167 (Jan. 17, 1905): cols. 79–80.
Dated, Washington, Dec. 13, 1904.

295. Peters' catalogue.
The Observatory, London, vol. 28 (Apr. and Aug., 1905): 185–186; 322,
Letters dated Feb. 6 and June 12, 1905.

296. Life in the universe.
Harper's Mag., vol. 111 (Aug., 1905): 404–408.
Also in Side-Lights on Astronomy (1906): 120–132; see no. 300 in this Section.

297. An observation of the zodiacal light to the north of the sun.
Astrophysical Jl., vol. 22 (Oct., 1905): 209–212.
In the *Journal*, vol. 23 (Mar., 1906): 168–169 is a "Note on Professor Newcomb's observations of the zodiacal light," by E. E. Barnard. This is followed by "Note by Professor Newcomb" (page 169).

298. Note on the astronomical value of ancient statements of solar eclipses.
Mo. Notices R. Astr. Soc., vol. 66 (Dec., 1905): 34–35.
This note is followed by comments on the note by P. H. Cowell.

299. A compendium of spherical astronomy with its application to the determination and reduction of positions of the fixed stars.
New York and London, Macmillan Co., June, 1906, 18+444 pp.
"The present volume is the first of a projected series having the double purpose of developing the elements of Practical and Theoretical Astronomy for the special student of the subject, and of serving as a handbook of convenient reference for the use of the working astronomer in applying methods and formulæ." Preface.
The following is an extract from a letter of Sir Robert Ball concerning his work on spherical astronomy (*Reminescences and letters of Sir Robert Ball*, edited by W. V. Ball, Boston, Little, Brown (1915): 161–162): "I have seen no notice of my book except one in the *Scotsman*, and I have only had one letter on the subject which calls for any remark. It was from Professor Newcomb, who, as you know, has recently published a book on the same subject. He wrote:
"It is very interesting to notice how completely the purpose of your work differs from that of mine. You treat the subject as an interesting branch of applied mathematics, while I have mostly in view the requirements of the working astronomer.
"This extract will be a useful pellet, when I am accused, as of course I may be, of having stolen everything in the book, from Newcomb's work. Had I not this, I should merely have had to fall back on the stupid fact that ninety-nine per cent of my book was written before Newcomb's appeared. This being merely a truth would, of course, be no use in connection with the average 'review,'" Compare no. 154 of this Section.
About 1,020 copies of the work were printed and it is now out of print.
Reviewed in *The Observatory*, vol. 29 (Sept., 1906): 366–368.
Reviewed in *Nature*, vol. 74 (Aug. 16. 1906): 379–380,
Reviewed in *Jl. British Astr. Assoc.*, vol. 17 (Oct., 1907): 44–45.
Reviewed in *Phil. Mag.*, 6 s., vol. 15 (Apr., 1908): 570–571.

300. Side-lights on Astronomy and Kindred Fields of Popular Science: essays and addresses.
New York and London, Harper & Bros., 1906. 7+349 pp.+Portrait.
CONTENTS: 1. The unsolved problems of astronomy (no. 241). 2. The new problems of the universe (no. 284). 3. The structure of the universe (no. 273). 4. The extent of the universe (no. 292). 5. Making and using a telescope (no. 127). 6. What the astronomers are doing (no. 274). 7. Life in the universe (no. 296). 8. How the planets are weighed (no. 245). 9. The mariner's compass (no. 125, Section V). 10. The fairyland of geometry (no. 33, Section III). 11. The organization of scientific research (no. 136, Section V). 12. Can we make it rain. (no. 85, Section V). 13. The astronomical Ephemeris and Nautical Almanac (no. 108). 14. The world's debt to astronomy (no. 192). 15. An astronomical friendship (no. 257). 16. The evolution of the scientific investigator (no. 128, Section V). 17. The evolution of astronomical knowledge (no. 216). 18. Aspects of American astronomy (no. 220). 19. The universe as an organism (no. 279). 20. The relation of scientific method to social progress (no. 46, Section V). 21. The outlook for the flying machine (no. 120, Section V).
Up to July, 1920, about 4,050 copies of this work had been printed: In June, 1906, 2,500 copies; in October, 1909, 750; in February, 1914, 300; in June, 1920, 500. Over 500 copies were sold in England.

301. On Mr. Cowell's discussions of ancient eclipses of the sun.
Mo. Notices R. Astr. Soc., vol. 64 (June, 1906): 470–472.

302. Development of the two principal non-secular terms in the radius-vector of a planet which are independent of the mean longitude of the disturbing planet.
Astr. Jl., vol. 25 (Dec., 1906): 111–114.

303. On the action of the planets on the moon.
Astr. Jl., vol. 25 (Feb. 26, 1907): 129–132.

304. [The sun's radiation.]
Science, New York, n. s., vol. 25 (May 24, 1907): 823–824.

305. The optical and psychological principles involved in the interpretation of the so-called canals of Mars.
Astrophysical Jl., vol. 26 (July, 1907): 1–17.
Cf. *Knowledge and Scientific News*, London, n. s., vol. 4 (Sept., 1907): 193–196.

306. Investigation of inequalities in the motion of the moon, produced by the action of the planets; by Simon Newcomb, assisted by Frank E. Ross.
Carnegie Institution of Washington Publ. no. 72, Aug. 1907. 8+160 pp.
Reviewed in *Nature*, London, vol. 77 (Nov. 14, 1909): 43–44.

307. The loss of energy by the sun.
The Observatory, London, vol. 30 (Oct. 1907): 384.

308. Note on the preceding paper [i. e. The canals of Mars, optically and psychologically considered, a reply to Professor Newcomb, by Percival Lowell.]
Astrophysical Jl., vol. 26 (Oct. 1907): 141.
"Reply to Professor Newcomb's note," page 142.

309. A search for fluctuations in the sun's thermal radiation through their influence on terrestrial temperature.
Trans. Amer. Phil. Soc., Philadelphia, n. s., vol. 21, pt. 5 (Mar. 1908): 309–387.
Read Oct. 4, 1907.

310. Considerations on the form and arrangement of new tables of the moon.
Mo. Notices R. Astr. Soc., vol. 68 (June, 1908): 538–544.

311. Fallacies about Mars.
Harper's Weekly, vol. 52 (July 25, 1908): 11–12.

312. Fluctuations in the moon's mean motion.
Mo. Notices R. Astr. Soc., vol. 69 (Jan. 1909): 164–169.

313. Comparison of ancient eclipses of the sun with modern elements of the moon's motion.
Mo. Notices R. Astr. Soc., vol. 69 (Mar. 1909): 460–467.
A note by J. K. Fotheringham follows this paper.

314. La théorie du mouvement de la lune, son histoire et son état actuel.
Revue générale des sciences pures et appliquées, Paris, vol. 19 (Sept. 15, 1908): 686–691.
Also in *Atti del IV. Congresso internazionale dei Matematici*, Roma, Tipografia della R. Accademia dei Lincei, vol. 1 (1909): 135–143.
Address as a vice president of the Congress.
Also printed as a pamphlet, Roma, 1908, 10 pp.

315. Preface [to A. O. Leuschner's "Tables of minor planets discovered by J. C. Watson. Part I]."
Mem. Nat. Acad. Sci., vol. 10, seventh memoir (1910): 197.
Preface signed by Simon Newcomb; dated Washington, 1908, March.

316. "Astronomy, Descriptive," "Astrophysics," "Comet," "Eclipse" (four of five sections), "Ecliptic," "Gravitation" (in part), "Jupiter: Satellites," "Latitude," "Light; Velocity," "Mars," "Moon," "Orbit," "Parallax," "Planet," "Planets: Minor," "Refraction: Astronomical Refraction." "Saturn," "Solar system," "Time: standard," "Uranus (astronomy)," "Venus (astronomy)," "Zodiacal light," in *Encylopædia Britannica*, 11th ed., 28 volumes.

Cambridge, University Press, 1910–1911; vol. 2 (1910): 800-808, 819; 6 (1910): 759–763, pls.; 8 (1910): 891–895; 12 (1910): 384–385; 15 (1911): 564–565; 16 (1911): 267–268, 623–626; 17 (1911): 761–765; 18 (1911): 154–155, 802–807, pls.; 19 (1911): 385–387; 20 (1911): 164–165, 760–762; 21 (1911): 714–719, pls.; 23 (1911): 29; 24 (1911): 231–232; 25 (1911): 357–358; 26 (1911): 987–988; 27 (1911): 788–789, 1013–1014; 28 (1911): 998–1000.

See also nos. 131, 271.

317. Researches on the motion of the moon, Part II. The mean motion of the moon and other astronomical elements derived from observations extending from the period of the Babylonians until A. D. 1908.

Astr. Papers, vol. 9, pt. 1 (1912): 249 pp.

Author's preface dated June 15, 1909. He died July 11, 1909.
Part I was published in 1878; see there (no. 101)

NOTE.—Since a new title, No. 180X, was inserted in this list, the total number of titles it this Section is 318.

Section III.

MATHEMATICS.

The titles of this section are listed under (*a*) Theory of probabilities and least squares, (*b*) mathematical texts, (*c*) miscellaneous. For other mathematical articles see Section II, nos. 102, 181, and 258; also Section V, no. 113.

(A) THEORY OF PROBABILITIES AND LEAST SQUARES.

Almost from the beginning of his scientific career, on to the closing years of his life, Simon Newcomb was intensely interested in questions involving the theory of probabilities, and in the subject of least squares. Such questions frequently occupied his leisure moments and had he been longer spared there is little doubt but that something more elaborate along these lines than he had yet published would have come from his pen. Among his MSS. there is considerable material on least squares. This seems to be preparatory to a text which should be one of a projected series, in which the compendium of spherical astronomy was the first work, "to cover as much of the field of practical and theoretical astronomy as I shall be able to deal with during the next few years." See under no. 299, Section II.

1. Notes on the Theory of Probabilities.

   Math. Mo. (Runkle's), Cambridge, Mass., vol. 1 (Jan., 1859), 136–139; (Apr., 1859): 233–235; (July, 1859): 331–335, 349–350; vol. 2 (Jan., 1860): 134–140 (May, 1860): 272–275; vol. 3 (July, 1861): 68; (July, 1861): 119–125; (Aug. 1861): 341–349.

   During the three years of its existence Runkle's *Monthly* consisted largely of problems proposed and solved. Prizes were offered for the best solutions and Simon Newcomb, W. P. G. Bartlett, and T. H. Safford were the judges.

2. "Solutions of problems in probabilities."

   Math. Mo. (Runkle's), Cambridge, Mass., vol. 1 (July, 1859): 349–350.

3. Solution of Prize Question: "Two rods 2 and 4 feet long, respectively, having their middle points connected by a string 1 foot in length are thrown up; show that the chance of their crossing is $\frac{1}{2}+2/\pi^2$."

   The Lady's and Gentleman's Diary, London, 1860, pp. 67–68.

4. On the objections raised by Mr. Mill and others against Laplace's presentation of the doctrine of probabilities.

   Amer. Acad. Proc., Cambridge, Mass., vol. 4 for 1857–1860 (1860): 433–440.

5. [Solution of the problem: "Two great circles are drawn at random on a sphere. What is the probability that their mutual inclination, taken less than 90, will be contained between any given limits, as n and m?"]

   Math. Mo. (Runkle's), Cambridge, Mass., vol. 3 (Dec., 1860): 68–69.

6. A mechanical representation of a familiar problem [in least squares].

   Mo. Notices R. Astr. Soc., vol. 33 (Suppl., 1873): 573.

   Paper read before the Philosophical Society of Washington, June 7, 1873. "Note on a mechanical representation of some cases in the method of least squares" on page 574.

7. Note on the frequency of use of the different digits in natural numbers.

   Amer. Jl. Math., Baltimore, vol. 4 (Jan., 1881): 39–40.

8. A generalized theory of the combination of observations so as to obtain the best result.

   Amer. Jl. Math., vol. 8 (Oct., 1886): 343–366.

   Reviewed in *The Observatory*, London, vol. 9 (Oct., 1886): 369–370.

9. Problem: "A pack of cards of any specification is taken—say that there are p cards marked 1, q cards 2, r cards 3, and so on—and, being shuffled, is dealt out on a table; so long as the cards that appear have numbers that are in descending order of magnitude they are

placed in one pack together—equality of number counting as descending order—but directly the descending order is broken a fresh pack is commenced, and so on until all the cards have been dealt. The probability that there will result exactly m packs or at most m packs is required."

Phil. Trans. R. Soc., London, series A, vol. 207 (Feb., 1908): 65.

Also in P. A. MacMahon, *Combinatory Analysis*, Cambridge, University Press, 1915, Section IV: "The Theory of Composition of Numbers," Chapter IV, "Simon Newcomb's Problem," pp. 187 f.

The problem occurs first in "Second Memoir on the Composition of Numbers" which Major MacMahon read before the Royal Society, Dec. 6, 1906. (The first memoir was read Nov. 24, 1892, and is to be found in the *Philosophical Transactions*, vol. 184 A, pp. 835–902.) The "problem under investigation" was brought to the Major's notice by Simon Newcomb to whom it was suggested by a game of "patience" played with ordinary playing cards which he found to be a recreation in the few hours that he could spare from astronomical work. See *The Observatory*, London, vol. 30 (Feb. 1907): 113

(B) MATHEMATICAL TEXTS.

10. Algebra for Schools and Colleges. (Newcomb's Mathematical Series.)

New York, Holt, June, 1881. 8 vo. 11+454 pp.

Eleven other editions or reprints varying in size from 250 to 1,050 copies each, were printed as follows: Sept., 1881; Aug., 1882; Sept., 1883; Aug., 1884; July, 1885; Aug., 1887; Aug., 1888 (destroyed by fire); Feb., 1889; Aug., 1895; Dec., 1896; Aug., 1903. The number of copies printed in all twelve editions totaled 8,800. The number of pages in the latest revised edition was 14+546.

Although "Algebra for Schools and Colleges" is on the title-page of the various editions, on the back of the book the title is simply "College Algebra" which was later changed to "Algebra for Colleges."

This book was written for his daughter Anita, now Mrs. (Dr.) McGee, who studied it in MSS. as it was prepared. This was finally published, and a whole series ef mathematical books followed.

The Answers have also been published separately in pamphlet form, New York, Holt, 1889, 25 pp.

10A. Key to Algebra for Schools and Colleges. (Newcomb's Mathematical Series.)

New York, Holt [April], 1882. 8 vo. 283 pp.

The second edition published in July, 1885, contained 2+297 pp. The third and last edition appeared in Aug., 1889.

The total number of copies printed for all three editions was 750. In the preface occur the statements: "The greater part of this key has been prepared, and the proofs read, by Professors J. Howard Gore, of Columbian University, Washington, and J. W. Gore, of the University of Virginia. ... A few oral exercises on the principles taught in the opening book have been added for the practice of beginners in the subject."

11. Elements of Geometry (Newcomb's Mathematical Course).

New York, Holt [August], 1881. 8+399 pp.

Five other editions or reprints were printed, as follows: Dec., 1882; Sept., 1884: Aug., 1887; Dec., 1888 (670 copies destroyed by fire, also 300 copies of the old edition); July, 1891.

The number of copies printed in all six editions or reprints totaled 6,000; of these the number sold totaled 3,902. The number of pages in the latest revised edition was 10+399.

See also under no. 13.

12. Elements of plane and spherical trigonometry with logarithmic and other mathematical tables and examples of their use and hints on the art of computation. (Newcomb's Mathematical Course.)

New York, Holt [April], 1882. 6+160+6+80+104 pp.

Seven other editions or reprints, varying in size from 250 to 1,225 copies each, were printed, as follows: Sept., 1882; Sept., 1883; May, 1887; March, 1889; Aug., 1893; May, 1898; March, 1902.

The number of copies printed in all of these editions or reprints totaled 3,975.

Elements of trigonometry [as a separate work]. 6+168 pp. 2,025 copies were printed in April, 1882, March, 1883, May, 1887, Feb., 1889, and Dec., 1906.

There was also issued as a separate work: Logarithmic and other mathematical tables, with examples of their use and hints on the art of computation. 6+80+104 pp. 12,258 copies were printed in April, 1882; Nov., 1882; April, 1886; May, 1887; March, 1889; Feb., 1892; Aug., 1893; Oct., 1895; Sept., 1896; May, 1898; July, 1901; Dec., 1905; June, 1908; Sept., 1912; Aug., 1914; June, 1916; July, 1918; July, 1919; June, 1921.

This is now the "best seller" among Newcomb's books; in 1921, 340 copies were sold.

13. Elements of plane geometry and trigonometry, with four-place logarithmic and trigonometric tables.

New York, Holt [September], 1882. 7+335 pp.

"The present work comprises most of Part I of the author's Elements of Geometry and the essentials of the first parts of his trigonometry, followed by a set of four-place logarithmic tables." Preface. 1,000 copies were printed; 500 lost by fire.

14. A School Algebra. (Newcomb's Mathematical Course.)
New York, Holt [June], 1882. 8+279 pp.
There were six other editions or reprints, as follows: Aug., 1882; Aug., 1883; Oct., 1887; Nov., 1888; March, 1889; July, 1891.
In all editions or reprints, 6,500 copies were printed.
Answers were published separately in pamphlet form, for example in 1889, 25 pp.

14A. Key to School Algebra.
New York, Holt, Aug., 1883, another edition, Aug., 1889.
Total number of copies printed, 500.

15. Elements of analytic geometry. (Newcomb's Mathematical course.)
New York, Holt [August], 1884. 8+357 pp.
There were five other editions or reprints published in: Jan., 1885; July, 1885; Feb., 1889; Sept., 1892; Apr., 1895.
In all editions or reprints the total number of copies printed was 4,000.
"Added is a brief course of reading in geometry." Preface.

16. Essentials of trigonometry, plane and spherical, with three and four place tables, logarithmic and trigonometric. (Newcomb's Mathematical course.)
New York, Holt [October], 1884. 6+187 pp.
There were other editions or reprints in Sept., 1890, 1895, 1899. In all, 1,250 copies were printed; 100 copies were destroyed by fire.
A few pages (167–187) were reprinted with cover title by W. H. Lowdermilk and Co., at Washington, in 1905, under the title: Three and four place logarithmic and trigonometric tables.

17. Elements of the differential and integral calculus. (Newcomb's Mathematical course.)
New York, Holt [September], 1887. 12+307 pp.
Other editions or reprints appeared in July, 1889, and Sept., 1892.
In all editions or reprints, 2,150 copies were printed.

(c) MISCELLANEOUS.

18. On a method in dynamics.
Astr. Jl., vol. 5 (Apr. 2, 1858): 121–127.
Dated Feb. 12, 1858.

19. Note on differentiation.
Math. Mo. (Runkle's), Cambridge, Mass., vol. 1 (Sept., 1859): 396–397.

20. On the mathematical theory of heat in equilibrium.
Math. Mo. (Runkle's), Cambridge, Mass., vol. 2 (July, 1860): 346–354.

21. Investigation of the dynamical theory of gases.
Amer. Acad. Proc., Cambridge, vol. 5, 1860–1862 (1861): 112–114.

22. [Note on Benjamin Peirce.]
Nation, New York, vol. 18 (Mar. 5, 1877): 157.
Anonymous.

23. Elementary theorems relating to the geometry of a space of three dimensions and of uniform positive curvature in the fourth dimensions.
Crelle's Jl., vol. 83 (1877): 293–299.
"Full extracts of this very important contribution to noneuclidean geometry are given in the *Encyclopædia Britannica*, article 'measurement.'" Quotation from no. 4, Section 1 of this bibliography.

24. Note on a class of transformation which surfaces may undergo in space of more than three dimensions.
Amer. Jl. Math., vol. 1 (1878): 1–4.
One of the results found is: "If a fourth dimension were added to space a closed material surface (or shell) could be turned inside out by simple flexure; without either stretching or tearing."

25. The fundamental definitions and propositions of geometry with special reference to the syllabus of the Association for the Improvement of Geometrical Teaching. [A. I. G. T.]
Nature, vol. 21 (1880): 293–295.

26. Show that $\log\left(1-\frac{2\eta}{1+\eta^2}\cos x\right)=-\eta^2+\frac{\eta^4}{2}-\frac{\eta^6}{3}+\cdot\cdot\cdot-2\eta\cos x-\frac{1}{2}\,2\eta^2\cos 2x$

$$-\frac{1}{3}\,2\eta^3\cos 3x-\cdot\cdot\cdot=\sum_{i=1}^{i=\infty}\text{ Thus: }(-1)^i\frac{\eta^{2i}}{i}-\sum_{i=l}^{i=\infty}\frac{2\eta^i}{i}\cos ix$$

Math. Questions with solutions from the Educ. Times, London, vol. 36 (1881): 116; Question no. 6859.

27. Remarks on the doctrine of limits.
Analyst, Des Moines, Iowa, vol. 9 (July, 1882): 114–115.

28. (1) The teaching of mathematics, Elementary Mathematics; (2) Mathematical teaching.
Educ. Rev., New York, vol. 4 (Oct., 1892): 277–286; vol. 6 (Nov., 1893): 332–341.

29. Modern mathematical thought.
Bull. N. Y. Math. Soc., vol. 3 (Jan. 1894): 95–107.
Also in *Nature*, London, vol. 49 (Feb. 1, 1894): 325.
An address delivered before the N. Y. Mathematical Society at its annual meeting, Dec. 28, 1893.

29A. Italian translation—Pensiero matematico moderno.
Rivista di matematica (Peano), vol. 4 (1894): 121–134.

30. The philosophy of hyperspace.
Science, n. s., vol. 7 (Jan. 7, 1898): 1–7.
Also in *Sci. Amer. Supp.*, vol. 45 (Feb. 12, 1898): 18450–18451.
Also in *Bull. Amer. Math. Soc.*, vol. 4 (Feb. 1898): 187–195.
Also in *Pop. Astr.*, vol. 6 (Sept., 1898): 380–389.
Presidential address before the American Mathematical Society, Dec. 29, 1897.

31. Note [on being elected editor in chief].
Amer. Jl. Math., vol. 20 (April, 1899).

32. Professor Thomas Craig, Ph. D. [Died May 8, 1900].
Amer. Jl. Math., vol. 22 (1900), one unnumbered page.
Appended to the sketch is the note: "The writer is indebted to Dr. L. P. Eisenhart for part of the material on which this notice is based."

33. The fairyland of geometry.
Harper's Mag., vol. 104 (Jan., 1902): 249–252.
Also in: Side-lights on Astronomy (1906); see no. 300 of Section II.

34. An account of Professor Runkle's *Mathematical Monthly*.
Amer. Math. Mo., Springfield, Mo., vol. 10 (May, 1903): 130–133.

35. Methods of teaching arithmetic.
Educ. Rev., New York, vol. 31 (Apr., 1906): 339–350.
Also in *Nat. Educ. Assoc. Proc.* (1906): 686–99.

Section IV.

ECONOMICS.

1. A critical examination of our financial policy during the southern rebellion.
   New York, Appleton, 1865. 222 pp.
   Reviewed [by F. Bowen], *N. Amer. Rev.*, New York, vol. 100 (Apr., 1865): 601–613.
   This work was published at Newcomb's own expense. Since the author was an unknown young man whose name on the title-page was given simply as "Simon Newcomb," all of the edition was not sold

2. Our financial future.
   N. Amer. Rev., vol. 102 (Jan., 1866): 100–135.
   Anonymous.

3. [Peto's *Taxation.*]
   N. Amer. Rev., vol. 104 (Jan., 1867): 255–261.
   Anonymous review.

4. The let-alone principle.
   N. Amer. Rev., vol. 110 (Jan., 1870 : 1–33.

5. The labor question.
   N. Amer. Rev., vol. 111 (July, 1870): 122–125.

6. Baxter's *National Debts.*
   N. Amer. Rev., vol. 114 (Jan., 1872): 189–193.

7. Jevon's *Theory of Political Economy.*
   N. Amer. Rev., vol. 114 (Apr., 1872): 435–440.
   By "S. N."

8. The session.
   N. Amer. Rev., vol. 117 (July, 1873): 182–223.
   Anonymous review of work, especially financial, in Congress.

9. Treasury and public opinion.
   Nation, New York, vol. 18 (June 4, 1874): 358–359.
   Anonymous editorial.

10. Thompson's *National Economy.*
    Nation, New York, vol. 20 (May 13, 1875): 333–335; vol. 21 (July 15, 1875): 41.
    Anonymous review, and note on the "Industrial League," Philadelphia.

11. The method and province of political economy.
    N. Amer. Rev., vol. 121 (Oct., 1875): 241–270.

12. [Jevon's *Money, and the Mechanism of Exchange.*]
    Nation, New York, vol. 21 (Dec. 16, 1875): 390–391.
    Anonymous review.

13. The ABC of finance, or The money question familiarly explained to every-day people in nine short and easy lessons.
    Harper's Weekly, Lessons I–III, vol. 19 (Dec. 18, 1875): 1018–1019; lessons IV–V, vol. 19 (Dec., 25): 1042· lessons VI–VII, vol. 20 (Jan. 1, 1876): 10; lessons VIII–IX, vol. 20 (Jan. 8): 30–31.

13A. The ABC of finance; or, The money and labor questions familiarly explained to common people, in short and easy lessons.
    New York, Harpers, s. d. [c. 1877], pp. 7–115. Another edition, 1878, pp. 7–115.
    Harper's Half-Hour Series, vol. 32.
    Preface: "A part of these 'lessons' appeared some time since in *Harper's Weekly*. The unexpected favor with which they were received, by being reprinted, in whole or in part, by newspapers in various sections of the country, has suggested their reproduction in a more permanent form. They are now completed, by the addition of several chapters bearing on the labor questions of the present day."
    There are fifteen lessons in the book which had a large sale.

14. Price on *Currency and Banking.*
    Nation, New York, vol. 21 (Dec. 30, 1875): 420-421.
    Anonymous review.

15. Walker on *The Wages Question.*
    Nation, New York, vol. 23 (July 6, 1876): 12–13.
    Anonymous review.

16. Shadwell's *System of Political Economy.*
Nation, New York, vol. 24 (June 28, 1877): 385–386.
Anonymous review.

17. Walker on *Money.*
Nation, New York, vol. 26 (Apr. 11, 1878): 244–245.
Anonymous review of a work published in 1878.

18. The silver conference and the silver question.
International Rev., New York, vol. 6 (Mar., 1879): 309–333.

19. The standard of value.
N. Amer. Rev., vol. 129 (Sept., 1879): 233–237.

20. Walker's *Money* [*in its relation to Trade and Industry.*]
Nation, New York, vol. 29 (Sept. 18, 1879): 197–198.
Anonymous review of a work published in 1879.

21. The organization of labor.
Princeton Rev., New York, (May, 1880): 393–410; (Sept., 1880): 231–246.

22. Principles of taxation.
N. Amer. Rev., vol. 131 (Aug., 1880): 142–156.

23. The two schools of political economy.
Princeton Rev., New York, n. s., vol. 14 (Nov., 1884): 291–301.

24. Principles of political economy.
New York, Harper's, 1886 [c. 1885]. 16+548 pp.
Reprinted in 1887, 1890, and 1895. In all 2,500 copies were printed.
Reviewed in *Science*, New York, vol. 6 (Nov. 27, 1885): 470–471, by E. J. James.
Reviewed in *Nation*, New York, vol. 42 (Jan. 14, 1886): 38–39.
Listed with comment in Sonnenschein's *Reader's Guide*. See also no. 33, Section I, of this bibliography.

25 Newcomb's *Political Economy.*
Science, New York, vol. 6 (Dec. 4, 1885): 495.
Letter in reply to criticisms in James's review, no. 24 (above).

26. Views of economists on the silver question.
Science, New York, vol. 7 (Mar. 19, 1886): 265–266.

27. The labor problem.
Independent, New York, vol. 38 (Mar. 25, 1886): 358.

28. An economist's advice to the Knights of Labor.
Nation, New York, vol. 42 (Apr. 8, 1886): 292–293.
Anonymous editorial.

29. A plain man's talk on the labor question.
Independent, New York, vol. 38 (May 13–Sept. 9, 1886).
"Society as a coöperative organization" (May 13): 581–582; "Railway monopoly" (May 20): 613; "Our common interests" (May 27): 646–647; "Benefits and evils of organized action" (June 3): 680; "How one man may do the work of ten thousand" (June 10): 718; "Was it good for us that we allowed one man to make a hundred million dollars?" (June 17): 748; "The past and the present of the mechanic" (June 24): 782; "The account current—answers to questions" (July 1): 811–812; "A talk to a Knight of Labor" (July 15): 877–878; "More of the railroad question" (July 29): 942–943; "Another talk to a Knight of Labor" (Aug. 12): 1006; "How can all get better wages?" (Aug. 19): 1036–1037; "Cheap labor and its effects" (Aug. 26–Sept. 2): 1067–1068, 1103; "Is waste a good?" (Sept. 9): 1133–1134; "The moral side of the question" (Sept. 16): 1165.

29A. A plain man's talk on the labor question.
New York, Harpers, 1886, 16 mo., 195 pp.
Preface: "The following chapters owe their inception to the editor of the *New York Independent*, in which journal the outlines of most of them have recently appeared. They are now recast, amplified, and submitted to the courteous consideration of the reader."
The edition of this book contained 1,500 copies.
Listed with comment in Sonnenschein's *Reader's Guide*.

30. Aspects of the economic discussion.
Science, New York, vol. 7 (June 18, 1886): 538–542.
Also in *Science Economic Discussion*, New York, The Science Company, 1886. Paper no. 5, pp. 57–67.

31. Can economists agree upon the basis of their teachings?
Science, New York, vol. 8 (July 9, 1886): 25–26.

32. What is a friend of labor?
Nation, New York, vol. 43 (Sept. 30, 1886): 265–266.
Anonymous editorial.

33. Dr. Ely on the labor movement.
Nation, New York, vol. 43 (Oct. 7, 1886): 293–294.
Anonymous review of R. T. Ely's *The Labor Movement in America*.

34. Soap-bubbles of socialism.
N. Amer. Rev., vol. 150 (May, 1890): 563–571.

35. The money question.
The Sun, Baltimore, vol. 109 (May 22–July 3, 1891).
"Professor Simon Newcomb on popular delusions. Too much of a good thing ..." (May 22): 1, 1½ cols.; "Prof. Newcomb discusses the philosophy of currency. What gives money its value ... second article" (June 18): suppl., 1¼ cols.; "Free coinage really means not silver but certificates. A dollar note for eighty cents ... third article" (June 27): suppl., 1½ cols.; "Prof. Newcomb's fourth article. Paper money discussed. Bank notes merely promises to pay ..." (July 3): suppl., 1¼ cols.

36. The economists and the public.
Nation, New York, vol. 52 (June 15, 1891): 510–511.
Anonymous editorial.

37. New-school political economists.
Nation, New York, vol. 53 (July 9, 1891): 27.
A letter dated Wash., July 3, 1891.

38. The problem of economic education.
Q. Jl. Econ., Cambridge, vol. 7 (July, 1893): 375–399.
Also issued in pamphlet form. Boston, G. H. Ellis & Co., 1893. 27 pp.

39. Has the standard gold dollar appreciated?
Jl. Polit. Econ., vol. 1 (Sept. 1893): 503–512.

40. [Review of R. T. Ely's *Introduction to Political Economy*, and *Outlines of Political Economy*.]
Jl. Polit. Econ., vol. 3 (Dec., 1894): 106–111.

41. The basis of economics as an exact science.
Science, New York, n. s., vol. 21 (Mar. 24, 1905): 447–449.

42. Employer's liability.
Nation, New York, vol. 82 (May 31, 1906): 440–441.
Anonymous editorial.

SECTION V.

MISCELLANEOUS.

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1. [Review of J. P. Cooke's *Elements of Chemical Physics.*]
   Math. Mo. (Runkle's), Cambridge, Mass., vol. 3 (Oct., 1860): 30.
   Anonymous.
2. Carey's *Principles of Social Science.*
   N. Amer. Rev., vol. 103 (Oct., 1866): 573–580.
3. International copyright.
   N. Amer. Rev., vol. 114 (Apr., 1872): 432–435.
   Anonymous.
4. Borderland of science.
   Nation, New York, vol. 18 (Mar. 12, 1874): 177.
   Anonymous review.
5. District investigation.
   Nation, New York, vol. 18 (June 25, 1874): 407–408.
   Anonymous.
6. [Note on the American Association for the Advancement of Science.]
   Nation, New York, vol. 19 (Aug. 20, 1874): 123.
   Anonymous.
7. Exact science in America.
   N. Amer. Rev., vol. 119 (Oct., 1874): 286–308.
   Review and extracts in "Editor's Table, Professor Newcomb on American Science." *Pop. Sci. Mo.*, vol. 6 (Dec., 1874): 338–244.
8. [Note on the Edinburgh *Quarterly*.]
   Nation, New York, vol. 19 (Oct. 29, 1874): 285–286.
   Anonymous.
9. Life insurance.
   International Rev., vol. 2 (May, 1875): 353–370.
10. [Note on the *Galaxy* for January.]
    Nation, vol. 22 (Jan. 6, 1876): 9–10.
    Anonymous.
11. Abstract science in America, 1776–1876.
    N. Amer. Rev., vol. 122 (Jan., 1876): 88–123.
12. Review of Croll's *Climate and Time* with especial reference to the physical theories of climate maintained therein.
    Amer. Jl. Sci., 3. s., vol. 11 (Apr., 1876): 263–273.
    Dated Wash., Feb. 21, 1876. The work referred to in the title was by James Croll and published at New York in 1875. See no. 57 of this Section.
13. Who are friends of negro suffrage?
    Nation, New York, vol. 24 (Jan. 25, 1877): 53–54.
    Anonymous editorial.
14. [Notes on Admiral Davis.]
    Nation, New York, vol. 24 (Mar. 1, 1877): 133–134.
    Anonymous.
15. Life insurance failures.
    Nation, New York, vol. 24 (Mar. 15, 1877): 157–158.
    Anonymous editorial.
16. [Note on the Smithsonian Institution Reports for 1876.]
    Nation, New York, vol. 25 (Oct. 11, 1877): 223.
    Anonymous.
17. What the party wants.
    Nation, New York, vol. 25 (Dec. 13, 1877): 360.
    Anonymous editorial.

18. [Review of *Our Inheritance in the Great Pyramid*, by C. P. Smyth.]
Nation, New York, vol. 25 (Dec. 27, 1877): 400.
Anonymous.

19. Professor Joseph Henry.
Nation, New York, vol. 26 (May 16, 1878): 320–321.
Anonymous editorial.

20. Education at the naval academy.
Nation, New York, vol. 26 (June 20, 1878): 400–401.
Anonymous editorial.

21. [Note on railway time.]
Nation, New York, vol. 26 (June 20, 1878): 405.
Anonymous.

22. An advertisement for a new religion.
N. Amer. Rev., vol. 127 (July-Aug., 1878): 44–60.

23. [Remarks on taking the chair as president of the American Association for the Advancement of Science and his reply to speeches of welcome.]
Amer. Assoc. Proc., Salem, vol. 26, 1877 (1878): 374, 377–378.

24. The course of nature: an address delivered before the American Association for the Advancement of Science, St. Louis, Aug. 22, 1878. By Simon Newcomb, retiring president of the Association.
Amer. Assoc. Proc., Salem, vol. 27, 1878 (1879): 1–28.
Also in *Independent*, vol. 30 (Sept. 5, 1878): 5–8, with the title "Simplicity and universality of the laws of nature."
Also in *Kansas City Rev.*, vol. 2, (Sept.–Oct., 1878): 356–367; 392–396.
Also in *Pop. Sci. Mo. Suppl.*, no. 18 (Oct., 1878): 481–493.
Also in *Jl. Sci.*, London, 3. s., vol. 1 (1879): 64–89.

25. [Note on the Woodruff expedition.]
Nation, New York, vol. 27 (Nov. 28, 1878): 334.
Anonymons.

26. Draper's *Scientific Memoirs*.
Nation, New York, vol. 28 (Jan. 16, 1879): 55–56.
Anonymous.

27. [Note on the *Princeton Review*.]
Nation, New York, vol. 28 (Jan. 23, 1879): 70.
Anonymous.

28. Law and design in nature.
N. Amer. Rev., vol. 128 (May, 1879): 537–542.

29. Why are Republicans hopeful?
Nation, New York, vol. 28 (May 15, 1879): 330.
Anonymons editorial.

30. Evolution and theology—a rejoinder.
N. Amer. Rev., vol. 128 (June, 1879): 647–663.

31. Politicians and State rights.
Nation, New York, vol. 28 (June 26, 1879): 430–431.
Anonymous editorial.

32. Sentimentalism in politics.
Nation, New York, vol. 29 (July 31, 1879): 70–71.
Anonymons.

33. [Note—"Confessions of an Agnostic" in the current number of the *N. Amer. Rev.*]
Nation, New York, vol. 29 (Sept. 4, 1879): 158.
Anonymous.

34. American Association for the Advancement of Science.
Nation, New York, vol. 29 (Sept. 4, 1879): 150.
Anonymous.

35. [Note on lightning rods.]
Nation, New York, vol. 29 (Oct. 30, 1879): 292.
Anonymous.,

36. [Note on Maxwell.]
Nation, New York, vol. 29 (Dec. 11, 1879): 403–404.
Anonymous.

37. The religion of to-day.
N. Amer. Rev., vol. 129 (Dec., 1879): 552–569.

38. [Notes on the Bureau of Education.]
Nation, New York, vol. 30 (Jan. 8, 1880): 28.
Anonymous.

39. Our political dangers.
N. Amer. Rev., vol. 130 (Mar., 1880): 261–279.

40. Biographical memoir [of Joseph Henry. An address read before the National Academy of Sciences, April 21, 1880. (With "a supplementary note")] in *A Memorial of Joseph Henry*, "published by order of Congress."
Washington, Gov't print. off., 1880, pp. 441–473.
Compare no. 144 of this Section.
Also in *Smithsonian Misc. Coll.*, no. 356, vol. 21 (1881): 441–473.
Also in *Biographical Mem. Nat. Acad. Sci.*, vol. 5 (1905): 1–35.

41. [Clark's *Geodesy*.]
Nation, New York, vol. 30 (June 10, 1880): 441–442.
Anonymous review.

42. The plan of the bosses at Chicago.
Nation, New York, vol. 30 (June 17, 1880): 449–450.
Anonymous editorial.

43. General Garfield and Credit Mobilier.
Nation, New York, vol. 30 (June 24, 1880): 467–468.
Anonymous editorial.

44. Signal service succession.
Nation, New York, vol. 31 (Dec. 2, 1880): 389–390.
Anonymous.

45. Modern scientific materialism.
Independent, New York, vol. 32 (Dec. 9, 1880): 1, cols. 1–3, The question stated; vol. 32 (Dec. 23, 1880): 1, cols. 1–4, Correlation of mental and material phenomena; (Dec. 30): 3, cols. 1–3, The possible endowments of matter; vol. 33 (Jan. 13, 1881): 3, cols. 2–4, Thought as a form of force; (Jan. 27): 2–3, cols. 3–4, 1–2, Vital action.

46. The relation of scientific method to social progress. An address delivered [as president] before the Philosophical Society of Washington, Dec. 4, 1880.
Washington, Judd & Detweiler, 1880, 15 pp.
Also in *Bull. Phil. Soc. Wash.*, vol. 4 (1881): 40–52.
Also in *Smithsonian Misc. Coll.*, Wash., vol. 25.
Also in Side-lights on Astronomy (1906): 312–329; see Section II, no. 300.

47. [Notes on time and B. F. Ishenwood.]
Nation, New York, vol. 32 (May 5, 1881): 316–317.
Anonymous.

48. [Note on P. Earl Chase.]
Nation, New York, vol. 32 (June 30, 1881): 459–460.
Anonymous.

49. Copyright.
New York Tribune (Oct. 22, 1881): 8, col. 1.

50. Letter to Prof. Krueger, containing suggestions respecting the international telegraphic code.
Vierteljahrsschrift Astr. Gesell., vol. 16 (Oct., 1881): 349–350.
Dated Wash., Sept. 6, 1881.

51. Speculative science.
International Rev., vol. 12 (Apr., 1882): 334–341.
A review of J. B. Stallo's *Concepts and Theories of Modern Physics*.

52. Reports of officers of the navy on the ventilating and cooling of the executive mansion during the illness of President Garfield. By Simon Newcomb and others.
Washington, Gov't print. off., 1882. 13 pp.

53. A visit to Cetywayo.
Harper's Mag., vol. 66 (Apr., 1883): 86–89.
This visit to the deposed king of Zululand was made while S. Newcomb was in Cape Colony for the 1882 transit of Venus.

54. The watchmaking industry in Switzerland.
Science, vol. 1 (Apr. 20, 1883): 296–297.
Letter dated Neuchâtel, March 12, 1883, and signed S. N.

55. The units of mass and force.
Science, Cambridge, vol. 2 (Oct. 12, 1883): 493–494.

56. The psychological mechanism of direction.
Science, Cambridge, vol. 2 (Oct. 26, 1883): 554–556.

57. On some points in climatology. A rejoinder to Mr. Croll.
Amer. Jl. Sci. 3. s., vol. 27 (Jan., 1884): 21–26.
Also in *Phil. Mag.*, London, 5. s., vol. 17 (Feb., 1884): 142–143.
Mr. Croll replies, pp. 275–281.
A rejoinder to Mr. Croll's reply (*Phil. Mag.*, Oct., 1883) to Newcomb's criticisms of his theory; see no. 12 of this Section.

58. What is a liberal education?
Science, Cambridge, vol. 3 (Apr. 11, 1884): 435–436.
Also in *Nature*, vol. 30 (May 1, 1884): 9–10.

59. Hasty naval legislation.
Nation, New York, vol. 38 (May 29, 1884): 461.
Anonymous editorial.

60. President Eliot on a liberal education.
Science, Cambridge, vol. 3 (June 13, 1884): 704–705.

61. [Reply by "Ed. *Nation*" to letter criticising Hasty naval legislation, no. 59 (above).]
Nation, New York, vol. 38 (June 19, 1884): 526.
Anonymous.

62. [Review of G. G. Stokes' *On the Nature of Light.*]
Nation, New York, vol. 38 (June 19, 1884): 534.
Anonymous.

63. Psychic force.
Science, Cambridge, vol. 4 (Oct. 17, 1884): 372–374.

64. Psychical research.
Science, Cambridge, vol. 4 (Dec. 5, 1884): 510–511.
Letter in reply to one by E. Gurney on psychical research.

65. Can ghosts be investigated?
Science, Cambridge, vol. 4 (Dec. 12, 1884): 525–527.

66. The Georgia wonder-girl and her lessons.
Science, New York, vol. 5 (Feb. 6, 1885): 106–108.

67. Mortality experiences of the Connecticut Life Insurance Company.
Science, New York, vol. 5 (May 8, 1885): 379–380.

68. Annual address of the president of the American Society for Psychical Research, Jan. 12, 1886. [On thought-transference.]
Boston (?), 1886, 24 unnumbered pages.

69. The telephone case.
Nation, New York, vol. 42 (Jan. 21, 1886): 50.
Anonymous editorial.

70. Professor Newcomb's address before the American Society for Psychical Research.
Science, vol. 7 (Feb. 12, 1886): 145–146.
Letter; see no. 68 of this Section.

71. Responsibility in the Navy Department.
Nation, New York, vol. 42 (Feb. 25, 1886): 164.
Anonymous editorial.

72. The condition of the Coast Survey.
Nation, New York, vol. 42 (Mar. 11, 1886): 208–209.
Anonymous editorial.

73. The telephone suit.
Nation, New York. vol. 42 (Mar. 18, 1886): 230-231.
Anonymous editorial.

74. Mischievous philanthropy.
Forum, vol. 1 (June, 1886): 348–357.

75. The work of the congressional commission on the surveys.
Nation, New York, vol. 42 (June 17, 1886): 502.
Anonymous editorial.

76. Some critics of the Geological Survey.
Nation, New York, vol. 43 (July 6, 1886): 26–27.
Anonymous editorial.

77. Science and immortality.
The Christian Register Boston, vol. 66 (Apr. 7, 1887): 211.

78. The reappearance of an old boss.
Nation, New York, vol. 45 (July 21, 1887): 46–47.
Anonymous editorial.

79. Concerning Higgins.
The Evening Post, New York (Sept. 18, 1887).
Anonymous, "From an occasional correspondent." Dated Washington, September 12.

80. The speed of propagation of the Charleston earthquake discussed by S. Newcomb and C. E. Dutton.
Amer. Jl. Sci., 3. s., vol. 35 (Jan., 1888): 1–15.

81. On the definitions of the terms "energy" and "work."
Phil. Mag., London, vol. 27 (Feb., 1889): 115-117.

82. Michel Eugène Chevreul.
Nation, New York, vol. 48 (Apr. 18, 1889): 320–321.
Anonymous editorial.

83. Utilizing the power of Niagara.
Nation, New York, vol. 49 (Aug. 8, 1889): 104-105.
Anonymous editorial.

84. A remarkable judicial decision.
The Evening Post, New York (Nov. 18, 1889).
Also in *Nation*, New York, vol. 49 (Nov. 21, 1889): 404–405.
Anonymous editorial.

85. Can we make it rain? By General Robert G. Dyrenforth and Professor Simon Newcomb.
N. Amer. Rev., vol. 153 (Oct., 1891): 398–404.
Also in L. Gathman, *Rain produced at will.* Chicago, 1891, 61 pp.
Also in Side-Lights on Astronomy (1906): 182–190; cf. no. 300 in Section II.
This provoked the pamphlet entitled: *Should the rainfall experiments be continued? A criticism of Prof. Simon Newcomb's contribution to the article in the North Americon Review . . . entitled, "Can we make it rain?"* By Edward Powers, Delaware, Wisc., 1892. 15 pp. The first paragraph of the "criticism" contains the following sentence: "His arguments are so superficial, so inconsistent, and so unscientific, both in their allegations and their methods, that they ought not to be allowed to pass unanswered." This pamphlet was, apparently, an insert for a revised edition of Powers's book *War and The Weather*, 1890.

86. Government rain-making.
Nation, New York, vol. 53 (Oct. 22, 1891): 309–310.
Anonymous editorial.

87. *Standard dictionary of the English language* . . . prepared by more than two hundred specialists and other scholars . . . 2 vols.
New York, Funk & Wagnalls Co., 1893–1895.
S. Newcomb was a member of the "editorial staff" under "Astronomy, mathematics, and physics."

88. Naval administration.
Nation, New York, vol. 56 (Mar. 2, 1893); 154–155.
Anonymous editorial.

89. Suggested nomenclature of radiant energy.
Nature, vol. 49 (Nov. 30, 1893): 100.

90. A French view of Franklin as a diplomatist.
Nation, New York, vol. 57 (Dec. 14, 1893): 447.
Letter signed "S. N."

91. Kidd's *Social Evolution.*
Nation, New York, vol. 58, (Apr. 1894): 294.
Anonymous review.

92. The elements which make up the most useful citizen of the United States.
Amer. Anthropologist, Washington, vol. 7 (Oct., 1894): 345–351.
By "Aristides"(=S. Newcomb) who was the winner of the first prize, $150 of two "Citizenship Prizes" offered in 1893 by the Anthropological Society of Washington for the best essay on the topic of not over 3,000 words in length.

93. To our readers.
Science, n. s. vol. 1 (Jan. 4, 1895) : 1–2.
Newcomb was the member of the "Editorial Committee" of *Science* dealing with "mathematics."

94. Why we need a national university.
N. Amer. Rev., vol. 160 (Feb., 1895): 210.

95. Report of the Watson trustees on the award of the Watson medal to Seth C. Chandler for the Nat. Acad. Sc., by Simon Newcomb, B. A. Gould, A. Hall.
Science, New York, n. s. vol. 1 (May 31, 1895): 477–481.

96. A Shepherd ovation.
Nation, New York, vol. 61 (Nov. 14, 1895): 340–341.
Anonymous editorial.

97. The wreck of the Columbia: a story.
Harper's Mag., New York, vol. 93 (Aug., 1896): 466–475.
S. Newcomb's first *essai* in the domain of fiction. His other romances are nos. 110 and 118.

98. French universities and American students.
Nation, New York, vol. 63 (Nov. 26, 1896): 400–401.
Dated Wash., Nov. 21, 1896.

99. International Conference on a Catalogue of Scientific Literature by S. Newcomb and J. S. Billings.
Washington, Govt. print. off., January, 1897, 2 pp.
54th Congress, 2d session, Senate Document no. 43, pp. 2–3. Report dated Wash., Oct. 15, 1896.
Also in *The Smithsonian Institution documents relative to its origin and history*, Washington, vol. 2 (1901): 1770–1771.

100. *The American Educator, a Library of Universal Knowledge*, 6 vols.
Philadelphia, Syndicate Publishing Co., 1897.
S. Newcomb is referred to as one of the 11 "associate editors and special contributors." See no. 143, in this Section.

101. France as a field for American students.
Forum, vol. 23 (May, 1897): 320–326.
Same condensed in *Public Opinion*, New York, vol. 22 (May 20, 1897): 629.

101A. French Translation—La France comme champs d'études pour les Américains.
Revue Internationale de L'Enseignement, vol. 34 (July, 1897): 20–27.

102. Science during the Victorian era.
Independent, New York, vol. 49 (June 17, 1897): 774–775.

103. [Review of C. Flammarion's *Lumen.*]
Nation, New York, vol. 65 (Dec. 9, 1897): 463–464.
Anonymous; written by Mr. and Mrs. S. Newcomb.

104. Naval reorganization.
Nation, New York, vol. 65 (Nov. 25, 1897): 411–412.
Anonymous editorial.

105. Two naval scientific bureaus, I. The hydrographic office; II. The naval observatory.
The Evening Post, New York, Jan. 14–Jan. 19, 1898): 1 col.+1 col.
Anonymous editorials.

106. The naval officer.
Nation, New York, vol. 67 (Aug. 11, 1898): 105.
Anonymous editorial.

107. The possibilities of invention.
Independent, New York, vol. 51 (Apr. 13, 1899): 1005–1007.

108. Has telepathy been established?
Independent, New York, vol. 51 (June 29, 1899): 1730–1733.

109. Science and government.
N. Amer. Rev., New York, vol. 170 (May, 1900): 666–678.

110. His Wisdom, the Defender: a story.
New York, Harper Bros., Oct., 1900. 7+328 pp.
Reviewed in *Nation*, vol. 71 (Dec. 6, 1900): 452. The edition of this work contained 1,544 copies. It is out of print.

111. Is the airship coming?
McClure's Mag., New York, vol. 17, (Sept., 1901): 432—435.

112. The problem of aerial flight.
Boston Evening Transcript, Nov. 16, 1901.
Also in *The Evening Star*, Washington, Nov. 16, 1901.
The title of the article as it appeared in *The Star* was somewhat different.

113. "Action and reaction," "Axiom" (in part), "Calculus," "Capacity" (in physics), "Centre of mass or gravity," "Centrifugal force," "Density," "Dynamics," "Energy," "Equilibrium," "Ether," "Extension" (in physics), "Finite" (in mathematics), "Force," "Geometry," "Gravitation," "Impenetrability," "Inertia" (in physics), "Infinite" (in mathematics), "Infinitesimal" (in mathematics), "Infinity," "Kinetic," "Kinetics," "Latent heat," "Limits" (in mathematics), "Mass" (in physics), "Matter," "Measurement," "Mechanical equivalent" (of heat), "Mechanics," "Mobility," "Movement" (of force), "Momentum," "Motion and rest" (in physics), "Nebular hypothesis," "Parallelogram of forces," "Perpetual motion," "Personal equation," "Physical science," "Point" (in geometry), "Potential," "Ptolemaic theory," "Resultant," "Space" (in mathematics), "Statics," theory (in science), "Unit" (of physical measurement), "Value" (in physical science), "Variable (and constant) quantity," "Vibration," "Vis viva," "Work." in *Dictionary of Philosophy and Psychology*, edited by J. M. Baldwin.
New York, Macmillan, vol. 1, A–L, 1901; vol. 2, M–Z, 1902.
All of the above-mentioned articles are signed "S. N.," one of the "contributors" in "Physical Sciences and Mathematics."

114. The metric system of weights and measures. [To fix standard of weights and measures by adoption of metric system.]
Washington, Gov't print. off., 1902.
Report of a hearing on the metric system before the Coinage, Weights and Measures Committee, Feb. 6–Mar. 6, 1902, 57th Congress, 1st session. S. Newcomb's statements made on Feb. 8, 1902, are reported on pp. 70–74.

115. Conditions which discourage scientific work in America.
N. Amer. Rev., vol. 174 (Feb., 1902): 145–158.
See *Rev. of Reviews* (English edition), vol. 25 (Mar., 1902): 262.

116. Shall we raise a statue to Shepherd?
Nation, New York, vol. 75 (Oct. 23 1902): 321–322.
Anonymous editorial.

117. Congrès international des savants à l'Exposition universelle de Saint-Louis, 19–25 septembre, 1904. Discours prononcés à un diner donné par M. S. Newcomb, président du Congrès, à quelques savants de France, 29 Mars. 1903.
[Paris, Impr. A. Boutillier, 29 Juillet, 1903.] pp. 10.

118. The end of the world: a story.
McClure's Mag., New York, vol. 21 (May, 1903): 3–14.

118A. Japanese translation by Kuroiwa Ruiko in daily newspaper *Yorodzu Choho*, Tokyo (May 6–25, 1904).
Translation arranged in alternate paragraphs with the English was published as a book of 90 pages, with the following dedication: "To Dr. Anita McGee this humble translation of her father's valuable work is most respectfully dedicated by the translator, who wishes to offer hearty thanks for her practical sympathy for our nation and to erect a slight monument in memory of her merciful deeds in this country by this translation." Dr. McGee had charge of the American nurses who gave their services to the Japanese Government for six months of 1904, during the Russo-Japanese war.

119. Shall we dismember the Coast Survey?
Nation, New York, vol. 77 (Oct. 1, 1903): 260.
Anonymous.

120. The outlook for the flying machine.
Independent, vol. 55 (Oct. 22, 1903): 2509–2512.
Also in Side-Lights on Astronomy (1906): 330–345; see Section II, no. 300.

121. The functions of the Senate.
Nation, New York, vol. 77 (Nov. 12, 1903): 375–376.
Anonymous.

122. The Senate's appointing power.
The Evening Post, New York, Nov. 12, 1903.

123. [In *A favorite quotation of mine*, a calendar published by the King's Daughters, Binghamton, New York, 1903, we find under March 24, 1904, page 38: "Whatsoever thy hand findeth to do, do it with thy might, Simon Newcomb."]

124. The Carnegie Institution.
N. Amer. Rev., vol. 178 (Feb., 1904): 172–185.
Also an extract in *Science*, vol. 19 (Feb. 12, 1904): 268–269.

125. The mariner's compass.
Harper's Mag., vol. 108 (Feb., 1904): 422–427.
Also in Side-Lights on Astronomy (1906): 140–154; see Section II, no. 300.

126. A statistical inquiry into the probability of causes of the production of sex in human off-spring.
Carnegie Institution, Washington, Publication No. 11.
Washington, June, 1904, 34 pp.
Quoted on pages 501–503 of J. A. Thomson, *Heredity*, London, Murray, 1908.

127. The coming International Congress of Arts and Sciences at St. Louis, Sept. 19–24.
Pop. Sci. Mo., vol. 65 (Sept., 1904): 466–473.

128. The evolution of the scientific investigator. [Introductory address delivered as president of the International Congress of Arts and Science at the St. Louis Exposition, Sept. 19, 1904.] In *Congress of Arts and Science, Universal Exposition, St. Louis, 1904*, edited by H. J. Rogers, volume 1.
Boston and New York, Houghton, Mifflin & Co., 1905, pp. 135–147.
Also in *Science*, vol. 20 (Sept. 23, 1904): 92–96.
Also in *Sci. Amer. Suppl.*, vol 58 (Oct. 2, 1904): 24098–24100.
Also in *Pop. Sci. Mo.*, vol. 66 (Nov., 1904): 92–96.
Also as a pamphlet, St. Louis, Universal Exposition, 1904, 24 pp.
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129. [Letter dated January 19, 1903, signed by Simon Newcomb, chairman, and six others, the "Committee on Plan and Scope" for the Congress of Arts and Science, University Exposition, St. Louis, 1904; in *Congress of Arts and Science*, ed. by H. J. Rogers.]
Boston and New York, Houghton, Mifflin and Co., vol. I, (1905): 8–10.

130. Our antiquated method of electing a president.
N. Amer. Rev., vol. 180 (Jan., 1905): 9–18.

131. [Method by which the Carnegie Institution can best promote research work in the exact sciences.]
Carnegie Institution of Washington Year Book, no. 3, 1904. Washington (Jan., 1905): 179–181.
Letter dated, May 12, 1904.

132. The Smithsonian Institution.
Nation, New York, vol. 80 (June 29, 1905): 516–517.
Anonymous editorial.

133. The cost of life insurance business.
Nation New York, vol. 81 (July 6, 1905): 67.
Anonymous.

134. Walking in Switzerland.
Nation, New York, vol. 81 (Sept. 28, 1905): 256–257.
Signed "S. N.," dated "On the Rhine, Aug. 7, 1905."

135. What the navy needs.
Nation, New York, vol. 81, (Dec. 28, 1905): 516–517.
Anonymous.

136. The organization of scientific research.
N. Amer. Rev., vol. 182 (Jan., 1906): 32–43.
Also in Side-Lights on Astronomy (1906): 165–181; see Section II, no. 300.

137. [American Metrological Society, by Simon Newcomb and James H. Gore.]

Medical Notes and Queries (edited by Henry W. Cattel), vol. 2 (Mar., 1906): 60–61.

Communication dated Washington, Mar. 12, 1906, appealing "for aid in promoting the progress of the metric system"; signed by S. Newcomb as chairman of the legislative committee and J. H. Gore as secretary of the Society.

138. Our navy.

N. Amer. Rev., vol. 182 (Mar., 1906): 321–322.

Anonymous, by "An American Citizen."

139. University athletics.

N. Amer. Rev., vol. 185 (June 21, 1907): 353–364.

Also in *College and the Future; Essays for the Undergraduate on Problems of Character and Intellect.* Edited by R. A. Rice. New York, Scribner, 1915.

One of 18 articles.

140. The prospect of aerial navigation.

N. Amer. Rev., vol. 187 (Mar., 1908): 337–347.

141. The problem of aerial navigation.

Nineteenth Century, vol. 64 (Sept., 1908): 430–442.

Also in *Living Age*, vol. 259 (Oct. 24, 1908): 195–205.

142. Awaits the inevitable hour.

Nation, New York, vol. 87 (Nov. 5, 1908): 437.

Letter dated, Washington, Oct. 28, 1908. On Dr. Rolf amending the reading in Gray's "Elegy."

143. How an encyclopaedia may be edited.

Nation, New York, vol. 87 (Nov. 19, 1908): 492.

Letter dated Washington, Nov. 7, 1908. It repudiates any connection whatever as "editor" of the *Twentieth Century Encyclopaedia*, Philadelphia, Syndicate Publ. Co., 1906, which seems to be simply another edition of *The American Educator* published by the same company in 1897, and for which S. Newcomb may have written a couple of articles. The title page of the latter work refers to him as one of the "associate editors and special contributors."

144. Modern occultism.

Nineteenth Century, vol. 65 (Jan., 1909): 126–139.

Also in *Living Age*, vol. 260 (Feb. 13, 1909): 387–398.

This provoked "Attitude of science to the unusual" by O. Lodge, *Nineteenth Century*, vol. 65 (Feb., 1909): 206–222; also in *Living Age*, vol. 260 (Mar. 20, 1909): 707–719. Cf. "Science and the supernatural," *New York Sun* (Feb. 21, 1909). See also Section I, no. 80.

145. Joseph Henry, physicist, 1797–1878, in *Leading American Men of Science*, ed. by D. S. Jordan.

New York, Holt, 1910. pp. 119–146.

Compare no. 40 in this Section and no. 46 in Section I. A number of paragraphs in the former are the same as in the sketch above.

146. The metric system of weights and measures. Why it should be adopted in the United States.

Washington, American Metrological Society, n. d. 6 pp.

It is signed T. C. Mendenhall, president; J. H. Gore, secretary; S. Newcomb, chairman of the publication committee. This report must have been published before 1902, since Mendenhall resigned the presidency of the society in 1901. Compare no. 114 of this Section.

NUMBER OF TITLES.

Section II. Astronomy	318
Section III. Mathematics	35
Section IV. Economics	42
Secrion V. Miscellaneous	146
Total	541

NATIONAL ACADEMY OF SCIENCES.

Volume XVII.
SECOND MEMOIR.

BIOGRAPHICAL MEMOIR RICHMOND MAYO-SMITH

1854-1901.

BY

E. R. SELIGMAN.

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1919.

Yours truly
Richmond M. Smith

RICHMOND MAYO-SMITH.

1854—1901.

By E. R. Seligman.

Richmond Mayo-Smith, son of Preserved and Lucy (Mayo) Smith, was born in Troy, Ohio, February 9, 1854. His father was a native of Massachusetts, son of the Rev. Preserved Smith, pastor of the church in Warwick, of that State. His mother was the daughter of Seth Mayo, of Medford, Mass.

On his father's side he was descended from the Rev. Henry Smith who came from England in 1636 and became the first pastor of Wethersfield, Conn., at which place he died in 1648. His son Samuel was one of the first settlers of Northampton, Mass., afterwards removing to Hadley. Three generations later Chileab Smith removed to the then newly settled town of Ashfield. His grandson, Preserved Smith, served in the Continental Army, afterwards studied at Brown University, and then entered the ministry. The greater part of his life he was pastor of the church at Rowe, Mass. The next Preserved Smith also graduated at Brown University and was pastor of the church at Warwick. His oldest son was Preserved Smith, father of Prof. Mayo-Smith, who went to Ohio in 1839, and engaged in business, first at Troy and afterwards at Dayton. He became a manufacturer of cars and a railroad man, being one of the group which built the Cincinnati, Hamilton & Dayton Railroad. Barney & Smith was, and is, the name of his car factory, and has a plant over a mile long. He was famous in Ohio for his benefactions. Lane Seminary of Cincinnati received over $100,000 from him, which was a much larger sum in those days than in these days of great gifts.

Prof. Mayo-Smith's mother, Lucy Mayo, was descended from the Rev. John Mayo, first settled pastor of the Second Church of Boston, which he served from 1655 to 1672. His colleague and successor was the celebrated Increase Mather who testified that Mr. Mayo was "a blessing to his people."

Richmond was the fourth son of his parents and received the name of his grandmother who was Beebe Richmond of Providence, and of his mother, a Mayo as aforesaid. When he was 2 years old the family removed to Dayton and here he attended the public schools (district and high school) and was thus prepared for college. Graduating from the high school in 1871 he entered Amherst College in the same year, completing his course in 1875.

Of his early life there is little to write. The family consisted of three sons, two older than Richmond, and one daughter, younger. One son had died in infancy. The New England traditions were upheld, family government being firm, but not harsh. Dayton was a town of 20,000 people in 1856 but grew rapidly in the next decade. Still the simple life was the rule. The public schools were probably as good as the average. Ohio in fact had early organized a good system of public instruction. Life was uneventful except for the period of the Civil War, and a boy of 8 to 12 years old could hardly appreciate the full significance of that struggle though doubtless he cheered for the soldiers and for the Union. His father had been a member of the Republican Party from its first organization and the sympathy of the sons was assured throughout the conflict. At school Richmond stood well and was what we may call a thoughtful boy though not precocious. He came quite naturally into the New School Presbyterian Church of which his parents were members.

At Amherst College Richmond had the reputation, which he always kept, of being extremely level headed and full of common sense. As one of his classmate, who has since risen to distinction, writes, he was one of the old reliables, efficient in whatever he undertook and faithful to the last degree. As his father was a prominent car manufacturer, the natural inference was that young Richmond would enter the same business, but his interest in history and economics, under the inspiration of Prof. John W. Burgess, led him into other paths. At the instigation of Prof. Burgess, he went to Europe, after graduating from Amherst in 1875, and spent two years at the universities of Berlin and Heidelberg, prosecuting his studies in economics and social science. In 1877 he was called to Columbia as instructor in history and political science, in 1878 he was made adjunct professor of political economy and social science, and finally, in 1883, he was promoted to the full professorship in the same department. When the School of Political Science was organized in 1880, he became one of the five original instructors, retaining at the same time his seat in the faculty of the School of Arts, as the college was then called. At the time of the reorganization of the university and the inception of the Council in 1890 he was made a member of that body, and continued as the elected delegate of the faculty of Political Science up to the beginning of 1901.

So much for the bare facts of his lifelong connection with Columbia. To form an estimate of his real influence it will be necessary to consider him in the threefold aspects of scholar, teacher, and citizen.

As a scholar Prof. Mayo-Smith had acquired a position of high rank among the economists of the country. He made numerous contributions to the scientific periodicals of America and England, and wrote occasionally for foreign publications like the German Verein für Socialpolitik. He was one of the original board of editors of the Political Science Quarterly in 1886, and almost every volume contained an article on some economic topic from his pen; he was one of the founders of the American Economic Association, and always took a deep interest in its welfare, attending its meetings regularly and almost invariably contributing a paper or taking a leading part in the discussion. His writings on economics proper covered a wide range of topics. Although he published only one volume on a special subject—the book on "Immigration and Emigration," which still remains the model of its kind—his articles and especially his numerous reviews of new books showed that he possessed a firm grasp on the fundamental principles of the science. As an economist his chief characteristics were thoroughness, unquestioned accuracy, open-mindedness, clearness of thought and expression, and a rare sanity of judgment.

It was, however, in the allied field of statistics—which has of recent years successfully vindicated its claim to be considered a coordinate if not an independent science—that Prof. Mayo-Smith won his greatest triumphs. He was indisputably the foremost American scientific statistician. From the very outset of his professional career he appreciated the fundamental importance of sound statistical methods in American public life, and he resolved to bend his utmost energies to the task of placing American statistics on a thoroughly scientific basis. His course on statistics was the first given in any American university, and for a long time remained the only one. His publications on the subject soon began to attract the attention of practical statisticians and won for him the admiration and friendship of such men as President Francis A. Walker and Carroll D. Wright. He became one of the founders of the rejuvenated American Statistical Association and before long was elected its vice president, a position which he still occupied at the time of his death. His reputation at home had now spread to such an extent that he was made a member of the National Academy of Sciences, a rare distinction at a time when the academy was in such doubt as to whether economics or statistics was a real science that it numbered only a single representative of those disciplines among its members. Shortly afterwards he was elected to the International Statistical Institute, which then had only half a dozen members in America. From this period date his wider international reputation and the beginnings of his warm friendship with such eminent scholars as Bodio of Italy, Levasseur of France, and Craigie and Edgeworth of England. He attended several of the European meetings of the institute, notably those of Berne, Paris, and St. Petersburg, and contributed occasionally to its Bulletin. The two volumes in which he summed up a part of his conclusions—"Statistics and Sociology" and "Statistics and Economics"—immediately won a place as the authoritative works on the subject, and have been largely used as text-books throughout this country.

The characteristics of Prof. Mayo-Smith as an economist stood him in good stead as a statistician. His sobriety of judgment led him to point out the limitations of the statistical method as well as the dangers which encompassed the subject; and his lucidity of thought and expression enabled him to invest with interest what to the average man seemed the driest part of the "dismal science." As a scientific statistician he was without a peer in America and his reputation attracted not a few students to the School of Political Science.

This leads us naturally to consider him in the next place as a teacher. It is rare to find a man who is at once a creative scholar and a successful undergraduate teacher. Prof. Mayo-Smith combined these characteristics. From the very outset he was occupied in teaching economics to undergraduates, and although the conditions of those early years, almost a half century ago, compelled him to emphasize the needs of a broader university development he retained to the last his warm interest in the college and its undergraduates. The instruction of the juniors remained in whole or in part in his hands, and his senior course was always with one exception the most popular of all the classes in history and political science and among the three or four largest electives in the whole institution. Numerous are the graduates of the college who continued with him the pleasant associations and the friendships formed during their undergraduate life. As a college instructor he was unusually conscientious, eminently fair, and uniformly courteous.

As a university lecturer, dealing primarily with graduates, he was no less successful. The interest which he instilled into his auditors in his lectures and especially in his seminar may be recognized from the fact that many of his former students are now filling professorial chairs, while others are occupying positions of dignity in the administrative services of State and Nation. The successful building up of the department was in no small measure due to his own rare modesty, to the utter absence of any attempt to enhance his own reputation by belittling that of his colleagues, and to his thoroughly scientific spirit of encouraging his subordinates to untrammeled and independent exertion.

Finally we must speak of him as a citizen and a man. He was not one of those who, amid the engrossing cares and exactions of a professional and scholastic career, forget that devotion to science does not excuse one from the equally high obligations of good citizenship. He was always warmly interested in the fight for good government. He thoroughly believed in the practicability of lending a hand to the unfortunate, and was so much attracted by the work of the University Settlement that he lived there at various periods in his career as a resident. He was so completely in sympathy with the principles of the Charity Organization Society that he served for many years as member of its council and acted until the last as the head of one of its district committees, sparing neither time not effort in his endeavor to make it a success.

Amid all these duties, both in and out of the university, he found leisure for not a little social intercourse. His friends outside the academic sphere were many and warm. What attracted them were the same qualities that won for him so much recognition in college circles. His intellectual honesty, his receptiveness, his unfailing courtesy and kindliness, his balance of mind and his rare good judgment all conspired to secure for him an influence which was equalled by but few in the university.

Prof. Mayo-Smith married in June, 1884, Mabel Ford, of Brooklyn, the sister of Paul Leicester Ford and Worthington C. Ford. They had two sons and two daughters. His son Richmond is a captain now in service in France and his daughter Lucie is the wife of Prof. U. B. Phillips, of Michigan University. His brother is Prof. Henry Preserved Smith of Union Theological Seminary.

Prof. Richmond Mayo-Smith was a charter member of the University Club in New York, being one of the first hundred asked to join. He was also a member of the Century Association and of the D. K. E. He was a vestryman of Christ Church and was one of the original members of both the American Historical Association and the American Economic Association. He died November 11, 1901, stricken down suddenly in the plenitude of his physical and intellectual powers. His career, brilliant though it was, had scarcely more than begun. Those who were privileged to know him intimately are aware of the fact that he had formed important plans for future work and usefulness, and there is no doubt that had he been spared to round out the usual term of life, he would have deserved still better of science and would have shed still more luster on the university to which he was so loyal and whose welfare he had so deeply at heart.

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NATIONAL ACADEMY OF SCIENCES.

Volume XVII.
THIRD MEMOIR.

BIOGRAPHICAL MEMOIR SAMUEL HUBBARD SCUDDER

1837-1911.

BY

ALFRED GOLDSBOROUGH MAYOR.

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1919.

Yours very sincerely

David W. Judd

SAMUEL HUBBARD SCUDDER.

1837-1911.

By Alfred Goldsborough Mayor.

On both sides of his house Samuel Hubbard Scudder was of Puritan origin, the first American ancestor on his father's side being John Scudder, who coming from London in 1635, settled in Charlestown, and from there went to Barnstable on Cape Cod. Here certain of his descendants still live, and have for generations followed the sea. Charles Scudder, the father of the subject of this biography, escaped the family calling through the accident of having come to Boston too late to join the vessel in which he was to serve as a cabin boy. He therefore remained in the city and entered upon a commercial career, becoming a well-known hardware and commission merchant. After living thus for fully 30 years he married for his third wife Sarah Lathrop Coit, daughter of a distinguished Puritan lineage, who traced her descent through the Manwarings and Saltonstalls to Gov. Winthrop of colonial fame.

Both Charles Scudder and his wife were firm supporters of the orthodox religion of their ancestry; he being a deacon in Union Church, of the Congregational faith, in Boston; and in this faith were their seven children reared, with all that strictness consistent to the salvation of their souls. It was a stern faith that of his ancestors, who had braved the storms of the North Atlantic to win a secure anchorage for their creed along the bleak shores of Massachusetts Bay, yet there was nothing of the sour æscetic in Charles Scudder, for the health-giving enjoyments of this world were as essential according to his views as were the exacting duties of religion, and a man of the world he was in the sense that he won and kept the cordial esteem of his fellow townsmen throughout a long and useful life in the business affairs of Boston.

Into this morally healthful atmosphere Samuel Hubbard Scudder was born on April 13, 1837. Among brick walls and stone pavements the great student of nature was first to see the light, but fortunately the family soon moved to "Roseland," a pleasant country home in Roxbury, 3 miles from the town of Boston. Here among the woods and fields of a 30-acre estate young Scudder spent his early years, his only known adventure being a successful attempt to jump over a cow, which resulted, however, in a broken arm on his part, but no recorded injury to the cow. He tells us, however, that wild nature made no appeal to his imagination in those days, yet somehow we suspect it registered its appeal unheeded at the time, but to be sprung into his conscious recognition later. Possibly it was the compelling force of indifference or ill-defined opposition that helped to move him to his life work, for when a child of 10 he, marveling at the beauty of a forest stick covered with brightly-colored fungi, brought it as a treasure to his father, who promptly threw it in the fire, calling it a "dirty stick." How many a career is in early life determined in response to the spur of misunderstanding? Yet for some years, bright boy though he was, nature made no conscious appeal to him, perhaps because at this time he was the admiring companion of his elder brother David, in whose footsteps as a potential naturalist he was content to walk unheedingly.

Had he not chosen the self-sacrificing career of a missionary in India, one thinks David might also have become a naturalist of distinction so replete is his journal with the mystery of the tropical jungle and interest in the forgotten races of the prehistoric past of India,[1] but he was destined to die in his youthful manhood in attempting to swim a flooded river in the mountains of southern India.

[1] See life and letters of David Coit Scudder, missionary in Southern India, by Horace E. Scudder, 1864, Hurd & Houghton, Boston.

Yet another brother in this gifted family was Horace Elisha Scudder, the well-known author, and editor for several years of the Atlantic Monthly.

Types they all were of the best that the heredity and the environment of New England produced in those epoch-making mid decades of the nineteenth century when culture came to soften the austere isolation of the Puritan, and the intolerance of old creeds gave place to an expanded sense of service toward all mankind.

At the age of 16 Samuel was sent to Williams College in order that he might come under the intellectual guidance of that great educator, Mark Hopkins. His elder brother David had preceeded him two years before, and in the following year Horace also entered the college. Thus in the congenial companionship of relatives and friends he was to spend the four pivotal years within which the trend of his life work was to be determined.

He entered apparently without plans for the future, but about six weeks after college had opened his sense of the beautiful was profoundly stirred by the sight of a glass case of butterflies upon the wall of a friend's room. He tells of his surprise to find that these beautiful things existed in such numbers in the immediate region of his home. At once he constructed a net and proceeded to collect, and although the frosts of autumn soon put a check upon his plan he had found his life interest and when a junior in college had definitely decided to devote his energies to the study of insects.

In 1857 he graduated from Williams College at the head of his class; receiving the degree of A. B., which the college very appropriately supplemented with an A. M., in 1860, and doctor of science in 1890.

One thinks that his choice of so unusual an interest for a life work was largely influenced by his ardent love of the open air and all that pertained thereto, for although not a wide traveler, Europe and Egypt marking the confines of his wanderings, yet, he knew New England thoroughly, and the rural beauty of her peaceful valleys, and the majestic boldness of her mountain peaks were the delight of all his years. His whole life was dominated by the charm of this intimate association with that New England wherein in his day so much of untrammeled nature still remained. Steeped in the charm of the Berkshire Hills he had spent his college years, and as a lover of the wild in all New England he was to live his manhood through. Thus while in college he became the leading spirit of the "Alpine Club of Williamstown" and later he was to become a founder, and the first vice president of the Appalachian Club and to succeed Prof. E. C. Pickering as its second president. It was he who suggested the name "Appalachia" for the Journal of the club, and for nine years he served as chairman of its publication committee. He himself contributed some charmingly composed articles, among them: "A climb on Mount Adams in winter"; "The Alpine Club of Williamstown, Massachusetts"; "A winter excursion to Tuckerman's Ravine"; "The White Mountains as a home for butterflies"; "The Alpine Orthoptera of North America"; "Retiring address as president of the club, 1878"; and "The showiest butterfly of Glen Ellis, Basilarchia arthemis."

Through deliberate choice when only 19 years of age he had definitely elected the field for his life work. Yet in view of his high moral and mental character, the rare charm of his personality, his remarkable mental balance, his energy, and mastery of detail in executive work he might have won success in almost any field of human endeavor wherein judgment, reliability, and erudition were required.

Within all scientific organizations with which he was connected he held high place in executive or business councils, and so remarkable was his organizing ability that every one of the twelve serial numbers composing his great work upon the butterflies of New England appeared promptly on the day announced for its publication.

Having graduated from Williams College it was but natural that he should enter the Lawrence Scientific School of Harvard University in order that he might become a pupil of the incomparable Louis Agassiz. So to Agassiz he went with the statement that he intended to devote his entire life to the study of insects. The great master shook his head, and drawing a very dead and discolored fish out of a bottle of alcohol he deposited it in the hands of young

Scudder telling him to observe and report. For 10 minutes he studied this unattractive object, and then endeavored to report, but fortunately the professor was away. For three whole days he gazed at that single fish before he could satisfy the professor upon the important point that it possessed "symmetrical sides with paired organs." Then followed eight months entirely devoted to the study of somewhat similar fishes, all Hæmulons, until the pupil saw Hæmulons in his dreams, and grew to associate the odor of preserving fluids with pleasant memories. One thing seemed thereafter to have been burned into his very nature; devotion to all but infinite detail. Indeed throughout his scientific career one wonders not so much at the great bulk of his writings, as at the vast mass of minute and accurate details of observation therein presented.

He was keen to appreciate the dependence of theory upon fact, and to recognize the broader significance of the former, but it is as an accurate recorder of minute details of structure in the insect world that he stands preeminent and apart from all other entomologists of the past or the present, and while in this respect he may in future be equaled he can hardly be excelled. The religious zeal, reverence, and devotion to faith that had characterized his ancestry appeared now in the ardor of his labor for science. With the controversial side of the theory of evolution he had but little to do, nor was he in any sense an experimentalist, but on the other hand almost our whole accurate knowledge of American orthoptera and of American fossil insects is due to Scudder's painstaking examination and description of the most minute details of structure exhibited by these forms.

A strange contrast there was between the two pupils of Agassiz, Scudder and Hyatt; for intimate friends though they were throughout life, the one spent his days in recording facts, and the other in building theories. The one profoundly influenced by his master, devoted a lifetime to the extension of a principle which had seemingly overwhelmed him in a single course; while the other reflecting almost nothing of the school which had trained him built always in generalities of the imagination.

For four years Scudder studied under Agassiz, and graduated in 1862 with the degree of B. S.

Then began his long association with the Boston Society of Natural History in which he served as recording secretary from 1862–1870, librarian 1864–1870, custodian 1864–1865, and 1866–1870; vice president 1874–1880, and president 1880–1887; when he declined reelection in order to devote his entire energies to scientific work.

His interest in library administration led to his appointment as assistant librarian of Harvard College 1879–1882, and he also held the office of librarian of the American Academy of Arts and Sciences. Also in 1877 the Massachusetts Horticultural Society elected him professor of entomology and ex-officio member of the committee on the library. In 1874 he founded the Cambridge Entomological Club, which under his guidance was for many years one of the most active and important entomological societies in America, numbering practically all of the ablest American students of insects among its members. Many important papers he published in Psyche, the journal of the club. For many years the regular meetings of this society took place in the genial warmth that emanated from the great open fireplace of his excellently equipped private laboratory, which was in a specially designed building apart from his residence at 156 Brattle Street, Cambridge. Scudder himself was always unconsciously the leading spirit of these happy occasions, and many an animated discussion took place lasting until far into the night.

His working collection and the excellent library he possessed contributed in no small measure to enhance the interest of these occasions, but it was his own rare unconscious charm, simple man of science that he was, that shone as a beacon to welcome us all, great and small, to the door of the seemingly enchanted chamber wherein his kindly spirit dominated, with never a thought that his own face shone as that of a great leader in the science he always loved with that same ardor that had inspired his college days at Williams.

Not only was he a founder of Psyche but he acted in the same beneficent capacity to the weekly journal Science and was its editor from 1883 to 1885. Indeed wherever his interest led him men delighted in his leadership. For years he remained most prominent in the affairs of the Boston Society of Natural History, to whose publications he contributed no less than 163 scientific papers.

The extensive explorations conducted by the United States Geological Survey in the decades following the Civil War had led to the discovery of many fossil insects, and no more fortunate choice of a specialist to study these could have been made than that of Scudder who remained attached to the staff of the survey as paleontologist from January 1, 1886, to July 31, 1892. Not only did he make a thorough study of American forms, but in 1891 he prepared a valuable index to the known fossil insects of the world.

It was but natural that his high attainments and unsurpassed productiveness in publication should attract world-wide attention and win for him the highest scientific recognition.

In 1898 he received the Walker grand prize of $1,000 from the Boston Society of Natural History in recognition of his preeminent contributions to entomology. In 1890 the Western University of Pennsylvania conferred upon him the degree of LL. D. In 1877 he was elected a member of the National Academy of Sciences, and of the American Philosophical Society in 1878.

He was also a fellow of the American Association for the Advancement of Science, being its general secretary in 1875, and becoming a life member in 1880. Other associations of which he was a member were the American Academy of Arts and Sciences, the New York Academy of Sciences, the Philadelphia Academy of Natural Sciences, the Davenport Academy of Sciences, Microscopical Society of Boston, the Entomological Society of Washington, and the Troy Scientific Association.

He was also recognized abroad by being elected to honorary fellowship in the Royal Society of Canada, Fellow of the Entomological Society of London, corresponding member of the Zoological Society of London, and of La Société Physique et d'Histoire Naturelle de Genève; and he was a foreign associate of the national entomological or zoological societies of The Hague, Petrograd, Vienna, Moscow, Madrid, Buenos Aires, and Brussels.

On June 25, 1867, he married Ethelinda Jane Blatchford the daughter of Edgcumbe Heath Blatchford and Mary Ann Hubbard. She died on June 9, 1872, leaving a son Gardiner Hubbard Scudder, born September 3, 1869.

After graduating with honors from Harvard University this young man entered the Harvard Medical School where his indefinable charm of manner coupled as it was with earnestness, industry, and exceptional mental ability gave high promise for the future; but he graduated only to be stricken with acute tuberculosis from which he died on December 26, 1896.

Broken by the weight of this appalling deprivation Samuel Scudder never recovered in health or spirit, for in the same year in which his son died, he had developed symptoms of paralysis agitans. Calmly preparing for the invalidism which awaited him he gave his books and pamphlets to the scientific societies in which his had so long been the leading spirit; and then with a patience which only so noble a character as his could show he spent the long years of waiting ministered to in all kindliness and care by his sister-in-law, Miss Blatchford, authoress of "Little Jane and Me," who in order to cheer the painful hours read to him day after day as he sat on the verandah of his home in Cambridge.

That remarkable interest in system and fascination for detail that had characterized his active life still survived in these passive years, for at his request Miss Blatchford read to him every word of the original folio edition of Dr. Johnson's Dictionary, including the preface and the definition of each and every word; almost the entire time between January 12 and October 24, 1905, being consumed in this manner. Finally the end came on May 17, 1911.

Far more he was than the most learned entomologist of his generation, for few men of science have endeared themselves to those around them as did he, endowed as he was with an innate quality of kindliness that seemingly unknown to him graced his every word and act. One recalls his tall handsome form and the strong interesting features so wonderfully relieved by the happy soul that seemed ever ready to burst forth in a bright flash of interest over any and all things of that manifold nature to the observation of which his life had been devoted.

He was the author of 791 scientific publications, chiefly systematic descriptions of Lepidoptera, Orthoptera, Neuroptera, Hemiptera and Coleoptera, and devoting special attention to fossil forms.

Yet such a brief summary gives a wholly imperfect idea of the wide scope of his interests, much less of the sunny charm of his more popular writings which always seemed to have caught the generous cheer of a June day of his native New England.

He was perhaps the only man of science in America who could write a deeply technical work upon Lepidoptera and at the same time without incongruity crowd the volumes with quotations from poetry and with popular excursuses upon all manner of fascinating subjects related to New England and its butterflies. Yet such is his incomparable three volume work upon the "Butterflies of the eastern United States and Canada with special reference to New England." He proposed popular names for at least 77 species of American butterflies and curiously so aptly chosen were these that most of them are now better known to the American public than are the older scientific designations which they supplanted in the popular imagination. Among his interesting discoveries he showed that *Basilarchia proserpina* is a hybrid between *B. arthemis* and *B. astyanax*. Also that we now have stranded as it were upon Mount Washington, N. H., and on Pikes Peak and other high mountains of Colorado above 12,000 feet, a butterfly (*Oeneis semidea*) which in the glacial epoch was widely spread over the Northern States but upon the retreat of the ice became confined to these two isolated regions. He also demonstrated that the group-genus Papilo is composed of butterflies of relatively primitive organization, and more closely related to the Hesperidæ than to the more recent and highly specialized Nymphalinæ.

The migrations, feeding habits, life histories, geographical distribution, dimorphism, morphology, and early larval and egg characters are all most philosophically yet fascinatingly dealt with in this great work which, had he produced no other, would have made him one of the world's leading entomologists. But he was the author of many other voluminous works which from the standpoint of systematic zoology, or paleontology were even more important.

The following list may give some rough idea of the extent of his activities and of the enormous energy he possessed. The numbers represent the number of papers he published upon each subject:

Lepidoptera, 168; Orthoptera, 180; fossil insects, 122; anatomy of insects, 19; evolution, 15; geographical distribution, 29; biographical, 25; reviews, 63; geological, 13; general entomological subjects, 85; habits of insects, 24; catalogues and lists of species, 28; nomenclature, 8; geography and exploration, 16; economic entomology, 17; embryology of insects, 6; songs of insects, 6; ethnology, 4; food plants of insects, 4; regeneration in insects, 2; public questions, 2; mammals, 1; fishes, 1; crustacea, 1; mollusca, 1.

It is remarkable that in his first paper, published immediately after leaving Williams College, he enumerates 28 species of snails, yet of all his following zoological papers only 7 are upon subjects other than insects. On the other hand, almost all the accurate knowledge we possess of American grasshoppers, cockroaches and crickets, and of fossil insects is due to Scudder. Indeed, according to Cockerell, the original descriptions of 1,884 species of animals are found in Scudder's writings. Of these 1,144 species and 233 genera are fossil insects, and 630 species and 106 genera are living Orthoptera, the remainder being chiefly fossil arachnids and myriopods, Coleoptera and the living butterflies of North America.

Scudder believed that generic names should be used to indicate differences rather than to show relationships. He was thus one of the type of systematists known as "splitters," and nowhere does this tendency appear in his works in a more accentuated degree than in his treatment of the generic names of butterflies.

Naturally in the vast mass of his writings, especially upon fossil insects, which must often be described from mere fragments, there are mistakes, many of which he himself corrected as the work progressed. An amusing instance of this sort is his description of Trichiulus, which he mistook for part of the hairy leg of a fossil centipede, but later, upon discovering that the specimen was more probably part of a fern leaf, he told his friends that it should be called "Tricky" ulus.

His work upon fossil insects was of the pioneer sort and thus much of it had perforce to be accomplished in haste; yet few naturalists who have been obliged to study under these adverse conditions have done as well as did Scudder. Mistakes must mar the pages of all leaders of science, and can be avoided only by the cardinal sin of doing nothing.

An excellent feature of Scudder's work upon fossil insects is the frequency of figures in his papers, which were provided despite the fact that he himself was unable to draw.

He believed the relationship between the paleozoic and the quaternary insects to be more remote than is now conceded to be the case; but withal he laid the foundation of the world's knowledge of American fossil insects and future work must be erected upon the structure resulting from his tireless labor and his genius for classification.

A notable set of useful publications are represented by his lists and catalogues, the most important being a catalogue of scientific serials of all countries from 1633 to 1876, and his well-known and widely used Nomenclator Zoologicus, first published in 1882 and 1884 and giving a list of generic names used in zoology.

He seemed to have but little desire to conduct experiments, nor was he much interested in economic entomology, and as a breeder of insect larvæ he was surpassed by Edwards and others, but in the accurate systematic recording of minute detail of external structure he had no peer in his time nor has any entomologist ever attained to his excellence in this respect. Deeply interested as he was in butterflies, he seemed to have almost an aversion to moths.

A biographical notice of Scudder, giving portrait and written by Prof. C. E. Fay, appears in Appalachia, volume 12, pages 276–279, 1911. Also in 1911, T. D. A. Cockerell published in Science, volume 34, pages 338–342, an interesting commentary upon Scudder's scientific labors, and a series of papers of somewhat similar purport were published in Psyche, volume 18, 1911, pages 175–192, the authors being J. S. Kingsley, W. L. W. Field, T. D. A. Cockerell, and Albert P. Morse. Biographical notices also appeared in the Canadian Entomologist, the Entomological News, and in the Harvard Graduate's Magazine.

In 1879 Dr. George Dimmock published a pamphlet upon "The Writings of Samuel Hubbard Scudder," in which he records 311 publications with brief reviews of the contents of each paper, and of references to it by other authors. Dr. Dimmock has kindly permitted me to make full use of this valuable list. In addition Dr. Samuel Henshaw permitted me to inspect Scudder's personal notebook, now deposited in the library of the Museum of Comparative Zoology at Cambridge, in which he records and numbers each of his papers as it appeared, the last entry being upon Lepidoptera and numbered 791. The list of papers herewith published is derived from these sources.

It is a pleasure to acknowledge my appreciation of the kindly interest and aid in the preparation of this biography shown by Miss Blatchford, Mrs. Horace Elisha Scudder, and other members of the family.

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NATIONAL ACADEMY OF SCIENCES.

Volume XVII.
FOURTH MEMOIR.

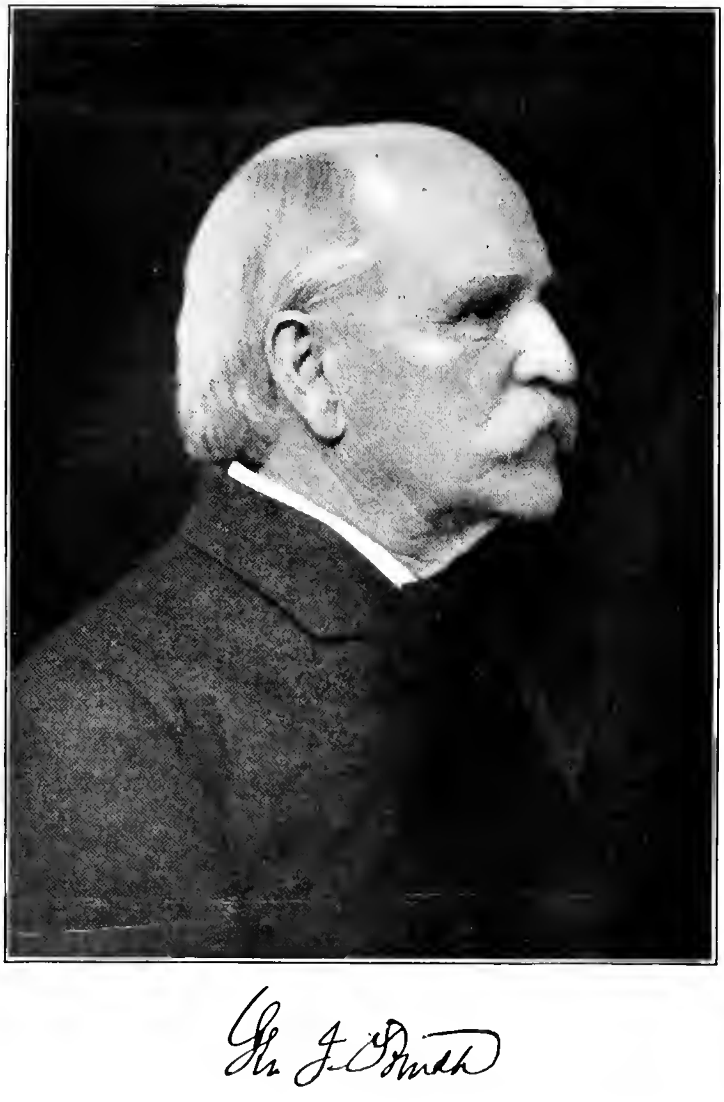
BIOGRAPHICAL MEMOIR GEORGE JARVIS BRUSH

1831-1912.

BY

EDWARD S. DANA.

Presented to the Academy at the Annual Meeting, 1920.



GEORGE JARVIS BRUSH.

1831–1912.

By Edward S. Dana.

[Reprinted with unessential changes from the American Journal of Science, May, 1912.

Prof. Brush, whose long life of active service for science and Yale University closed on February 6, 1912, will always be remembered as a pioneer in the building up of scientific education in this country. His energy, his indomitable will, his courage in contending with obstacles, and his rare administrative ability were devoted for nearly 40 years with intense singleheartedness to the School of Science from which he obtained his degree in 1852. As the reward of his devotion and that of his colleagues, he had the satisfaction of seeing the school expand steadily from the smallest of beginnings until it was established as a vigorous and growing department of Yale University. He began his work when the value of science, and that of the scientific methods of the laboratory, were but meagerly appreciated in the country; when he resigned from active service in 1898, science had won a large place in every institution and schools of science were to be found at many centers of learning.

Prof. Brush was also an able and trained worker in a special field of science, contributing largely to mineralogy through his own original work and acting as an inspiration to his students, who carried on the research in his favorite subject when his energies were diverted into administrative lines.

George Jarvis Brush was born on December 15, 1831. He was the seventh in line of descent from Thomas Brush, who settled in Southold, Long Island, in 1653, and who is believed to have been the first of the name in America. The father of Mr. Brush was Jarvis Brush, and his mother, Sarah Keeler. The family home was in Brooklyn, N. Y., where the father was in active and successful business as a commission and importing merchant. In 1835, when still a young man, he retired from business, satisfied with the competency he had gained, and moved with his family to Danbury, Conn., where he resided for some six years until 1841, when he returned to Brooklyn. The early education of George was received in private schools in these two places. When fifteen years old he was sent to a school at West Cornwall, Conn., kept by Mr. Theodore S. Gold, and it was here that his interest in science was first aroused. Mr. Gold was an admirable teacher for such a student, for he was enthusiastically devoted to mineralogy and other branches of natural history, and had a rare power in arousing the interest of his pupils in these subjects. Although young Brush was with Mr. Gold only six months, the effect upon his subsequent career was profound. The evidence of this was not shown, however, at once, for the traditions of the family led him to look forward to a business life. After leaving the West Cornwall school he took a position with a mercantile house in Maiden Lane, New York City, and remained there about two years; occasional mineral excursions were his only indulgence in science. But fate had a wider career in store for him. In consequence of a serious illness in 1848 he was compelled to give up the confining life of business, and it was decided that he should devote himself to farming. This decision led him to come to New Haven in October, 1848, to attend the lectures of Profs. John P. Norton and Benjamin Silliman, jr., in agricultural and practical chemistry, recently established in connection with Yale College. The college catalogue for 1848 includes his name as a member of the second class in the "School of Applied Chemistry." His work in New Haven was, however, interrupted when in October, 1850, he went to Louisville, Ky., as assistant to Prof. Benjamin Silliman, jr., instructor of chemistry and toxicology in the medical department of Louisville University, a position which he retained till the spring of 1852. During this period, in the spring and summer of 1851, he traveled extensively in Europe as one of the party of the elder Proj. Benjamin Silliman. At the Yale commencement of 1852, after a special examination made necessary by the absence alluded to, he received the new degree of Ph. B. just established. It is most interesting that the man who was destined to build up this department of the institution into the strong and flourishing Sheffield Scientific School should have been a member of the first class to receive a degree. In this class of 1852, which began with 14 members, 7 were graduated, 4 of whom later became prominent in science, and one of these, Prof. William H. Brewer, worked shoulder to shoulder with Brush in the work for the school for many years.

The college year of 1852–53 was spent as assistant in chemistry at the University of Virginia, and it was here that, associated with Prof. J. Lawrence Smith, a series of studies were prosecuted on the "reexamination of American minerals"; three papers with this title were published in volumes 15 and 16 of the American Journal of Science. This work in mineral chemistry served to show both his ability in research, his grasp of scientific methods, and his interest in the subject. It also made him feel the necessity of further scientific study and training. After spending the summer of 1853 as assistant in charge of the department of mineralogy in the Crystal Palace at the International Exposition in New York, he sailed in the following November to Germany. The years 1853 to 1855 were spent in Germany, at first at Munich with Liebig, von Kobell, and Pettenkofer, and later at the mining school at Freiberg, Saxony. These years were rich in results, not only in the scientific training they gave, but also in the opportunities for close association with his professors and fellow students.

In 1855 Mr. Brush was elected professor of metallurgy at New Haven, in the Yale Scientific School that had been slowly developing ever since its beginning in 1846. To train himself for his future work he spent another year abroad, studying at the Royal School of Mines in London and also visiting the chief mines and smelting works of Great Britain and the continent. In January, 1857, he entered upon the duties of his professorship of metallurgy; later, in 1864, his chair was broadened so as to include mineralogy, and in 1871 it was finally limited to the latter subject, the one in which he was particularly interested. Of his work after the time when he became professor in the Scientific School, one who was later his colleague for many years wrote of him in 1881: [1]

> From this time on the history of Prof. Brush has been the history of the special scientific department of Yale College, which, in 1860, owing to the liberal benefactions of Mr. Joseph E. Sheffield, received the name of the Sheffield Scientific School. He came to it while it was not only without reputation, but without appreciation or expectation. He came to it while it was poor beyond even that decent poverty which apparently belongs, in the nature of things, to institutions of learning—while it was in a state of mind so unorganized that as a whole it could hardly be said to have a being at all. It exhibited, indeed, a good deal of life in the college catalogue, but beyond that its vitality did not extend. There was vigor enough in certain of its departments, expecially in that of civil engineering, under the charge of Prof. William A. Norton; but in such cases it was a vigor due to the energy of the individual instructor, and therefore almost certain to disappear whenever he disappeared. To bring these scattered units into an organic whole, to build up a complete and consistent scheme of scientific education, which should have both definite and lofty aims, which should train men thoroughly in scientific methods, and which should continue to exist by its own inherent vitality after the men who established it should have passed away—all this became by degrees a main work of Prof. Brush's life. His energy, his judgment, his executive capacity, and his devotion soon gave him the leading direction in the affairs of the institution. He was for a long period its secretary; he has always been its treasurer; and when, in 1872, a more formal organization of its faculty was felt to be desirable, he was elected as its presiding officer, a position which he still retains. Others have done their part toward developing various departments of the school, but its growth, as a whole, the position which it has acquired among scientific institutions, whatever that position may be, has been due to him very much more than to any other one man connected with it. * * *

In 1872, as above stated, Prof. Brush was made director of the Sheffield Scientific School, to which he had already devoted 15 years of his life. This position he held until 1898, when he resigned his active duties, both professorial and administrative. His time and energies of necessity were, from 1872 on, more and more absorbed by the labor of planning for the school as a whole and caring for its many interests. In 1873, Dr. George W. Hawes was

[1] Popular Science Monthly, vol. 20, pp. 119, 120, November, 1881.

appointed assistant in mineralogy, and much of the active work of teaching devolved upon him; thus in the later seventies, Prof. Brush had practically resigned his laboratory instruction and finally, in 1884, he was compelled to give up his lectures also. Dr. Hawes remained in charge of the department until 1879, during which time the classes in laboratory work were transferred to the Peabody Museum after its completion in 1876. In 1879, Dr. Hawes was called to Washington and Dr. S. L. Penfield took his place as instructor in mineralogy; later the latter was made assistant professor (1888), and finally professor of mineralogy (1893); in his able hands Prof. Brush felt that his favorite subject was fully cared for, as was well proved by the work that was published from the Sheffield laboratory of mineralogy. It may well be imagined with what deep sorrow the elder professor saw each of his assistants and helpers cut down in their prime—Hawes in 1882, and Penfield in 1906.

In 1898, as has been stated, Brush resigned his active responsibilities as professor and director. The remaining years of his life were for the most part spent in New Haven, in close touch with the same interests to which he had devoted his life. He continued as secretary and treasurer of the Sheffield trustees until 1900, when he retired as secretary and was elected president of the board. He gave up the treasurership in 1904, but retained the presidency until the end, presiding at the annual meeting in November, 1911.

During the period that has been alluded to, Brush took the liveliest interest in all that pertained to mineralogy, the instruction, the active research, and the increase of his private collection, although he himself, as he sometimes a little pathetically expressed it, was "doomed to turn the crank of the machine." The various duties of the director of the rapidly growing school, financial and administrative, were, however, fully to his taste, and it can hardly be regretted that his time and strength were given so fully to them. His health, on the whole, was not seriously impaired as years increased, until the spring of 1911, when a trouble with the heart developed which from that time increasingly limited his physical activity. The decline was slow and for the most part, until near the end, without suffering, and on February 6, 1912, he passed gently away. The great kindliness of his strong nature was never shown more clearly than in the closing months of his life. In 1864 he was married to Harriet Silliman Trumbull, who died in 1910; three daughters survive him.

The interest taken in minerals by Mr. Brush, when a boy of 15, was rapidly developed during his student years under the stimulating influences at Munich and Freiberg. This interest continued unchanged through his life, though, as has been stated, the pressure of administrative work finally robbed him of the opportunity for active study He developed early a remarkably keen eye for recognizing mineral species, even those which were a puzzle to an ordinary mineralogist. When a schoolboy with Mr. Gold he began to collect minerals, and as years went on and his ability to obtain specimens by purchase or exchange increased, he accumulated a large and very valuable collection. This collection was especially notable for its completeness for the purposes of scientific study and the type specimens which it contained; the history of each specimen was also recorded with the utmost care. His active work as a collector, aided by that of his associates, continued till 1904, when he formally presented his collection, then numbering about 15,000 specimens, to the Sheffield Scientific School, adding to this gift a fund of $10,000 for its maintenance and increase. This collection was housed in the old building of the Sheffield School until its removal to his room in the Peabody Museum in 1876. Here it remained until 1904, when it was placed in a room specially prepared for it in Kirtland Hall, where it is now in charge of Prof. William E. Ford, the successor of Prof. Penfield. He took the greatest satisfaction in having it cared for, arranged, and catalogued; and one of the keenest pleasures of his later years consisted in going over the collection and aiding in the final work upon it.

A mineralogist with so keen an eye and interest in his subject must of necessity have been both a teacher and investigator. In the former direction the influence of Prof. Brush was widely felt, particularly during the decade beginning with 1864. Many students were inspired by his enthusiasm, and carried the knowledge and skill acquired from him to other centers of learning. The work of Prof. Brush in the original study of minerals began in 1849, when he was only 18 years old. From then for 25 years he was active, and a series of about 30 papers gives a record of the results attained. In 1878, and later, he took time from his absorbing administrative labors, and, in conjunction with a younger colleague, published a series of papers on the newly discovered locality at Branchville, Conn.

In 1874 his "Manual of Determinative Mineralogy" was brought out; this contained a clear summary of blowpipe methods and principles and also a series of determinative tables adapted from the German tables of von Kobell. In the preparation of this work, especially the latter part, Dr. Hawes took a prominent part. A revised edition was issued in 1878, and later the work was entirely rewritten on an expanded scale by Prof. Penfield. The most important editions of the book as thus revised were those of 1896 and 1898. Prof. Brush also made important contributions to the System of Mineralogy of Prof. James D. Dana. Of the ten supplements to the fourth edition of 1854, he prepared the eighth, ninth, and tenth. In the preparation of the fifth edition of 1868 he took an important part; the statements of the blowpipe characters of the different species were written by him, and, in most cases, the facts given were based upon his own independent experiments. His close knowledge of mineralogy also enabled him to aid the author at many points in the prosecution of his task. The first appendix to the fifth edition, issued in 1872, was prepared by Prof. Brush. Another contribution to the science to which he was devoted was the presidential address before the American Association for the Advancement of Science at Montreal in 1882; this was a thorough and valuable summary of the early history of American mineralogy. Prof. Brush became an associate editor of the American Journal of Science in 1863 and retained that position until 1879. The pages of the journal contain about all of his papers on mineralogical subjects.

It has been shown that the influence of his early life tended to turn Mr. Brush into an active business career. Fortunately for the world this was not to be his life's work, but to one familiar with him and what he accomplished, the influence of this early training is clearly shown. He was distinctly a man of affairs, of quick, sure judgment, firmness of resolution, and great energy. The successive steps by which the Sheffield Scientific School grew under his guidance, from 1857 on, show at every stage his ability and his strong hand. Without discussing this subject in detail, it may be stated that the success of this, the most important work of his life, can hardly be overestimated. The school at the beginning had almost no funds, but it early attracted the interest of Mr. Joseph E. Sheffield, and this interest was wisely and tactfully guided and stimulated by Mr. Brush. As the result of this, the school received from Mr. Sheffield a considerable endowment and, in 1861, was formally called the Sheffield Scientific School. The endowment was still further increased later, especially by the provisions of the will of Mr. Sheffield, who died in 1882. It would be difficult, without detailed historical discussion, to give any adequate idea of the complexity and difficulty of the problems of the growing school and of the skill and wisdom with which they were met and solved by Mr. Brush. One particular matter may be mentioned here. The school, in 1863, became the land grant college of Connecticut under the land grant act of the Federal Government. The sale of the land yielded an income which was most important to the school at a critical time in its growth. Later, in 1892, this fund was transferred by the State to the Storrs Agricultural College, but in the contest over the subject the interests of the school were so ably handled by Mr. Brush that in the settlement it received outright a sum of $150,000, thus putting it in a better position than that which it had before occupied.

The financial skill shown in the management of the interests of the school was also used for the benefit of the funds of the Peabody Museum, of which Mr. Brush was one of the original trustees appointed in the deed of gift of Mr. George Peabody in 1866. It was largely through his able management that the original $150,000 grew so steadily and surely that the $100,000 set apart at the beginning amounted to the $176,000 needed to pay for the building completed 10 years later. Mr. Brush sometimes alluded with satisfaction to the fact that he had the foresight to exchange the 5 per cent Massachusetts State bonds of the original Peabody gift for the "seven-thirties" of the Civil War loan, thus producing a rapid increase in the available funds.

It is also interesting to note that for many years he was a director in the Jackson Iron Co. of the Lake Superior district. He was, further, a director in the New York, New Haven & Hartford Railroad from 1893 until his death, attending all the meetings with great regularity.

Prof. Brush was elected a member of the National Academy of Sciences in 1868 and received the degree of doctor of laws from Harvard University in 1886. He presided as president of the American Association for the Advancement of Science at Cincinnati in 1881, and delivered the presidential address at Montreal the following year. He was an honorary member of the Mineralogical Society of England, a foreign member of the Geological Society of London, of the Geological Society of Edinburgh, of the Royal Bavarian Academy of Sciences of Munich, and various other learned societies, both at home and abroad.

The portrait accompanying this sketch has been reproduced from a photograph taken about 1897.

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NATIONAL ACADEMY OF SCIENCES.

Volume XVII.
FIFTH MEMOIR.

BIOGRAPHICAL MEMOIR SAMUEL WENDELL WILLISTON

1852-1918.

BY

RICHARD SWANN LULL.

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1919.

SAMUEL WENDELL WILLISTON.

1852-1918.

By Richard Swann Lull.

Part I.—Biographical Sketch.

In his immediate family, Prof. Williston stood as a conspicuous figure, as a scholar, a man of research, and one who by an innate superiority made himself what he was. For he owed little to his forebears other than the heritage of those sterling qualities which have made New Englanders in general so vital a force in the evolution of our national character and prestige; his scientific tendencies were an individual characteristic, and he stands as the only recorded Williston to follow lines of scientific research.

Williston's father, Samuel Williston, was a blacksmith, and, although a man of considerable native ability, was totally untrained in the affairs of book men. He possessed, however, that pioneer spirit which impelled so many eastern men to migrate to the developing West and seek in a new environment the elusive fortune which the East did not provide. Hence, while Williston was born in Boston, his development, in so far as environment exerted a control, was due almost exclusively to the stimulating conditions of the newly invaded West. Here he spent his boyhood. Of less robust physique than were his three older brothers, he sought companionship in whatever books came his way, reading without discrimination, largely because the volumes were so few. His was a laudable ambition, however, for he very soon announced his determination of being the most learned man in Kansas.

His schooling was necessarily erratic, but none the less progressive, beginning with the alphabet, which was learned from the lettering on the cookstove, and continuing through the elementary schools of Manhattan, Kans., coupled, as has been said, with the most omnivorous reading. It was largely due to the influence of his mother, Jane Turner, that Williston and his brothers had any opportunity for schooling, for she determined that they should not suffer the handicap of illiteracy against which her husband had to contend.

Williston's first interest in paleontology was aroused in his seventh year. The boys had often gathered clams in the Blue River near Manhattan, but he found fossil clamshells on the summit of a hill known as Blue Mont. He knew clams could not crawl on land, and accordingly sought of his father and Sunday-school teacher the solution of the mystery. Their explanation, had they but known, was like that by which the ancient Greeks sought to reconcile the presence of mollusks' shells high upon the hills around the Mediterranean, and to the boy the simple Biblical explanation of their being relics of the Deluge seemed at that time sufficient and served to awaken an interest in the Book of Genesis which he had not had before. There were also large stones filled with fossil shells of lower Permian age in the boys' favorite swimming hole, and these constituted Williston's first subjects for paleontological study.

Fishing and hunting were the father's favorite recreations, and the preparation of the fish for cooking was young Samuel's task. Catfish, shad, and river sturgeon, the last with its apparent lack of a vertebral column, in place of which there was a long fibrous rod, the notochord, gave rise to much speculation on the part of the boy, and this also served directly to stimulate his interest in natural history.

Blue Mont College had been founded in 1859, but was merged into the State Agricultural College in 1864, and two years later Williston was permitted to enter it as a student. Stimulated by his reading, he soon decided to become an author, but the nearest approach possible at this time was to aid in the printing of a semiweekly newspaper at Manhattan. It was during this service that Williston's first literary contribution appeared—a supposedly humorous account of the capture of Jefferson Davis, by the "printer's devil," who was at that time but 13 years old.

However, the value of learning the printer's trade did not outweigh that of further schooling, so Williston was sent back to the Agricultural College to continue his work. Here he read Lyell's "Antiquity of Man," which made him a firm believer in evolution, despite its evident antagonism to the teaching of the church. His friend and preceptor, Prof. Mudge of the Agricultural College, to whom he owed so much, remained opposed to the doctrine until his death. Under Prof. Mudge, Williston studied natural philosophy, chemistry, botany, geology, zoology, veterinary science, mineralogy, surveying, spherical geometry, conic sections, calculus—a range of subjects possible only in the older days. In 1869 unrest again seized Williston, so in spite of the fact that he had not completed his collegiate education he decided to seek his fortune, and after somewhat varied and disheartening experiences received the opportunity of doing railroad construction work, first in a clerical, later in an engineering capacity, until finally his health, which was still not at all robust, compelled him to give up such work and return to college. He completed his course in 1872, taking the bachelor of science degree, for he did not feel sufficiently proficient in Plato and Herodotus to make up the back work necessary for the degree of bachelor of arts. The panic of 1872 and 1873 made it impossible for him to obtain employment as a civil engineer. This circumstance proved to be of vital importance in his career, for, an early interest in medicine reawakening, he determined to study under the supervision of the family physician, Dr. Patee, of Manhattan, a regular procedure in those days, when all that was required was that a student of medicine "read" in some physician's office for three years, taking two courses of lectures of four or six months each, the second merely a repetition of the first, before coming up for his degree. Williston was given very little advice or direction in his studies, except that he was told to study anatomy and physiology first. For material he excavated in an old Indian burial ground, and the study of the bones thus exhumed directed his attention to osteology, in which he later became so high an authority.

Trouble in the Agricultural College in 1873 led to the dismissal of Prof. Mudge, and Williston, not understanding the situation, took the former's classes for a while. The apparent injustice of the matter, however, made him so strong a partisan of Prof. Mudge that his manifestation thereof proved more than the authorities could stand and he was asked to leave. Otherwise he might have succeeded his preceptor as a teacher of comprehensive "science."

Williston's convictions concerning evolution, the result of absorbing the writings of Darwin, Huxley, Tyndall, and especially a German writer, Buecher, coupled with evidences from his own observation, led to his delivering in the Congregational Church of Manhattan what he believed to have been the first public lecture in favor of evolution ever given west of the Mississippi River. This was in February, 1874, and was, as he himself says, given with the cocksureness of youth, the address being lacking neither in positive nor dynamic statements. Such a thing was daring in those days, nevertheless Williston was shocked at the severe criticism which he received in the local press.

Meanwhile Prof. Mudge was carrying on geological explorations in western Kansas and had discovered the famous specimen of the Cretaceous toothed bird, *Ichthyornis*, which by pure accident he sent to Prof. Marsh rather than to Prof. Cope, for whom he intended it. Marsh's interest was promptly stimulated, and in his characteristic way he immediately engaged Mudge to collect fossils for Yale College. Mudge and a young assistant collected for a while in the northwestern part of the State, and then, as the hope of success seemed more promising in the Smoky Hill Valley, decided to move thither. Fear of the Indians, however, proved to be too much for the assistant, and Mudge was forced to seek other aid. He engaged one of his former students, H. A. Brous, who in turn invited Williston to accompany him, and after fulfilling an engagement to play the cornet in a band on July Fourth, Williston began what was to be his subsequent life work as a paleontologist. Thus, as he says, "It was this accidental and thoughtless decision that led to my life's devotion to Paleontology. Had I not gone with him in all probability [to-day] I would have been a practitioner of medicine somewhere in Kansas."

Upon the completion of the summer's campaign, Williston went to the University of Iowa for the first course of medical lectures, but in the meanwhile Prof. Marsh's attention had been called to him, probably because the specimens collected by each man were marked with his name. At any rate, in February Williston was invited to come to New Haven, and the offer was eagerly accepted, for, as he says—

I had lived practically all my life remote from scientific men, and authors were almost unknown. I had always been a bookworm of the most accentuated type; I had grown to reverence, almost to worship, the writers of books and especially of scientific books. * * * Such men as Huxley, Darwin, Dana, Gray, and Marsh were my ideals of all that was great and good. I thought them impeccable and almost infallible. My greatest ambition was to follow humbly in their footsteps—to write a book sometime myself and to make discoveries.

Hence the first meeting of Prof. Marsh and the young westerner on March 19 or 20, 1876, was of great moment to the latter, and he records his impressions of the professor in no uncertain terms. The remainder of his visit was spent chiefly in the study of bird skeletons, and by May 1 he was once more in the field in Kansas with a larger party, again in charge of Mudge. A long season was followed by Williston's return to New Haven, and in 1877 he was himself for the first time placed in charge of the Kansas party, while Mudge was sent to Texas.

Williston hoped very much to do original work, and with this end in view spent much of the preceding winter in studying fish skeletons in his own time, although under Marsh's direction, but when he asked permission to do actual research on the Cretaceous fishes which he believed Prof. Marsh had no intention of studying it was denied him on the ground that it would distract his attention from his regular duties. Williston soon realized that he would probably never have the opportunity of doing independent research on fossil vertebrates so long as he was Prof. Marsh's assistant, and this realization was to have a very important influence upon his future career. The season of 1877 was very long and tiring, as he spent no fewer than 10 months in the field, and it was during this period that his interest in insects, at this time chiefly beetles, was aroused. On his return to New Haven, in January, 1878, he was determined to find some independent field of research, and after mature deliberation chose the Diptera, of which he eventually became the foremost American authority. But one more season, that of 1878, was spent in collecting for Prof. Marsh, and from this work Williston was recalled in July. The following January a new contract was made between them, whereby Williston was permitted to complete his medical studies, which he did, taking his M. D. from Yale in June, 1880.

Upon graduation, Williston was appointed assistant in osteology in Yale College, and in 1881 he was placed on the Government pay roll as assistant paleontologist. In December of that year he married Miss Annie I. Hathaway, of New Haven, who survives him, with four of their five children. He remained with Prof. Marsh until 1885, although discontented, chiefly on account of the repressive policy of the latter. Hence in 1885 their relations were finally severed, Williston receiving the degree of doctor of philosophy from Yale at commencement.

He was now somewhat at a loss as to what course to pursue. He finally, however, refused the offer made by Dr. C. V. Riley, the United States entomologist, to serve as his chief assistant, and began the practice of medicine, in addition to which he acted as assistant editor of Science, under Prof. Scudder. In September he was appointed demonstrator of anatomy in the Yale Medical School, spending his days in New York in his capacity as editor and his evenings at Yale in teaching. July of the next year brought him the title of assistant professor of anatomy, at a very small salary, which he was forced to eke out by his medical practice and by serving as town physician. It was as a health officer of New Haven in 1888 that Dr. Williston carried through single-handed an epidemic of smallpox, caring for the sick and burying the dead with a singleness of purpose and devotion to duty which in war times would have won for him a high military honor. The year 1887 saw his appointment as professor of anatomy at Yale; 1890 brought an offer from the Kansas Agricultural College which was declined, but an appointment as professor of geology in the University of Kansas was accepted in September of that year.

Much that has been said of Prof. Williston's early life and struggles has been gleaned from a manuscript autobiography prepared by him in May, 1916, and kindly placed at the writer's disposal by Mrs. Williston. With the acceptance of the chair at Kansas, however, he thought the "recollections could with propriety end." The man had most assuredly found himself, and the upbuilding of his character and education was accomplished when he entered thus upon the final phase of his scientific career. It is nevertheless to be regretted that he ended his autobiography here, for his later career, while less romantic, was of greater importance to science, both from the standpoint of teaching and of research.

Dr. Williston's term of service in Kansas extended from 1890 to 1902, and to the title of professor of geology were added those of professor of anatomy and dean of the School of Medicine. In addition, he was appointed a member of the State board of health, of which it is said that, largely because of his enthusiasm for work in behalf of the health of the community and his ability to get things done by injecting new life into that body, it has since had the reputation of being one of the most efficient and progressive of the State boards of health. He served also as a member of the State board of medical examiners (1901–2). The year 1902 brought the call to the University of Chicago as professor of paleontology, and there his affiliation lay with the Department of Zoology until almost the close of his career, when he was made director of the Walker Museum in addition to his professorial duties.

The manysidedness of Dr. Williston's accomplishments is abundantly attested by the varied character of his employment, in which, at any rate in his earlier life, he was to a certain extent the victim of circumstances. He could not always follow his greatest inclination, but invariably recognized opportunity and made the most of conditions which might well have discouraged a lesser man, and, as the final results show, these opportunities all served to make the fruition the more abundant and valuable when he came to the fullness of his career.

Williston was a born teacher. My greatest impression of this came at the initial meeting of the Paleontological Society in Cambridge in 1909 where, under President John M. Clarke's administration, a number of us were setting forth, usually from a read manuscript, our ideas concerning the aspects of paleontology. Then rose Williston, whose paper was on "The Birthplace of Man," walked to the front of the desk, and without notes, in a simple conversational manner unfolded a marvelous exposition of his theme. Without a thought of disparagement of the other contributions, Williston's stands supreme as one of the finest and most inspiring presentations I have ever heard, and I knew at once why as a teacher he was eminent. The direct testimony of three of his students bears this out. Riggs says of him in a letter:

> His attic-study [at Chicago] and limited exhibition space became the Mecca of every paleontological pilgrim. This brought him in turn a limited but permanent fund to carry out his work; brought greater opportunity for extended publication; and brought also an honorary degree from his alma mater. These were the outward expressions of approval. There came with it a following of eager and enthusiastic students. They gathered in his little study and marveled at his lectures. They followed him regularly and often to the Field Museum for demonstrations. They marveled more at his enthusiasm and the broad scope of his conceptions than at the intrinsic interest of his subject.

I am also permitted to quote from Prof. Case, who says:

> I believe that the "Mark Hopkins and a log" idea of a university was never more nearly realized than in Dr. Williston. His knowledge of men and things was so wide and his acquaintance with many branches of science so intimate that in the heat of a barren fossil field, or under the stars at night by the side of a camp fire, some bird, or flower, or fossil, some insect—"one of mine, I named it in 1870-odd"—would start a talk that held his little band of student assistants enthralled until hunger, thirst, or sleep were forgotten.

Prof. Williston was greatly interested in the scientific society of the Sigma Xi, and in a number of educational addresses delivered under the auspices of that organization, emphasized very strongly the principles of training and practice for which it stands: a broad training in the sciences, but, above all, that productive scholarship which is manifest in a high quality of original scientific research. Williston's influence in such education and his own attainments in line with these principles were recognized by the society, which conferred upon him its vice presidency from 1899–1901, and its presidency from 1901 to 1904. He was also a member of the Sigma Xi council for the years 1895 to 1904, 1907 to 1909, and 1910 to 1918, and was instrumental in forming the Chicago chapter in 1903.

Dr. Williston's addresses, which have been mentioned, are notable, and of the several which have been printed, the most important are those before the Kansas Academy of Sciences in 1897, the Ohio State chapter of the Sigma Xi in 1903, the Kansas chapter in the same year, and the Yale chapter in 1917. His presidential address at the sixth biennial convention of the society was considered so important that part of it is incorporated into the appendix to the constitution and is often read to initiates as the best summation of the principles for which the Sigma Xi stands. Still another noteworthy address was that delivered before the National Educational Association at Denver in 1909, on the subject, "Has the American college failed to fulfill its function?"

It has perhaps been evident that Williston's inclinations would have led him at once into vertebrate paleontology as a field for research, with the probable result of more than doubling the quantity and increasing with greater knowledge the quality of his output in that department of science; but here opportunity passed him by and circumstance drove him to entomology as an outlet for the pent-up energies of his creative mind. And his work in that field was of the highest quality, as Riley's offer surely shows, for, as Williston himself says, "Had I accepted the place of chief assistant perhaps I would now be the United States entomologist." Williston's research began with the beetles, but he speedily turned his attention to the flies, the results being published first in 1877, a few papers together in 1878, then exclusively from 1880 until 1886, when his second paleontological paper appeared. From 1887 until 1896 the entomological papers were still the bulk of his output, but from this time on those in paleontology became more and more numerous until the insect research practically ceased in 1899. In 1908, however, Williston did a remarkable thing in laying aside his paleontology and taking up once more the study of the flies, his purpose being to make a final (third) revision of their taxonomy and publishing his "Manual of the North American Diptera." In this final volume, which is both compendious and minute in detail, Williston shows a breadth and accuracy of knowledge surprising in any case and doubly so when one considers that he had done no research on the flies for more than a dozen years.

Williston also wrote of recent zoology, mainly on the habits of creatures which came casually within the scope of his observation; he wrote of sanitation and river pollution, of mankind in the abstract and specifically when called upon to pay tribute to departed colleagues. But his main research, as with his teaching, lay with the vertebrates of the geologic past, and herein the volume of his work equals that on the insects and in the prejudiced eyes of a fellow vertebratist has a value which greatly exceeds it. For the vertebrate work is not solely systematic, as was the entomological, but gave opportunity for broad generalizations, anatomical, evolutional, and philosophical, of a very high order.

At the University of Kansas the local paleontology naturally attracted Williston's attention, partly because his initial work with Prof. Mudge in 1874 was in the rich Niobrara Cretaceous, and because the work was in part that of the Kansas University Geological Survey. For more than 12 years, with the material secured by Dr. F. H. Snow and Judge E. P. West as a nucleus, Williston sought to build up the university collections, embodying the scientific results in Volumes IV and VI of the State survey. This research deals largely with the creatures of the Niobrara chalk, all of which are marine or aerial, with the exception of a rare dinosaur or two.

At Chicago, Williston found that his predecessor, Dr. Baur, who had also served for a number of years under Prof. Marsh at Yale, had already made some collections of Permian material, and this fact gave the trend to his future work. As Mr. Riggs (letter) says of him:

> He made expeditions into the Trias and then into the Permian of the Southwest. Year after year his collectors were sent into this field and soon publications announced their discoveries. Despite the rigors of climate, the insufficiency of funds and the protests of his field men, he clung to this field and its problems for 12 years, ending only with his life. He unearthed a fauna which has been much sought but little known. With only a single preparator, with no illustrator but his own pen and brush, he made known this strange and primitive reptilian fauna with a celerity and acumen which astounded his co-workers.

In this exploration Williston found great difficulties in his way, for he says in "American Permian Vertebrates" (p. 2):

The [Texas Permian] beds are the most difficult of exploitation of any known to me in a field experience of 35 years. Usually the fossils are more or less hidden in concretionary nodular masses, almost invisible or indistinguishable to the untrained eye until they have been broken up and weathered, when the inclosed fossils have lost much of their value. Rarely single bones and even whole skeletons are found in clay deposits almost or quite free from matrix, but many such are not to be expected.

Finally, however, as a result of painstaking research, bone beds, notably the Cacops bed discovered by Paul Miller in 1909, were found which yielded considerable more or less perfect material. It was also Williston's privilege to study the Marsh collection of Permian material at Yale, one result of which was the unearthing of specimens from storage, the perfection of which was totally unsuspected, notably the practically perfect Limnoscelis type. As a result, Williston, supplemented by E. C. Case, who also had access to the American Museum material, has given us a knowledge of Paleozoic air-breathing vertebrates, Amphibia and Reptilia, which was almost unhoped for. It was largely because of the quality of his research in this line that Yale University honored herself by admitting Prof. Williston to the doctorate for the third time, as the degree of doctor of science was conferred upon him in June, 1913.

Williston's life is a stirring tale of one who rose superior to heredity, environmental limitations, and the petty discouragements of life, especially those due to financial restrictions in the pursuit of a costly science. He immortalized himself not only in the amount of his published research, of over 4,000 printed pages, some of them bearing the impress of genius, but in the knowledge and inspiration which he instilled into those whose privilege it was to sit at his feet. Certain of these, such as Branson of the University of Missouri, Sellards and Beede of the University of Texas, Logan of the Mississippi Agricultural College, and Moore of the University of Kansas, have followed lines of work more strictly geological; but Case of the University of Michigan, Riggs of the Field Museum, Brown of the American Museum, Moodie of the University of Illinois, and Mehl of the University of Missouri form a group which will worthily carry on his vertebrate research. Vale magister!

PART II.—PUBLISHED RESULTS.

CONTRIBUTIONS TO ENTOMOLOGY.

The list of Dr. Williston's published writings embraces a considerable range of subjects, and in the two departments of entomology and vertebrate paleontology includes works of high authoritative value. Those in entomology being outside the narrow limits of the present writer's research, he must turn to others for a critical review. Dr. J. M. Aldrich, of the United States National Museum, has kindly sent me an estimate of this department of Williston's activities, and with his permission I extract from it the following:

Williston never held an official entomological position. But he found time to do much valuable work as a pioneer in dipterology. * * * His interest in the flies began to be serious about 1878. At this time Osten Sacken had returned to Europe, and there was not a single American student of the order but Edward Burgess, the Boston yacht designer, who published only one small paper. So Williston was virtually alone on the continent. In the absence of guidance, he plowed his way by main strength (as he often narrated to the writer) through descriptions of species until here and there he made an identification, which served as an anchor point for a new offensive. He had few definitions of genera, so had to work backward from the species. After a year or two of this tedious and time-wasting effort, he came upon Schiner's Fauna Austriaca, in which the Austrian families, genera, and species of Diptera as known up to 1862–1864 are analytically arranged and succinctly described. To his immense relief and satisfaction, he now found that all his American flies could be traced to their families, and most of them to their genera, in this fine work. He was so impressed by the saving of time accomplished that his own publications coming later show the effect of this early experience on every page; everywhere he has the beginner in mind and is clearing the way for him.

In a few years he began publishing tentative papers analyzing the American families and genera of the flies. These he extended and enlarged in a pamphlet in 1888, and again in a bound volume in 1896; and in 1908 published a third edition still more complete, with 1,000 figures, his well-known "Manual of Diptera." This third edition is his main contribution to entomology. It is a handbook unapproached by anything else dealing with a large order of insects.

From necessity he published it at his own expense; it was eight years before the receipts from sales covered the cost of printing, but happily he lived to see this consummation.

His other papers of his early period, 1881–1889, dealt with Asilidæ, Conopidæ, Tabanidæ, and smaller groups, and especially with Syrphidæ, in which his fine monograph of 1886 is still in universal use, and by the taxonomic genius of its author has created in the United States an ineradicable belief that the family is an easy one, well adapted for the beginner to publish in; a mistaken belief, but highly complimentary to the monographer.

From 1890 his more important papers were concerned with tropical Diptera (Mexico, St. Vincent, Brazil), and with bibliography. As his official duties grew more exacting, he gradually abandoned entomology, but he had as many farewell appearances as an opera singer, for he could not resist the temptation to come back again and again. Even as late as the spring of 1917, when he was visiting the writer and reveling once more in a collection of Diptera, his old enthusiasm came back so strongly that he planned describing some new genera, and in fact did publish one (Annals Ent. Soc. Amer., vol. 10, p. 23). But after 1896 he did little work on the order except in preparing the third edition of his Manual, which cost him two years of arduous work, as he drew 800 figures with his own hand. His deep interest in genera and his very wide acquaintance with them, together with his universally recognized taxonomic ability, made him, in the period 1890–1900, the peer of Osten Sacken, Brauer, and Mik as a world authority in Diptera.

PALEONTOLOGICAL RESEARCH.*

The first of Prof. Williston's paleontological papers appeared in 1878—a brief discussion of the American Jurassic dinosaurs [1]—and was followed in the next year by an expression of opinion on the dinosaurian origin of birds.[2] One or two other dinosaur papers followed at rare intervals, but it was not until 1890 that he began his more intensive study of vertebrate forms. His removal to Kansas in 1890 reawakened, as we have seen, his interest in the fauna of the Kansas Chalk, and the beginning of a series of papers upon these forms resulted, the initial one being on a plesiosaur from the Niobrara Cretaceous of Kansas (1890).[5] The same year there appeared a morphologic paper on the structure of the plesiosaurian skull,[6] of which, as Williston says, our knowledge had previously been very incomplete. In this paper he announces for the first time the presence of sclerotic bones within the orbit, the single temporal arch, and other important details of structure. The following year saw Williston's attention turned to the mosasaurs and pterosaurs of the Niobrara, his initial article in each group appearing at that time.

PTERODACTYLS.

Williston's first paper on the pterodactyls [7] is based upon a well-preserved specimen of Pteranodon in the Kansas University Museum, and from the skull he argues against the probability of the remarkable elongated occipital crest figured by Marsh and since proved to be correct, although Williston held to his opinion for a long period of years. He also described in detail the hinder extremities, and finally gives a very excellent summary of the anatomical peculiarities of the genus Pteranodon, based upon his own observations and those of Prof. Marsh.

The second paper by Williston on the pterosaurs is that entitled "Kansas Pterodactyls" (1892).[9] In this he lists the species of Pteranodon previously described by Marsh and Cope, and those of the genus Nyctosaurus described by Marsh. He then passes to a discussion of the morphology of the skull and pubis of the former genus, followed by a full description of a new specimen of *Nyctosaurus gracilis* Marsh, which was preserved in the Kansas University Museum, and which served to put the genus on a more secure basis. Finally the author summarizes his views as to the relationship of the pteranodonts, expressing a belief that instead of being confined exclusively to Kansas, as had been thought, they may also occur in Europe in the form of the genus Ornithostoma Seeley.

In 1893, Williston again wrote of the Kansas pterodactyls,[11] this time stating emphatically his belief, backed by recent publications by Prof. Seeley, of the congenerousness of the forms Ornithostoma and Pteranodon, and the precedence of the former name. He adds that Cope was able to see this while Marsh was not, notwithstanding the latter's wealth of material on which to base an opinion. It is interesting to note, however, that the latest authority, Eaton, in 1910 still holds to the opinion of Marsh, using the name Pteranodon for the American types, as

* Superior figures in this section refer to the serial numbers of the articles listed under "Paleontology" in the appended bibliography.

does O. P. Hay in his catalogue of fossil Vertebrata (1902). This paper of 1893 gives further morphologic description of the pelvis and hind limb of *Pteranodon* (*Ornithostoma*) *ingens*.

But three more papers on this interesting group appear from his pen: on the mandible of Ornithostoma (1895),[21] on the skull (1896),[22] and a restoration in 1897.[26] In his report on the Geological Survey of Kansas, 1898, there is a view (frontispiece) of the reptiles of the Kansas Cretaceous ocean, previously published in Popular Science Monthly, in which a number of pteranodons are seen, one clinging to the cliff, the others in the air, and none of them display the crest in its full development as held by Marsh and now abundantly proved to be correct.

In 1902 [56, 63] and 1903,[68] Williston described in detail a remarkable specimen of Nyctodactylus which had recently been discovered in the Kansas Chalk and which was so complete that many details of anatomy of the group were learned from it. As usual, not only does he give a very detailed description of the morphology of the animal, but his picture of its small body, not larger than one's fist, compared with the 8 feet of wing expanse, the peculiar articulation of the hind limbs, giving it a most laborious gait when on the ground, and the conjectures as to its young, which could not have been viviparously born—all have a striking interest to one who would visualize as living beings the creatures of the past. His arguments, moreover, are so complete that one feels instinctively that his conclusions are well founded

MOSASAURS.

The paper on the Kansas mosasaurs in 1891 [8] gives the first morphologic description of a complete skeleton of a member of this interesting group, although, as Williston says, Baur had already studied and figured another genus, the description of which had not been published. In his introduction, Williston discusses the nomenclature of the mosasaurs, with its very much confused synonymy, which he later was privileged partially to unravel. In his morphologic description he shows his powers of visualizing as a living form the creature under his observation, for, as he says (p. 345):

It is doubtful whether there was ever another vertebrate animal so admirably adapted for rapid and varied movements through the water. Though the smallest of the mosasaurs, it [*Clidastes velox*] was by far the most graceful in its proportions, the most delicate and exquisitely constructed in its details.

Marsh had denied the presence of sclerotic plates. Williston, however, says:

It is certain that none of the Kansas forms of this order were covered with bony scutes, as described by Marsh, the bones so described being, undoubtedly, sclerotic plates.

This observation was subsequently verified by the finding of impressions of the mosasaurian skin.

In 1892,[10] Williston, aided by his pupil, E. C. Case, wrote still more extensively of the mosasaurs of Kansas. This work, Part I, includes the genus Clidastes, and opens with the usual specific list and the authors' conception of the synonymy. Then follows a morphologic description of *C. velox* and a discussion of the synonymy. The new species, *C. westii*, is also described in comparison with its nearest allies.

The next year [12] Williston published his first restoration of a mosasaur, that of *C. velox* (*vide supra*), which, with certain modifications, served as a basis for his restoration of 1897 that has since become standard. No further mosasaur papers appear until 1897, when a new genus, Brachysaurus, is described,[29] the extremities of Tylosaurus, discussed,[30] and the principal genera, Clidastes, Platecarpus, and Tylosaurus, restored as full length, rather diagrammatic skeletons. These figures are also now accepted as standard and have been republished a number of times.

"The Range and Distribution of the Mosasaurs," 1897,[32] is an extremely important paper in which Williston discusses not alone the synonymy, but also the geographic and geologic range of the entire group, together with some important generalizations concerning their distribution and relationships.

Then follows Williston's monumental work on the Upper Cretaceous paleontology of Kansas, 1898,[39] in which no fewer than 138 pages and 62 plates refer to the group under discussion. This work virtually completes Williston's investigations of the mosasaurs, for but three minor papers on additional anatomical features and a thoughtful article on the relationships and habits appear subsequently. The 1898 memoir is a work of monographic value and completeness, as a résumé of its contents will show. The opening pages are an historical summary of the work previously done on the mosasaurs. Succeeding this comes a section on the range and distribution of the group and a generic and systematic summary. This is followed by an elaborate series of comparative anatomical descriptions, in which the homologies of the cranial and other skeletal elements are discussed with that detail and degree of accuracy of which Williston's broad anatomical knowledge made him master.

Next come systematic descriptions and a discussion of the biology of the group, with restorations. He speaks of the creatures as marine lizards of moderate size, ranging from 10 to perhaps 37 or 38 feet, living in shallow waters, although some of the larger of them ventured far out to sea. Their feeding habits, as evidenced from the very peculiar lower jaw which had a joint in its mid-length, are discussed, but Williston felt that the rigidity of the breast girdle precluded any very remarkable feats in the way of swallowing bulky prey. He believed that the food consisted of the numerous small fishes which swarmed the seas with them—possibly an occasional young mosasaur such as, curiously enough, is almost unknown as a fossil. He believes, further, that the mosasaurs rarely came ashore, although they must have done so for egg laying, as there is no evidence that they were viviparous, but the body is not sufficiently serpentine, nor the limbs sufficiently strong, for terrestrial locomotion. They were very pugnacious, as numerous exostoses on the skeleton show. The body was covered with a scaly skin, the scales closely resembling those of a large monitor in size and shape. This knowledge is based upon a specimen of Tylosaurus in which the carbonized scales are present on the anterior part of the body. Not only are the skeletal restorations of the three principal genera given, but a restoration in the flesh of *Clidastes velox*, with the associated *Uintacrinus* and *Ornithostoma* (*Pteranodon*) *ingens*.

The publication of this memoir, supplemented by the researches of Dollo of Belgium, gives us a body of information concerning the mosasaurs as authoritative as it is complete, and one which has served as a basis for all subsequent research upon the group.

PLESIOSAURS.

The plesiosaurs of the Niobrara also naturally attracted Williston's attention, and he published his first paper on the group in 1890,[5] describing a new species, *Cimoliasaurus* (*Elasmosaurus*) *snowii*, in which he pays particular heed to the hitherto little known skull. Another paper, based upon the same specimen, appeared in Science about the same time.[6] In 1893,[13] Williston wrote on an interesting food habit of the plesiosaurs, but did not discuss them again until 1897,[28] when he described another new form from the Kansas Cretaceous (Comanchian). In 1902 [57] there appeared a morphological paper on the plesiosaurian cranial elements and still another [59] on the restoration of *Dolichorhynchops osborni*, a new Cretaceous plesiosaur. This latter skeleton was worked out of the matrix and mounted, and is to-day one of the very few such free mounts in the country.

The paper on certain homoplastic characters in aquatic air-breathing vertebrates,[61] published simultaneously with the one just mentioned, is the forerunner of Williston's much later work on "Water Reptiles of the Past and Present." In the former he sums up the general lines of adaptation which all secondarily adapted aquatic vertebrates must follow, and includes some interesting observations on the plesiosaurs, their rather clumsy form, lack of speed, and feeding habits, for he believed that many of them fed largely upon cephalopods and other invertebrates, as did the ichthyosaurs; the plesiosaurs, however, lived in relatively shallow water, as compared with the ichthyosaurs. He speaks here again of the stomach stones, later called gastroliths, found in abundance with the remains of plesiosaurs, and, in some instances, carried several hundred miles from their source. He held, however, that the plesiosaurs differed not a little among themselves in habits, as evidenced by their great variations in form. They exceeded in size the largest mosasaurs, but were never a match for the latter in prowess or voracity. Like the gavials, they were comparatively harmless creatures. "Were they living to-day, [they] would find unopposable foes in the vicious and cruel crocodiles. They were relatively stupid and slow, cruel enough to the smaller creatures, but of limited prowess. But in structure and habits they are among the most remarkable of all the animals of the past or present." (Water Reptiles, p. 76.)

Williston's most extensive memoir on the plesiosaurs appeared in 1903,[67] as a publication of the Field Columbian Museum, during the time he served that institution as associate curator of the division of paleontology, in addition to his professorial duties in the University of Chicago. This paper was called Part I, and was to have been followed by another, which, however, never appeared. He speaks of the great number which have been described from the United States, 32 species and 15 genera, of which in not a single instance has there been even a considerable part of the skeleton made known, while the skull is known in but three, and only one of these has been described. And yet plesiosaurs are not at all rare in American deposits or collections. The monographic studies on the group, undertaken by Williston, were for the purpose of clearing up the confusion which then existed concerning these animals, but he deemed it wise, as there was still much to be done, to publish his detailed researches on the three species *Dolichorhynchops osborni, Brachauchenius lucasii* and *Cimoliasaurus snowii,* rather than wait for the completion of the entire work, and it was fortunate that he did so, in view of the fact that the second part did not appear. This was to contain the descriptions and illustrations of two or three other skulls.

The origin of the plesiosaurs Williston also proposes to discuss in a later paper. Here he contents himself with merely saying that he believes their nearest affinities among all reptiles, recent or extinct, to be with the dicynodonts (see table facing p. 133). After the introduction there is a catalogue and brief bibliography of the North American plesiosaurs, followed by the morphological description of the three species mentioned. Another new species is described, *Polycotylus ischiadicus,* a further description of *Plesiosaurus gouldii* Williston is given, propodial bones of young plesiosaurs which are abundant in the Chalk are described, and the essay closes with a discussion of the peculiar food habit of the plesiosaurs of which he also wrote in 1902. This last brought forth a discussion from Dr. C. R. Eastman which was met by Williston in a rejoinder in Science for October 22, 1904.[69]

The plesiosaurs are still further discussed in a paper entitled "North American Plesiosaurs: Elasmosaurus, Polycotylus and Cimoliasaurus," appearing in 1906.[78] In this instance, the study was based largely upon material in the Yale Museum, some of which had been collected and studied by the author himself twenty years or so before. Prof. Marsh had begun a critical study of the Yale material, hence much of it was prepared and some illustrations made, all of which, through the courtesy of the curator, Prof. Schuchert, were placed at Williston's disposal. The genus Cimoliasaurus is defined as distinct from the long-necked Elasmosaurus. Of the latter, a number of species, two of them new, are described. The genus Polycotylus is also clearly diagnosed, and Trinacromerum is believed to be distinct from Polycotylus although the reasons for this belief are not given. No generalizations are included in the paper.

Two years later,[86] Williston again published on the genus Trinacromerum, mainly a morphologic description of the type species, *T. bentonianum,* to which he adds another new species, concluding with a summation of the family Polycotylidæ, which is defined, with a list of genera and species and their bibliography. Finally there is a list of the described North American plesiosaurs, 36 in all, arranged in stratigraphical sequence.

A paper on Brachauchenius, published in 1907,[79] discusses not only the characters of this remarkable genus, but the relationships of the plesiosaurs as a whole. In discussing similarities between them and the turtles, Williston concludes that such as they show are due solely to parallel evolution, and that there is only a remote relationship between the two orders in osteological structure.

"The plesiosaurs," he says (p. 489), "could not have been derived from any ancestors that might by the widest stretch of imagination be called Chelonia, or Chelonia-like. Nor could the turtles have come from any forebears even suggesting the sauropterygian structure. I am still strongly of the opinion that the Sauropterygia were derived from a primitive therocephalian ancestry; while I am firmly of the opinion that the turtles have had a quite independent origin from some primitive cotylosaurian; like the Chelydosauria, as Case has forcefully shown. The turtles occupy a phylum distinctly their own, no more intimately related to the plesiosaurs than they are to the ichthyosaurs or rhynchocephalians. I can not accept the contention of McGregor that the Ichthyosauria had a primitively saurocrotaphous (I need not apologize for the word) type of skull, but would rather believe that they, too, enjoyed a genealogical line all their own from the most primitive type of reptiles, and that they should no more be grouped with the dinosaurs and crocodiles than with the plesiosaurs and theriodonts."

A very excellent final summary of Williston's knowledge and beliefs concerning the Sauropterygia, both plesiosaurs and nothosaurs, is given in his book on the water reptiles (1914). It is to be regretted, however, that his more ambitious project of monographing the group in full was not carried to completion, though much that he did was of morphologic value.

DINOSAURS.

Prof. Williston wrote but little of the dinosaurs, and that mainly upon the two genera Claosaurus and Stegopelta which have been preserved in the marine Cretaceous of Kansas. His early papers are brief ones: "American Jurassic Dinosaurs" (1878),[1] "Are Birds derived from Dinosaurs" (1879),[2] and "Note on the Pelvis of Cumnoria (Camptosaurus)" (1890).[4] In 1898,[37] in the same volume of the Kansas Geological Survey which includes his great work on the mosasaurs, he discusses dinosaurs in general, and specifically the *Claosaurus agilis* from the Niobrara, with Marsh's restoration of *Trachodon* (*Claosaurus*) *annectens* by way of illustration. There is, however, no new information contained in the paper.

Another article in 1898 [45] is on the sacrum of Morosaurus, a brief morphological description of a specimen in the Kansas Museum. In 1899 Williston conducted an expedition to the Freeze Out Hills of Wyoming (Morrison formation), and it was then and there that the reviewer first met him. The party collected the more familiar Morosaurus, Diplodocus, and Stegosaurus, and a carnivore, Creosaurus, which is the subject of a brief paper published in 1901.[55] In it Williston discusses the distinctions, which are by no means clear, between Creosaurus and Allosaurus, and concludes that his specimen, of which he has the nearly complete fore limb, belongs to the former genus because of the very slender scapula. He also comments on the age of the so-called Atlantosaurus beds of Marsh, now held to be Morrison, and believes that they should bear the name Como, unhesitatingly referring them to the lower Cretaceous.

In 1905 [76] Williston published his most notable contribution to dinosaurian discovery when he described a new genus of armored dinosaurs, Stegopelta, from the Cretaceous of Wyoming. This dinosaur, which comes from what Williston has called the Hailey shales, has been further and much more minutely described by Roy L. Moodie in 1910, and proves to be one of a rather extensive group of forms sharply distinct from the aberrant Stegosaurus which has given its name to the armored dinosaurs as a whole. In 1910 [93] Williston, with Pierce Larkin, described a new sauropod dinosaur from the Trinity Cretaceous of Oklahoma, of interest as one of the two last recorded instances in time of the American Sauropoda.

That Williston had further unpublished ideas of great value on the dinosaurs was evident from his verbal discussions of the group. It is to be hoped that in his incompleted work on the reptiles many of these opinions are recorded. They are of course included in his several reptilian classifications, notably the table of 1917 (facing p. 133).

CROCODILIA AND CHELONIA.

Williston made a number of contributions to our knowledge of the crocodiles and turtles, mainly, however, in connection with other forms of the same faunal horizons. For instance, in his 1898 work on the fauna of the Niobrara Cretaceous, one finds four pages devoted to crocodiles,[38] a general statement concerning the group, and a specific description of the only Kansas form, *Hyposaurus vebbii* Cope. The turtle section of the same work, pages 351–369, is only in part the work of Williston,[40] the remainder being from the pen of Prof. Case. The former discusses the turtles of the Chalk and the appearance of the group in time, by way of introduction. He then passes to a morphological description of *Desmatochelys lowii*. There are no generalizations on either the Chelonia or the Crocodilia until the work on "Water Reptiles of the Past and Present" (1914).

BIRDS, FISHES, AND MAMMALS.

Prof. Williston concerned himself but little with the birds, largely because of their rarity in the geologic levels with which he was most familiar. He did, however, make a few observations on their derivation in 1879,[2] wrote on the dermal covering of Hesperornis in 1896,[23] and, in 10 pages of his Kansas Cretaceous report, 1898,[36] summarized the birds from the Niobrara Cretaceous. In his list of Kansas birds he follows Marsh's erroneous lead of including Hesperornis in the Ratitæ; he feels, however, that the mere possession of teeth is not enough to justify its inclusion in a separate group, and the name Odontornithes is in consequence abandoned. A restoration of Hesperornis based upon Marsh's figure of the skeleton is included.

Williston's study of fishes is comparable to that of birds—the result of his association with the Kansas Chalk. He does little with the class, and that little does not greatly advance our knowledge, as in certain of the other groups. His study of the Tertiary mammals is of like character, and in no sense ranks with his masterful researches on the aquatic reptiles of the Cretaceous and upon the Permian tetrapods.

PERMIAN VERTEBRATES.

Williston's first essay on the vertebrates of the Permian appears in 1897[27] and is based upon a small collection obtained in the excavation of a well in Cowley County, Kans., from near the base of the Permian as defined by Prosser. Another paper in the same year[33] describes a labyrinthodont tooth from the Kansas Carboniferous which has the same curious infolded structure as in the case of Mastodonsaurus of the Old World Trias. Two years later[51] appeared a third paper on the Paleozoic Tetrapoda, this time on the genus Eryops Cope, mainly on the morphology of the coraco-scapula, with a note and illustration of the lower jaw in addition.

After another five years[72] came a valuable morphological and phylogenetic discussion entitled "The Temporal Arches of the Reptilia." This was invoked largely by the work of Prof. Osborn on the reptilian subclasses Synapsida and Diapsida, which appeared the previous year; the main dissension on Williston's part is as to the use of the term Synapsida proposed by Osborn for the group of reptiles with a single temporal arch, "since this group really does not differ in any essential respect from the Synaptosauria (in the wider sense) of Fürbringer and differs from the Synaptosauria of Cope, as most recently defined by him, chiefly in the inclusion of the Cotylosauria." Williston goes on to say (p. 175): "But I believe that Cope was right in separating the two groups, since he recognized, as does Osborn, the ancestral relations of the Cotylosauria to both the single and double-barred reptiles."

Furthermore, Williston can not accept as definitely proved or even probable the conclusion that the reptiles are really diphyletic, since the turtles seem to have had an independent origin from the cotylosaurs. Cope's scheme of relationships, published in 1896, seems to express fairly well Williston's views of reptilian phylogeny at this time.

The work on water reptiles, 1914, contains the following (p. 15):

> It may be said decisively that no classification of the reptiles into major groups, into superfamilies or subclasses that has so far been proposed is worthy of acceptance; there is no such subclass as the Diapsida or Synapsida, for instance, and we have very much more to learn about the early reptiles before any general classification of the reptiles can be securely founded. [See table facing p. 133.]

Hence, the significance of Williston's study of the Paleozoic forms which we are discussing.

In a "Notice of some new reptiles from the upper Trias of Wyoming," 1904,[71] Williston describes four new genera and species of reptiles from a horizon which he calls the Popo Agie beds. The material is meager for either generic or specific identity, and no conclusions other than suggestions of relationships are given. In 1908, he published at least three papers on the Paleozoic tetrapods, one on Lysorophus,[80] a Permian Urodele, the skull of which he discusses and figures at some length, showing the creature to have been of snakelike body, with feeble powers of vision, probably perennibranchiate, bare-skinned, and more or less mud-burrowing in habit. He does not believe that the genus stood in direct ancestral relationship with the living Necturus and Proteus, but thinks it very probable that it was close of kin to the ancestors of these forms (see table facing p. 133). This same paper discusses salamander-like footprints from the Texas red beds and newly discovered ventral ribs in Labidosaurus.

Another article, entitled "The Cotylosauria,"[84] is very largely a redescription of *Labidosaurus incisivus* from a specimen in the University of Chicago collection originally described by Case. Williston also discusses the history of the origin and use of the term Cotylosauria and adds a protest against the later work done on the taxonomy of the reptiles, as follows (p. 148):

In a recent review of the literature of the Reptilia, I find all of the older groups usually called orders have been raised in recent years by well-known writers to superordinal or subclass rank, save the Ichthyosauria and Chelonia, the two groups of all others most entitled to high rank! And most of the suborders have been elevated to orders—thirty or more. And what has been gained?

Williston's third paper on these ancient forms, published in 1908, is on "'The Oldest Known Reptile'—*Isodectes punctulatus* Cope."[85] This species, which is from the Coal Measures of Linton, Jefferson County, Ohio, was unhesitatingly referred by Cope to the Reptilia and said by him to be "the first identification of a true reptile in the Coal Measures." However, because of recent studies connecting the Stegocephalia so intimately with the Reptilia, it is somewhat hazardous to affirm positively that the specimen, which lacks the skull with its distinctive parasphenoid bone, is a true reptile. Nevertheless, Williston does not see in the skeleton a single character which is not reptilian. M. Thévenin, of France, had recently described an air-breather from the uppermost Carboniferous of France under the name *Sauravus costei*. This the distinguished author believed to be rhynchocephalian, but Williston does not consider it either a stegocephalian or cotylosaurian type, as in the American forms the final proof would lie in the degree of reduction of the parasphenoid bone, whether or not the condyles were paired. He further states that from the evidence here shown it is clear that the primitive reptilian phalangeal formula was that now persistent in the Lacertilia and Sphenodon, 2, 3, 4, 5, 4, the number 2, 3, 3, 3, 3, so characteristic of the mammals, being a late specialization and having no genetic relationship with the similar formula of most turtles. In other words, the phalangeal formula is not of the great importance that some authors attach to it.

Finally, Williston says (p. 400):

There are those who believe that the reptiles arose from two distinct groups of the Amphibia, one from the Microsauria, the other from the Temnospondyli, and I must confess that Isodectes helps that theory materially, for its relationships with the Microsauria on the one side can not be gainsaid. But, the close relationships between such forms as Pariotichus, Procolophon, Telerpeton, the Pelycosauria, the Cotylosauria, Pareiasauria, and Temnospondyli complicate matters here exceedingly, and leave the whole subject still in great obscurity.

In the table of 1917 (facing p. 133), Williston derives the Amphibia and Reptilia as a whole from the Protopoda, known only from their footprints in Devonian and Mississippian rocks.

The year 1909[90] brought forth one of the most important of Williston's papers, "The Faunal Relations of the early Vertebrates," short but very fundamental, and a basis for much which was to come. Here he compares in some detail the successive land faunas of North America with those known elsewhere from Mississippian time through the Mesozoic, and gives a graphic table showing the distribution, both in space and in time, of the principal groups above the fishes. He summarizes his evidence as follows (p. 399):

The Pennsylvanian fauna has nothing distinctive, at least till near the close; there must have been a continuous and free interchange of land animals with the eastern continent till near the close. Before its close, it had already diverged and certain true reptiles had appeared. Before the beginning of Permian times an interruption of migration occurred, producing a complete and continuous isolation of the Permian American fauna. With the close of these times a long interval elapsed, during which physical conditions were almost uniform over a large part of the Rocky Mountain area at least, during which interval we have no records of land or fresh-water life, but which is represented in part by marine forms of remarkable character, possibly in part derived from American ancestors. With the reappearance of land forms in the Upper Triassic we find certain evidence of free migrations again, with the closest relationships between eastern and western forms, none of which could have been derived, immediately at least, from the known American Permian types. The marine vertebrates of the Upper Jurassic, the next American air-breathers of which we have any knowledge, indicate an advance in specialization over the contemporary forms from the eastern continent, but they also indicate a continued migration of the aquatic forms at least. With the land forms again appearing at the close of the Jurassic and in the Lower Cretaceous, we find strong evidence of a community of faunas, but with a striking absence, hitherto, of some of the smaller forms known from earlier times in the eastern continent. The Upper Cretaceous again shows a belated arrival on the western continent of eastern types, after their advent or even disappearance there. With the exception of certain Triassic marine types, we have no distinctively American Mesozoic groups of air-breathing vertebrates, until we reach the Benton, Niobrara, and Pierre Cretaceous, all indicating a continued, but possibly restricted, intermigration between the eastern and western continents during the whole of Mesozoic times. * * * That the communication between the two continents in Pennsylvanian time may have been by way of the North Atlantic region is not at all improbable. Indeed, taking into consideration the close relationships known to exist between the European and American type[s] of this period, closer perhaps than existed at any subsequent time during the Mesozoic, this more direct way of communication would seem very probable.

Williston goes on to adduce evidence in favor of the belief of a southern communication between Africa and South America and, during part or all of Mesozoic time, free communication between North and South America. He feels that there may have been one trans-Atlantic bridge, the southern one, but that this was sufficient nevertheless to afford a means of intermigration between both the northern and southern continents of the old and new worlds.

The discussion of the relationships of the various amphibian, reptilian, and mammalian groups in this paper gives expression to Williston's beliefs, some of which are most decided, although his evidence is not always forthcoming.

Another paper of the same year [88] was on the skull and extremities of Diplocaulus, a very curious microsaurian from the Permian, with a head remarkably extended in its transverse diameter. The paper is largely morphologic—the brief discussion of the taxonomic rank of the group which Williston would make the family Diplocaulidæ of the Microsauria.

Two other papers, one on Pariotichus [89] and one on Trematops,[91] follow. Both forms are from the Permian of Texas, and the partial result of the expedition to these beds sent out by Chicago University during the autumn of 1908. The Pariotichus skeleton is of particular interest because for the first time the natural skeleton of a cotylosaur is known, with all of its bones in anatomical relations, scarcely a single one being disturbed by extraneous force in fossilization; so that from it a clearer and more authentic description could be given than ever before.

Seven genera of Permian reptiles are enumerated as pertaining to the Pariotichidæ, he having added one, Labidosaurus, to the original six included within the family by Cope.

Trematops is also represented by an almost complete skeleton, this time of a rachitomous amphibian curiously intermingled in situ with the remains of a cotylosaurian reptile. The amphibian forms the type of a new genus and species, and has as its nearest ally the well-known Eryops originally described by Cope, although its smaller size, greater slenderness, and head structure separate the genera widely.

Four papers on Permian vertebrates came from Williston's hand during the year 1910, one of which [98] discusses the skull of the reptile Labidosaurus, while another [97] makes known in detail the entire skeleton and armor of a remarkable new genus, Cacops, and to a lesser extent another new genus, Desmospondylus, and erects two new families: Dissorophoridæ to include Dissorophus Cope and Cacops Williston, and Trematopsidæ, based upon the previously described genus Trematops.

The material here described was sought and found in the "barren" deposits of the Permian of northern Texas, which so rarely pay for exploration, but which, when they do, pay abundantly in the degree of perfection of the material; for, as Case has observed, but one or two specimens a season can be expected from these clay beds. Mr. Paul Miller discovered in 1909 a remarkable bone bed containing, according to Williston's estimate, 50 or 60 skeletons, with not another indication of bone in adjacent exposures of several hundred acres, save a few ounces of fragments found a half mile away. The great majority of the skeletons belong to the genus Varanosaurus Broili, of about the same size—that is, 4 feet in length; there is, in addition, a femur of Desmospondylus, while all of the amphibian remains belong to Cacops. The skeleton which is figured as the type of Cacops is unusually perfect and is mounted with great skill, only certain of the phalanges being restored, together with the distal segments of the limbs from the right side; it is, moreover, almost entirely one individual.

Of it Williston says (p. 279):

The creature as mounted presents an almost absurd appearance, with its large head and pectoral region, absence of neck, and short tail. It is very certain that it possessed no other dermal ossifications than those of the median dorsal carapace, and it would seem almost as certain that the creature was aquatic or largely amphibious in its habits. * * * What the significance of the dermal carapace was I am at a loss to suggest. That it could have been of protection to the creature seems more than doubtful, whatever may have been its use in Dissorophus, where it covered the whole dorsal region. But this coincidence is remarkable; with an external turtle-like ear opening, it had also the beginning of a turtle-like carapace. And this parallelism is also seen in Diadectes [this it will be remembered is an amphibian], with dorsal dermal plates and turtle-like ears. * * * Whatever may have been the habits of the creature, it, with its nearly related Dissorophus, must be classed among the oddities of vertebrate paleontology.

In his paper on new Permian reptiles, 1910,[96] Williston describes in part the material taken from the so-called Craddock bone bed, discovered by Paul Miller in the autumn of the previous year on the Craddock ranch near Seymour, Tex. These fossils include a great variety, among which was the type of *Aræoscelis gracilis* and of a new family, the Aræoscelidæ. He also discusses the problem of the development of the holospondylous vertebræ, which has given rise to much contention among paleontologists, and of which he wrote in detail in the last year of his life.

In the next year, 1911, came the publication of an important book, "American Permian Vertebrates." [100] This, as the author says, comprises a series of monographic studies, together with briefer notes and descriptions, of new or little-known amphibians and reptiles from the Permian deposits of Texas and New Mexico. The sources of the material are mainly three—the University of Chicago collection, made in recent years by field parties under the charge of Paul Miller or the author; earlier collections of the University of Texas, made by Prof. E. C. Case; and finally, the Permian fossils in the Marsh collection at Yale, many of which were unknown to science until brought to light for study by Prof. Williston. An interesting comment upon our knowledge of reptilian classification shows that the time is not yet ripe to attempt phylogenies of the groups other than the dinosaurs, crocodiles, phytosaurs, pterosaurs, and rhynchosaurs, because we are less sure of them than we were a dozen years ago. The more recent general classifications of the reptiles by Cope, Osborn, Boulenger, and others have offered suggestions of value, but are by no means the real solutions of the reptilian and amphibian phylogenies. Certain morphological problems are discussed in the following pages and the author has given what seem to be the legitimate conclusions regarding the immediate relationships of the forms under discussion. The present work, however, is offered more as a contribution to our knowledge of ancient reptiles and amphibians, with such summaries and definitions, based chiefly upon American forms, as the evidence at hand permits. A summary of the genera from the Texas Permian follows:

Amphibia: Lysorophus, Diplocaulus, Trimerorhachis, Eryops, Cacops, Dissorophus, Aspidosaurus Cardiacephalus.

Reptilia: From the uppermost beds, Labidosaurus, Naosaurus, Dimetrodon, from lower horizons, Naosaurus, Dimetrodon, Clepsydrops, Varanosaurus, Trispondylus, Casea, Aræoscelis, Captorhinus, Diadectes, Seymouria, etc., of which perhaps the most characteristic are Labidosaurus of the upper and Cricotus of the lower zone.

Williston feels confident, however, that no definite line can be made between the two divisions, and that at present Clear Fork can be used in a general way to designate the upper, and Wichita the lower part of the Texas deposits.

In the paper on Permian reptiles, published in Science in 1911,[104] Williston proposes a classification for the therocrotaphic reptiles (excluding the Theriodontia): Order Theromera [later he uses the spelling Theromorpha]; suborders Pelycosauria, Poliosauridæ, Edaphosauridæ, Caseidæ, Aræoscelidæ(?), Therocephalia, Anomodontia, Dinocephalia, and Dromasauria, the first five American, the others African. In his restoration of the cotylosaur Seymouria in the same year,[101] he makes known to us, aided by a very accurate drawing, the complete osteology of the creature that stands lowest in rank among reptiles, approaching in many ways the contemporary amphibians, for, as he says, so far as the characters are shown in the figure, there is not a single thing to differentiate the form from an amphibian, unless it be the apparent absence of the cleithrum. The palate is different from that of other known reptiles, though distinctly reptilian in structure. Williston continues (p. 236):

> The American cotylosaurs, more especially the Diadectidæ, Limnoscelidæ, and Seymouriidæ, show marked resemblances in many ways to the contemporary amphibians, in their short legs, broad feet, enormous humeral entocondyle, digital fossa of the femur, pronounced adductor crest, as well as girdles; but I do not believe that these resemblances were so much the result of phylogeny as of convergent evolution, the adaptation to similar environmental conditions and similar habits.

In "A new family of reptiles from the Permian," 1911,[105] Williston describes briefly the contents of a collection of Permian fossils from New Mexico in the Marsh material at Yale, made more than 30 years before. This was found in beds equivalent stratigraphically to the lower or Wichita division of Texas. Certain forms are either closely allied to or identical with those of the Texas beds, others are quite different; this Williston attributes to differing environmental conditions, since the identical or allied forms of New Mexico are from the red clays and red sandstones which are quite like those of the Texas deposits, while the unlike forms are from sandstones and clays unlike anything in the latter State. There is also a complete absence of concretions and of fish remains in New Mexico. While a full discussion of the Yale material was published in "American Permian Vertebrates," a remarkable new form, Limnoscelis, was described somewhat in extenso, as it is not only the finest thing of the collection, but is one of the most notable specimens of a reptile ever obtained from the Permian deposits of America. There is more than one individual represented, so that parts lacking in one are present in another; but one specimen is practically perfect and is in essentially complete articulation, the skeleton lying as the animal died. *Limnoscelis paludis* is a cotylosaur, representing the new family Limnoscelidæ, a large form, 7 feet over all, powerful, of carnivorous habits, but a subaquatic or marsh-dwelling reptile, with limbs strongly suggestive of the turtles. The relationship lies most closely with Diadectes and Pareiasaurus, which, together with Propappus also, may perhaps be placed in the same order of reptiles. A restoration of Limnoscelis by Williston was described in 1912.[107]

A joint paper by Williston and Case, in the same year,[106] treats of the allied skulls of Diadectes and Animasaurus. Perhaps their most remarkable feature is the differentiated dentition, with strong chisel-shaped incisors and curious transversely elongated cheek teeth. They have usually been considered as herbivorous, but the character of the incisors, the absence of any power of trituration in the unworn maxillary teeth, and the possibility of the use of the palatine processes of the maxillaries as accessory organs of mastication lead to the suspicion that the animals were not exclusively, if at all, herbivorous, and that they may have included the less well-protected invertebrates in their diet.

A very important paper entitled "Primitive Reptiles, a Review," also appeared in 1912.[108] This summarizes our knowledge of the Permocarboniferous tetrapods of the world, correlating those characteristics upon which phylogenies and classification must depend. Of the foreign forms, Williston had no autoptic knowledge, but he had studied personally nearly all of the known American material and was thus in position to speak authoritatively. The characters of these creatures are grouped under those which are constant and those which are inconstant and variable. It is conceivable that with a more complete knowledge of certain genera some of the constant characters will be transferred to the variable list, but unless error has been made the reverse will not be possible. These characters which are enumerated are the chief ones upon which we must depend, for the present at least, for the classification of the known Permocarboniferous reptiles.

Williston expresses emphatically his lack of faith in the DeVreesian "mutation theory" of the origin of species, nor does he believe that any paleontologist can defend such a theory. And he does not consider that any theory of the origin of species, or even of evolution, can get very far when *time* is left out of account. If, in any series of phylogenetic forms, we find a gradual transformation of structure, or the gradual acquisition of new characters, we do right in uniting them all in a single group, for the sole end of all taxonomy is phylogeny. Williston here defines the two larger groups, the Cotylosauria and Theromorpha, discussing also the relationships of the Old World Protorosauria and Proganosauria, and then describing the reptiles of the Lower Permian of Europe. This is followed by a discussion of the position of the Microsauria and of Lysorophus, which he now believes to have no direct ancestral relationships with any modern vertebrates, but to owe its resemblance to certain existing types to community of habit (see, however, table facing p. 133).

The genus Aræoscelis, originally described by Williston in 1910, is further discussed in two papers in 1913.[111,114] His final conclusions as to its place in reptilian taxonomy are startling, for he believes it to be the first known lizard, and that from the Lower Permian. Aræoscelis can not be placed in any known order of reptiles, unless it be admitted to the Squamata, and he does not think that the differences from the Squamata will justify its ordinal separation if we are to classify organisms phylogenetically. He says: "I would rather modify the definition of the order Squamata to include the genus as a representative, doubtless with Kadaliosaurus also, of a distinct suborder, the Aræoscelidia." He believes that after he has published the full details of Aræoscelis his readers will agree as to its phylogenetic association with the Squamata as in the general acceptance of the genus Lysorophus as an ancestral urodele. In "The Osteology of some American Permian Vertebrates," 1914,[122] he gives this further evidence in the form of a complete discussion of the osteology of Aræoscelis, the entire skeleton of which is now known with the exception of the tail beyond the fourth vertebra. He again compares the genus with certain foreign types, notably Protorosaurus, Kadaliosaurus, Paleohatteria, the Proganosauria and Ichthyosauria, and thus concludes (p. 400):

> I have urged that the resemblances of Aræoscelis to the Squamata would justify its inclusion in that order as a suborder, under the name Aræoscelidia, coordinate with the Lacertilia and the Ophidia. And I believe that will be its final disposition under some subordinal designation. But it seems to me that the relations with Protorosaurus and Kadaliosaurus are too definite, too pronounced, to warrant their dissociation. I would therefore propose to unite these three genera, together with, provisionally, Haptodus and Callibrachion, under the order Protorosauria of Seeley, and place the order immediately before the Squamata in any serial classification of reptiles.

This he brings out graphically in the table of 1917 (facing p. 133).

A restoration of Aræoscelis is given, both skeletal and in the flesh, and the creature is described as an extremely light and slender, terrestrial and arboreal reptile, with springing powers, and possibly with a parachute development of the body membrane. Its length, when adult, was about 2 feet.

Another skull of the curious Casea adds to the information given concerning this reptile in "American Permian Vertebrates." There is also a description of Arribasaurus, a new genus based on *Dimetrodon navajoicus* Cope, and a discussion with figures of the primitive structure of the mandible in reptiles and amphibians.

A joint paper by Williston, Case, and Mehl appeared in 1913,[117] a large quarto memoir on the Permocarboniferous vertebrates of New Mexico. This is divided into several chapters, all but one of which are by Williston and Case. Chapter I is geological, a description of the vertebrate-bearing beds of north-central New Mexico, whereas the others are all concerned with vertebrate description, of which the most notable are the discussions of the skull of Aspidosaurus, of a nearly complete skeleton of Diasparactus, of Ophiacodon, and of the pelycosaur Edaphosaurus.

Prof. Williston's book on "Water Reptiles of the Past and Present," 1914,[118] has been repeatedly referred to, but its importance is such that it should be discussed in somewhat greater detail. It summarizes in a most authoritative manner our knowledge of the reptiles which have become adapted to aquatic life, and also includes an important chapter on the classification of reptiles, for, as he says, the classification of reptiles is still a matter of much doubt and uncertainty, no two authors agreeing on the number of orders or the rank of many forms. Many strange and unclassifiable types which have come to light in North America, South Africa, and Europe, have thrown doubt on all previous classification schemes, and have weakened our faith in all attempts to trace out the genealogies of the reptilian orders, and classification is merely genealogy. It is only the paleontologist who is competent to express opinions concerning the larger principles of classification of organisms, and especially the classification of reptiles. The neozoologist, ignorant of extinct forms, can only hazard guesses and conjectures as to the relationships of the larger groups, for he has only the specialized or decadent remnants of past faunas upon which to base his opinions.

The third chapter is an illuminating discussion of the skeleton of reptiles, in which the principal elements are not only fully described, but illustrated by the author's drawings. The chapter on the Age of Reptiles contains a chart (that of 1909) showing the range in time of the various reptilian suborders, beginning with the Carboniferous. Each important horizon is taken up in turn and the character of the sedimentation and location of the chief exposures discussed. This section is illustrated by Williston's restorations of various Permocarboniferous reptiles.

The fifth chapter discusses the principal structural changes which water-living brings about, comparing the reptiles in their modifications with other important aquatic types. Then in orderly sequence the water-inhabiting groups are discussed: Sauropterygia; Lystriosaurus of the Anomodontia; the Ichthyosauria, in which the culmination of aquatic adaptation is reached; Mesosaurus, of the Protorosauria; many of the Squamata, especially the marine iguana, Amblyrhynchus; and the agialosaurs and mosasaurs.

Another chapter treats of the Thalattosauria, recently described by Merriam, and of Champsosaurus of the Rhynchocephalia. Crocodile-like forms are included under two orders, Parasuchia and Crocodilia, Geosaurus, an upper Jurassic crocodile, going to the extreme and developing an ichthyosaur-like tail for swimming. The final chapter discusses the Chelonia, the most sharply distinguished order of reptiles, and the one which has had the most uniformly continuous and uneventful history from the Triassic up to the present time.

In "Restorations of some Permocarboniferous Amphibians and Reptiles," 1914,[121] Williston presents some interesting interpretations in the flesh of these ancient tetrapods, drawing them personally after a careful study of the more or less complete skeletons in the collections of the University of Chicago, the American Museum, and Yale University, the technical descriptions of which had recently been published. Of these he says (p. 57):

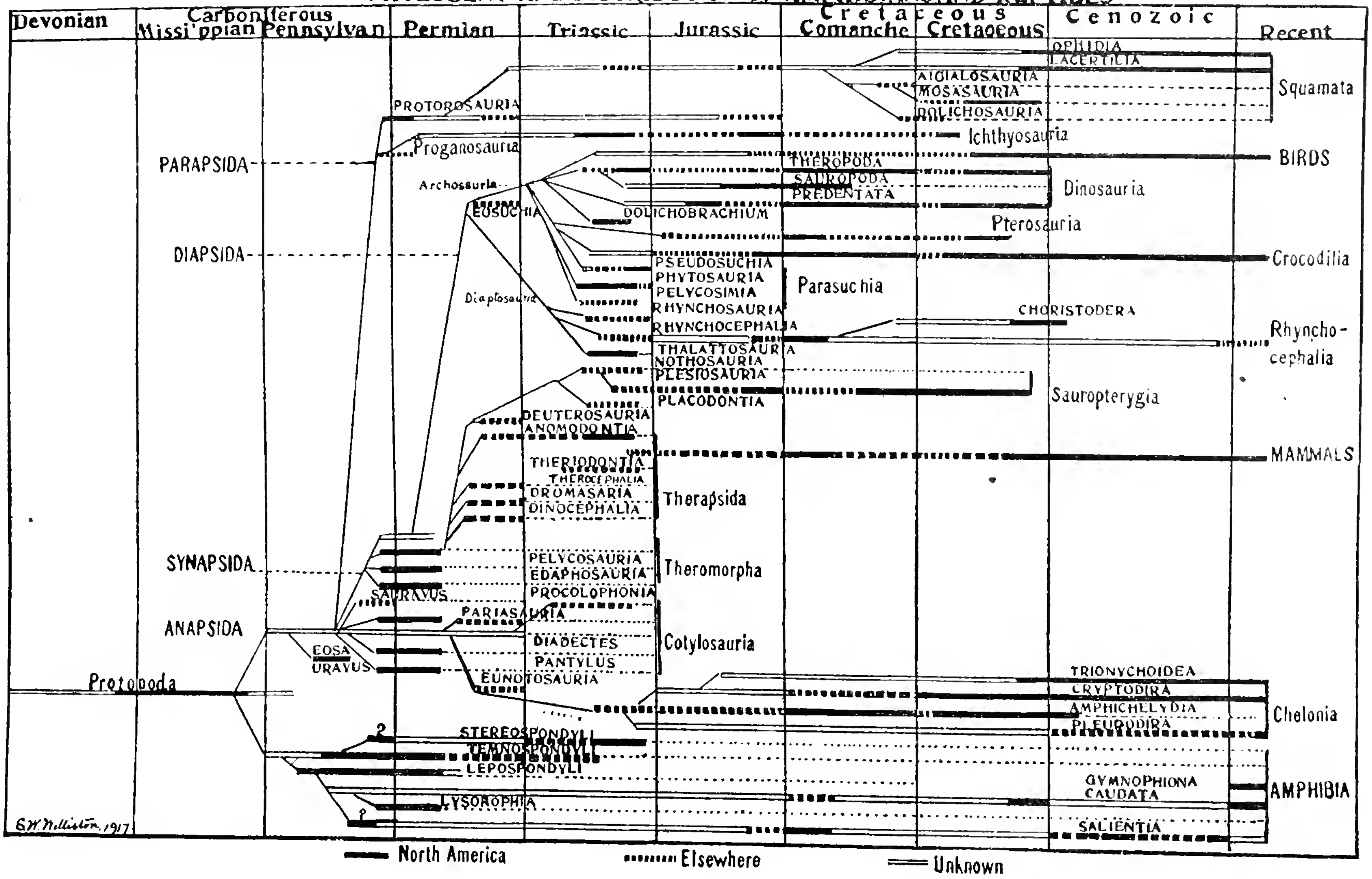
> I will not attempt to give any technical details of their structure here; my only desire is to place before the general student of geology something of what I see, after years of study of the fauna, in some of the animals that lived in Texas and New Mexico during the closing times of the Pennsylvanian and the early times of the Permian. The land vertebrate fauna of those times in America must have been very rich. More than 40 distinct genera of amphibians and reptiles are represented in the collections of the University of Chicago, and the remains of at least a dozen more are preserved in the American Museum and at Yale University. It is the oldest fauna of reptiles known in the world, and by far the most comprehensive of the older amphibians known. The animals of the South African Karoo system are nearly all of later age, upper Permian as distinguished from lower Permian and Carboniferous, and they were, for the most part, more highly specialized and less primitive.

Williston says, in conclusion, that whatever may be the merits of these restorations as works of art, they have been drawn with the most scrupulous accuracy so far as form and proportions are concerned, the musculature derived from the study of living reptiles, and they are all based upon practically complete skeletons; in a few only the precise length of the tail is yet unknown, or the front toes.

In 1915 Williston described *Trimerorhachis insignis*, a temnospondylous amphibian, from abundant material;[123] two genera of Permian reptiles, Glaucosaurus, with immense orbits, and Chamasaurus of the slender jaw;[125] as well as a new genus and species, *Mycterosaurus longiceps*, a pelycosaur related to Dimetrodon.[124]

Several papers of importance appeared during 1916. In Part II of the "Osteology of some Permian Vertebrates,"[130] Williston describes in detail the curious Pantylus from Texas, which as he says, is, so far as his knowledge goes, the earliest reptile in geological history having a bony dermal armor. Isodectes is also further discussed, and the species *Theropleura retroversa* Cope, which had been known from the centrum of a single vertebra, is now described practically in toto. The ventral ribs of this form are very remarkable, numbering some 200 on a

PHYLOGENY AND DISTRIBUTION OF AMPHIBIANS AND REPTILES



side. This is followed by a discussion of the origin of the sternum from the anterior ventral ribs in the Amniota, for which the evidence, according to Williston, seems complete.

The paper entitled "Synopsis of the American Permocarboniferous Tetrapoda," 1916,[131] is of the highest possible importance, for in it we have almost the last statement by Williston concerning these forms which he knew as did no other. In commenting on his paper on primitive reptiles, 1912, Williston says (p. 193):

The lists of constant characters [see p. 016] then given have been reduced, as I felt sure they would be, by recent discoveries. * * * The final distinction between the two orders [Theromorpha and Cotylosauria] thus seems to be limited to a single character, the absence or presence of the temporal perforation, a character which, it might be urged, is not of supreme importance, though Broom considers the Cotylosauria a superorder.

The following pages present a synoptic review of the generic, family, and ordinal characters of the American Permocarboniferous Amphibia and Reptilia as Williston interprets them, in the hope that it will serve as an inventory of our present knowledge, regardless of personal views as to its taxonomic application. He does not attempt to characterize the varions proposed suborders of reptiles, because he does not know how to measure them, nor how to distinguish them from families; nor is he at all sure, on the other hand, which are family and which are merely generic characters. Illustrations of the more important types are included in the summary.

The skeleton of Trimerorhachis is again discussed in 1916.[129] The animal had been described by Williston before, but now for the first time a connected skeleton has been fonnd, through which alone, as he had predicted, the ribs, tail, and feet could be made known. The creature had the small limbs and broad neckless body of the modern Necturus, and Williston believes that the type under consideration was an aquatic animal incapable of progression on land, and in all probability, like Necturus, a perennibranchiate.

Labidosaurus is described in detail in 1917,[133] some half dozen very perfect specimens having been found by Mr. Miller near the Craddock ranch in 1916. The sclerotic plates of the eye are demonstrated and the entire skeleton shown, together with a flesh restoration. The peculiar rakelike teeth of the premaxillæ are bent backward, however, so that they effectually lock the lower jaw and would prevent its opening were that their position during life. An extremely important paper on the phylogeny and classification of reptiles was also published in 1917,[134] and represents Williston's last published views in the matter of the relationships of the four classes of terrestrial vertebrates, all expressed graphically and with great clarity in a table somewhat similar in general plan to the one published in 1909, although that was merely a table of distribution in time and space while to the present one is added a graphic view of the phylogenies. The 1917 table is here reproduced.

His most primitive group he calls the Protopoda, including therein the upper Devonian footprint, Thinopus, and subsequent forms known only from their tracks in the Mississippian. From these he derives the Amphibia on the one hand and the Reptilia on the other, representatives of each group being known from the Pennsylvanian, hence the inference that the division occurred during Mississippian time. Of the reptiles, he recognizes four great divisions, the Anapsida or Cotylosauria, Synapsida, Diapsida, and Parapsida, deriving the mammals from the second and the birds from the third. His use of Osborn's terms is of interest, for he was critical of them in earlier years (see p. 126). As he says (p. 413):

It was Cope who, years ago, first suggested that in the temporal region of the skull the surest criteria for the classification of the Reptilia are to be found. Woodward carried the suggestion further, and showed their availability, but it was Osborn and McGregor who first applied them definitely. They assumed too much, as we have seen, but the credit is due to Osborn, more than to anyone else, for the foundation of a true reptilian phylogeny, and to him we owe especially a better knowledge of the double-arched reptiles. He has called them the Diapsida, and there is no better name for them. After the elimination of the forms which we are sure do not belong with them, we are all now, I think, in accord as to their phyletic unity.

The group or subclass of single-arched reptiles, with due modifications of the original concept, may properly bear the name Synapsida given to it by Osborn. It is the group that gave origin to the mammals and has long since been extinct. The temporal opening which, as

Williston believed, arose by the separation of the squamosal and jugal, and not by a definite perforation of any bone, is the sole character by which the group is ultimately distinguished from the Cotylosauria, its ancestral stock. What further phylogenetic work Williston did for his incomplete book on the Reptilia is not now evident to the reviewer. At present the paper under discussion forms the final published statement by one of the highest authorities.

But two papers other than reviews came from the press in Williston's final year, one on the evolution of vertebræ,[136] the other, Part III of the "Osteology of some American Permian Vertebrates." [137] The first of these discusses the homologies of the elements of vertebræ, primitive and otherwise, with their evolution, and is of great value to the student. The other describes further the genera Eryops Cope, Chenoprosopus Mehl and Naosaurus Cope, differentiating the last clearly from the closely allied Edaphosaurus.

GEOLOGY.

In his geological writings, Williston merely discussed such formations as he was concerned with paleontologically, for he was, like most vertebratists, primarily a comparative anatomist, and concerned with geological matters largely as he was with geographical ones, merely from the standpoint of distribution. He wrote of the Kansas Chalk, of semiarid Kansas, of the Kansas red beds, a summary of Kansas geology for a popular work by Angelo Heilprin, on the Laramie (Lance) Cretaceous of Wyoming, on the red beds and Morrison of Wyoming, and finally, with Case, on the Permocarboniferous deposits of the Southwest.

MAN.

A number of papers on man came from the pen of Williston, again largely, one might say, as a by-product of his other research. They discuss chiefly the occurrences of prehistoric man in Kansas, and he records one of the few authentic instances of the occurrence of human artifacts with extinct animals in America. He also wrote two papers on human evolution, of which the second, on the birthplace of man, has already been alluded to as an address delivered before the Paleontological Society in 1909 (see p. 118).

SUMMARY.

The most notable results of Prof. Williston's research lie, aside from the insects, almost entirely within the groups of Amphibia and Reptilia of the Paleozoic and Mesozoic. Compared with the volume and worth of this research, his other work on the fishes, birds, and mammals is almost negligible. He taught, however, many biologic, anatomic, and taxonomic truths of far-reaching application, so that a student of vertebrates of any class, either recent and extinct, can not afford to overlook his results. He gave us much that we know of the fauna of the Cretaceous, notably of the pterosaurs, plesiosaurs, and mosasaurs, and to him we also owe a very large part of our exact knowledge of the Paleozoic air-breathers, for his indefatigable work in the field and laboratory, aided by a few, very devoted co-laborers, has brought to light a fauna amazing in its extent and degree of perfection—entire skeletons of forms many of which were either new to science or known in very fragmentary condition. Williston not only gave a very clear understanding of the osseous morphology of the forms under consideration, throwing much light upon such vexatious problems as the homologies of the cranial elements, of the individual vertebræ, and of the amniotic sternum, but by careful comparative study of existing forms was enabled to restore his creatures in the flesh in a way that, anatomically at least, is thus far above criticism. He discussed at some length the life conditions, feeding and other habits, prowess, and evolutionary adaptations of the forms which he studied, and his knowledge was such that he could generally recognize such resemblances as were the result of convergence and such as actually implied a like heritage. His ideas concerning the phylogenies of the amphibian and reptilian groups developed somewhat slowly, due to his desire that such should be founded upon a considerable body of attested fact. In his final paper on phylogenies, in 1917, he acknowledges, as the best that we have, those broader groupings of such men as Osborn, whose work he was inclined to criticize most emphatically when it first appeared 15 years before.

Williston laid a broad and fundamental foundation for the fabric of our knowledge concerning the cold-blooded air-breathers, building solidly and securely much of the superstructure as well. It is doubtful whether later students of the reptiles particularly will find much that is amiss, especially when the last work of the master shall have been published posthumously. On the other hand, it is the writer's belief that they can build thereon fearlessly, knowing that that which has been done is secure.

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NATIONAL ACADEMY OF SCIENCES.

Volume XVII.
SIXTH MEMOIR.

BIOGRAPHICAL MEMOIR CHARLES RICHARD VAN HISE

1857-1918.

BY

THOMAS C. CHAMBERLIN.

Presented to the Academy at the Autumn Meeting, 1919.

CHARLES RICHARD VAN HISE.

1857-1918.

By T. C. Chamberlin.

When the career of a leader in science happens to coincide with the rise of a new epoch in the field of research which he cultivates, it is by no means easy to apportion the work of the leader in creating the epoch and the influence of the epoch in developing the leader. But it is always comforting to reflect that whatever may be a just apportionment of the reciprocal influences, the association of a great worker with a great epoch at least bespeaks the genius of the leader in seeing the possibilities of the opportunity and making common cause with them, whether by gaining from them or contributing to them, or by both.

The beginning of the scientific career of Charles Richard Van Hise fell in rather closely with the rise and spread in America of the new art of microscopic petrology and the epoch-making science that arose from it. The new art had begun to develop somewhat in the Old World while young Van Hise was yet a student, but he was one of the first in America to recognize its epoch-making power, and aid in its development; he was quite the first I think to bring its resources to bear upon the study of the crystalline rocks of the interior. He was clearly one of the leaders in realizing the higher and broader values of the new science in the interpretation of the origin and history of the ancient metamorphic terranes. The new departure was one of much moment in the history not only of petrology, but of geology. Up to this time the means of determining the precise nature of the complex rocks formed of minutely intermixed crystals were both limited and untrustworthy. The revelations made by scrutiny under the microscope by the aid of polarized light and other appliances, formed a new epoch in this basal science. To attempt to employ it at all in that early day, when its difficulties were so little known, made demands on the courage of the young men who ventured to try it and called for the fullest resources of their training in the basal sciences involved. The first official products of the new art in America seem to have been the work of two young men—one at the east, Dr. George W. Hawes, of the State Geological Survey of New Hampshire, whose early death was a sore loss to science, and one in the interior, Dr. Charles R. Van Hise, of the Wisconsin Geological Survey, who soon rose to eminence in the development of the new science.

Dr. Van Hise's first contribution was entitled "The Crystalline Rocks of the Wisconsin Valley," and formed the body of Part VII of Volume IV of the Wisconsin Survey of 1873–1879. It was a joint report, the senior author of which was the lamented Irving, under whose guidance and inspiration young Van Hise had pursued his geological studies in the University of Wisconsin. This report indeed was a part of their joint labor as teacher and pupil. The story of the working relations of Irving, the teacher, and Van Hise, the student, as they struggled together in the laboratories of the old Science Hall of the University of Wisconsin, to bring to bear the light of the new methods on the obscure old rocks of the Wisconsin Valley, is among the most delightful reminiscences of those who were permitted to come into close touch with them at this interesting stage of their mutual development. While Van Hise was working with the microscope on these obscure old rocks he came upon what he thought was a new and diagnostic characteristic in one of the constituents under his study, and he had the insight to see that, if his impression was sustained, it would be a valuable contribution to the new petrological science as well as an aid in the practice of the new art. Naturally he was greatly elated; but the conscientious Irving, who by instinct as it were always played the rôle of the cautious and critical trainer, kept the young enthusiast's elation in curb by no end of objections while he gave special piquancy to them by that brusque humor that was peculiarly Irving's own. Still, in the face of all this, Van Hise held his ground sturdily and after each bout with his trainer went back to his lathe and his microscope undaunted and eager to find further confirmation of his conclusions, until at length he proved his case beyond question or cavil. This early proof of his sturdiness and steadiness of purpose, supported by his clearness of insight and his firmness of induction, were true forecasts of the mental trend that ever after marked the strong scientific leader into which young Van Hise soon grew.

This earliest official work of Van Hise in connection with Irving was carried on during the closing years of the Wisconsin Geological Survey of 1873–1879. So declared was the high quality of their work that immediately on the close of the State survey, the services of both Irving and Van Hise were sought by the National Survey and the work they had so well inaugurated in Wisconsin was continued without interruption not only, but extended to the whole field of the ancient crystalline rocks in the interior of the United States.

At the time of the lamented death of Irving in 1878, their joint work on these ancient rocks had already developed into varied and comprehensive lines of research. All these now fell to the charge of Dr. Van Hise. The final report on their joint work appeared under Van Hise's editorship in an important report entitled "The Penokee Iron-Bearing Series of Michigan and Wisconsin" (Monograph XIX of the U. S. Geological Survey, 1892). The manuscript for this was transmitted in 1890, but the published volume did not appear until 1892. Besides elaborate discussions of the formations that make up this great series and critical microscopic descriptions of the constituent rocks, an important feature was the establishment of a standard section of the crystalline series of the Lake Superior region, which has been a basis of reference ever since, although naturally additions have been made to it in the progress of later study.

In 1896 Van Hise, jointly with W. S. Bayley and H. L. Smyth, transmitted to the National Government a second monographic work entitled "The Marquette Iron-Bearing District of Michigan" (Monograph XXVIII, U. S. Geological Survey, 1897). This was a natural sequel and companion work to the preceding monograph on the Penokee Iron-Bearing series. Among the important features of this report was the discovery that the Marquette series embraced two divisions, separated by unconformities. This volume also contained a fuller development of the important doctrine that the present richness of the iron ores is due in part to the purification of the original ores and in part to the concentration of the iron compounds from above downward, both processes being the work of the natural circulation of the meteorological waters. In the treatment of the Basement Complex, the oldest recognized series of rocks, the very significant fact was brought out that the schistose members of the series were originally surface deposits, largely of volcanic origin, and that the granitic and granetoidal masses of the region had been intruded into these surface formations and hence were younger. It had previously been generally supposed that the granites and the granitoidal rocks were simply cooled portions of the molten globe which was then commonly postulated as an early state of the earth. It now appeared, however, that these supposed relics of the crust were in reality later and younger than the schistose rocks which at the time formed the outer part of the earth. Furthermore, it appeared that most of these schistose terraines had in their turn been laid down on a previous surface. This significant discovery left this region barren of all direct evidence of the supposed molten globe. It is interesting to note that about the same time, as well as later, similar evidence was forthcoming from other regions of ancient rocks of like type which, as in this case, had been supposed to be parts of the original crust of the molten earth. The joint effect of these suggestive revelations was to rob the doctrine of a molten earth of practically all field evidence. These very radical determinations have been sustained by subsequent inquiries, and they thus constitute a contribution to the interpretation of an early stage of earth history of the first order of importance.

There closely followed this report on the Marquette series a monograph of like nature on "The Crystal Falls Iron-Bearing Region of Michigan," the joint work of Drs. Clements, Smyth, and Bayley, under the general supervision of Van Hise. To this Van Hise prepared an introduction in which he brought into comparison the leading features of analogous formations elsewhere in the Lake Superior region in the United States and in Canada.

Three other monographs of like nature were later prepared by colleagues under the supervision of Dr. Van Hise, viz: "The Mesabi Iron-Bearing District of Minnesota," by C. K. Leith (Monograph XLIII, U. S. Geological Survey, 1903); "The Vermillion Iron-Bearing Series of Minnesota," by J. M. Clements (Monograph XLV, U. S. Geological Survey, 1903), and "The Menominee Iron-Bearing District," by W. S. Bayley (Monograph XLVI, U. S. Geological Survey, 1904). These taken with the preceding treatises, make in all six ponderous volumes on the iron-bearing series of Lake Superior. Altogether these embrace over 3,000 quarto pages, and are illustrated by multitudes of figures and maps, making up a monumental series quite unmatched in its own line, a testimony to the invincible industry of Dr. Van Hise. It scarcely need be said that these placed Van Hise at the head of workers on the iron-bearing series of the Algonkian or Proterozoic ages.

While these studies had centered on the great iron-bearing series of Lake Superior, they had involved careful discussions of the adjacent formations of other types, and so were regional monographs as well as specific formational treatises.

There followed these regional monographic studies, in an order that was natural to the trend of an expanding mind always prone to take large views of his field, a series of papers of a broader range. Among these was a series of elaborate discussions of the correlations of the oldest known formation, the Archean, and the next following systems, which lie unconformably upon these and upon one another in due order, the Algonkian series, since grouped under the name Proterozoic. These discussions formed a part of a notable series of correlation papers published by the National Geological Survey in 1892, under the general editorship of the late Grove Karl Gilbert. They have proved very helpful to all workers in this difficult field.

In 1904 there appeared what many regard as the climacteric paper of Dr. Van Hise, "A Treatise on Metamorphism," a ponderous quarto of 1,286 pages, discussing in a masterly way and in great detail the leading modes by which the nature of rocks are changed and the agencies and conditions that take part in these changes. As all the rocks which he had been studying so diligently during the preceding two and a half decades had undergone such changes in some large measure, but yet in quite different degrees and in quite different ways, he was amply equipped for this great work by intimate personal familiarity with the phenomena. In this work Van Hise made a special effort to reduce the phenomena of metamorphic rocks to the laws of chemistry and physics. This opus magnum has had a profound influence on the progress of opinion on this important phase of geologic research. It was shortly after the completion of the manuscript of this monumental work that Dr. Van Hise was called to undertake the administration of the University of Wisconsin, and with the assumption of this great task his more active geological studies ceased.

One of his greatest contributions, however, appeared seven years later in collaboration with Dr. Leith, whose relations to Van Hise were much the same as those of Van Hise to Irving. This was a comprehensive summary work on "The Geology of the Lake Superior Region" (Monograph LII, U. S. Geological Survey, 1911). In this important work, there were gathered the mature ideas of both authors as these had gradually grown into fullness and ripeness as the result of the studies and restudies of the previous 30 years. It is a masterly endeavor to set forth, in generalized form, the characteristic features of the iron and copper bearing series, their relations to one another and to the great basement complex on which they rest, and to interpret the origin of the ores that give these formations their extraordinary economic values, while at the same time it sets forth the long and varied history of the region. It is not, of course, to be regarded as the final word on these vast themes, but it sums up a long series of intensive studies of great fruitfulness. Far from holding it as a final utterance, its authors speak of it merely as the first of a series of such monographs to be hoped for in the future, a series which shall carry forward similar comprehensive treatment to greater and greater fullness and perfection as exploitation shall reveal more and more of the hidden structure that prevents completeness now. In spite of such modest disclaimers, it stands as a really monumental work, marking a great epoch in the scientific elucidation of an intricate region of extraordinary interest and of representative character. On the geological side, it is a climacteric work, comparable to the treatise on metamorphism on the physicochemical side.

The intensive studies of Van Hise on the iron-copper-bearing formations naturally led him to more general studies of the philosophy of ore deposits and directed him in issuing a series of special papers on ore deposits, among which "The Principles Controlling the Deposition of Ores" (Journ. Geol., Vol. VIII, 1900) and his presidential address before the American Association for the Advancement of Science, delivered at Denver in 1901, may be taken as types. In these the function of magmatic waters in the original enrichment of lodes and that of vadose waters in secondary enrichment of these were strongly set forth and assigned leading rôles.

With his acceptance of the presidency of the University of Wisconsin in 1903, Dr. Van Hise made a serious and at first confident effort to continue his geological researches in addition to his administrative duties, but he soon became so deeply engrossed in the humanistic phases of his new work that there was little time left for effective research in the old lines, and so his foremost interest shifted to new lines. The old and new interests, however, merged, in a measure, in his study of the application of natural resources to the general welfare of man, especially the conservation of natural resources, to which he made several notable contributions, among them the best book on the subject.

It was natural that he should pass from this special line of economic study to the more general aspects of current commercial and industrial questions. In these his chief interest seems soon to have centered on the coordination of effort which he held to be the key to the solution of the vexed questions that agitate this field. Most notable among his writings in this line is his book "Concentration and Control, a Solution of the Trust Problem in the United States."

The utter breakdown of the political tenets that had incited the leading industrial legislation of the United States previous to the war, just as soon as the real stress of war had brought out the realities of the case, and the precipitate rush of the Nation into practices diametrically opposed to those adopted in its previous legislation, deeply interested President Van Hise and led to his book "Conservation and Regulation in the United States During the War."

President Van Hise was profoundly interested in the war and made its probable, intellectual, ethical, and economic outcome a special subject of study. As an administrator he vigorously marshaled the resources of the institution over which he presided in support of a strenuous prosecution of the war, while personally he contributed directly to it by lectures, papers, and other service of notable value. His most conspicuous service was the aid he rendered in the conservation and allocation of our food resources. As the war drew to a close he became especially interested in the formation of a League of Nations. He prepared an address on this subject in which, with his ever-present regard for the practical and the attainable, he drew with greater definiteness than most other advocates the features which such a league should, in his judgment, embody. This was essentially his last contribution to the public welfare.

As the administrator of a great educational institution, President Van Hise naturally regarded science as the bedrock on which educational practice should be based, but he did not interpret science in any narrow or technical sense; he viewed it broadly as an expression of the carefully sifted and thoroughly proved reality disclosed in each and every field of inquiry. Research as an indispensable condition for discovering, demonstrating, and enlarging the body of science, as also for rescrutinizing and renovating that which had previously passed for science, he held absolutely essential to a true university. He went farther and regarded it as essential also to education in all grades; for the renovation, the reconstruction, and the reshaping of the subject matter taught in all the grades he held scarcely less vital to primary education and the public welfare than the addition of new subject matter on the frontiers of knowledge. Important as he held original research to be, however, he held its application to the affairs of life and its incorporation into the lives of citizens as a working, guiding, inspiring factor to be an equally important function and an equally imperative obligation of a State institution. He was fortunate in coming into the presidency of an institution whose working lines were already set in the directions he approved. With his inherited advantage he pushed the university forward in its adopted lines with great success.

Respecting what is to be regarded as a permissible function of a State university and what is to be regarded as nonpermissible or scarcely permissible in the uncertain borderland between what is accepted doctrine and what are debatable issues in political, social, and religious fields—particularly in matters where organized bodies of citizens differ—President Van Hise was rather strongly predisposed to put a distinctly broad interpretation on the functions of the university. He thought it not only the privilege but the duty of the university to give the State leadership, even in lines regarded by some others as at least debatable. While this view did not go so far as to include the precise matters that divided the organized political parties, it yet did embrace matters closely akin to these, matters felt by some others to fall within the outer borders of party policy. The more conservative policy of leaving a clear margin of safety between the conceded fields of scientific inquiry in such matters, on the one hand—in which all right-minded citizens should concur—and the fields of party conflict, on the other, seemed to him to fall short of the full duty of the university to the State. As a natural result of his vigorous advocacy of some policies held by others as debatable, friction of the milder sort arose at times and made the path of his administration less smooth than it might have been under the more conservative policy, but this never went so far as to loosen the great hold of the institution or of its president on the affections and pride of the people of the State. His administration of the university was a declared success; both he and the university under his care exercised a profound influence on the intellectual and material progress of the State.

In his scientific inquiries great pains marked every part of the research and all stages of preparation of the results. Combined with invincible industry there was a steadiness of purpose that drove the work constantly forward to completion. Virility, sturdiness, and strength of grasp were leading traits. He seems to have suffered less loss of time and energy from hesitancy or vacillation than is common to workers of less steady purpose. His intellectual tread was firm; but yet there was openness of mind, readiness for reconsideration, and suceptibility to change of view. He abandoned old views in favor of new with promptness and periodically reconsidered his conclusions with a view to revision. He persistently sought deeper and larger intellectual perspective. A notable trait was his strong desire for the significance of phenomena and the philosophy that lay in their depths. His power of generalization was pronounced and came declaredly into play in his larger conclusions relative to metamorphism, ore deposition, and the genesis of the great terranes he studied.

His home life was singularly happy, though shadowed in his last years by the death of a beloved daughter. He leaves a devoted wife and two affectionate daughters. His personal qualities were of the highest order. He was a congenial companion in the office, the laboratory, and the field. His point of view was large and liberal, always incisive, often humorous. His convictions were strong, and the courage of his convictions never seemed to fail him. He was outspoken and manly in bearing, frank, and strong in his friendships. He respected the sincere and called forth sincere respect in return.

He received a due measure of the honors his work merited. Williams, Dartmouth, Chicago, Yale, and Harvard conferred upon him their highest honorary degree. A long list of scientific societies in this country and abroad honored themselves and him with membership. He was chosen to the presidency of practically all the scientific societies to which he could be regarded as naturally eligible.

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NATIONAL ACADEMY OF SCIENCES.

Volume XVII.
SEVENTH MEMOIR.

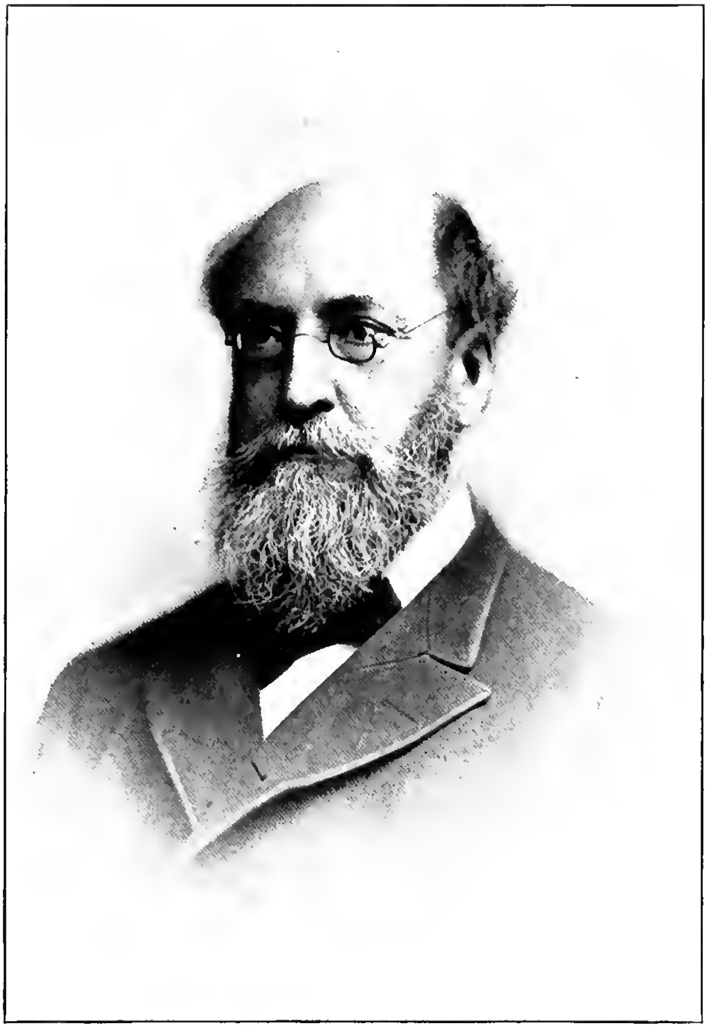
BIOGRAPHICAL MEMOIR BENJAMIN APTHORP GOULD

1824-1896.

BY

GEORGE C. COMSTOCK.

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1922.



B. A. Gould

BENJAMIN APTHORP GOULD.

By George C. Comstock.

Benjamin Apthorp Gould was one of the incorporators of the National Academy of Sciences, a conspicuous figure in its early annals as well as in the history of American science; or *Science in America*, as Gould is careful to say. Untoward events have so delayed the preparation of his biography that in considerable measure material once available for that purpose seems now irretrievably lost, and a quarter century after his death his career must be studied and his achievements told by a stranger who never saw him and who labors under unexpected difficulties in obtaining adequate material. There is a dearth of that intimate information commonly to be obtained from relatives and close family friends, and its place must here be taken by published memoirs and the recollections courteously supplied by some of his professional associates. In great part this sketch is, from necessity, based upon secondary sources such that inevitably much is lacking that would illumine the man's character, and even in its formal parts, such as the bibliography, entire completeness can not be assured.

B. A. Gould, jr., as he early indited his name, was born in Boston on September 27, 1824, of sturdy English ancestry that upon both sides had been long resident in Massachusetts. Inspired with a lifelong interest in genealogy, local history, and antiquities, he prepared and twice published a Gould genealogy and from the second, revised and enlarged edition of this work, it appears that both his father and his mother were descended in the sixth generation from the Pilgrim Fathers of a date not long subsequent to 1620. These ancestors had been substantial citizens, landholders and leaders in their communities, and their chief seat appears to have been the estate at Topsford, not far from Boston, established by the immigrant ancestor, Zaccheus Gould. The more remote ancestry may be traced back through English rural records for an additional six generations, during which they appear as substantial yeomen, established not far from London, drawing from the soil their living and by will transmitting their modest estates from generation to generation. The earliest known appearance of the name antedates the discovery of America.

At the modern end of the line the father of B. A. Gould, jr., also a Benjamin Apthorp Gould, having graduated from Harvard College in 1814, became head master of the Boston Latin School, which he conducted successfully for many years, during which he acquired a reputation for unusual scholarship, based upon his work as editor of numerous classical texts. He married in 1823 Lucretia Goddard and to them were born four children, the eldest of whom is the subject of this memoir. Failing health led the father to withdraw from his academic career and after a journey abroad for recuperation he established himself in Boston as a merchant in the East Indian trade. The activities and interests of the parent, here noted, found strong reflection in at least the earlier parts of the son's career.

During the father's absence from home the youthful Benjamin was entrusted to the care and guidance of an aunt, Hannah Gould, who is described as a poetess of some fame and a woman "characterized by a cheerful, frolicsome spirit and earnest piety." Gould speaks of her with much respect and she appears to have had large influence in molding the lad's temperament to her own standards and likeness.

Trained in the Latin School in which his father had taught, and imbued with a lifelong respect and fondness for its lore, the lad entered Harvard College at the age of 16 and there followed for some years the cult of the ancient tongues in which he had been reared. But in increasing measure his interest shifted to physics and especially to mathematics which, under the inspiring influence of Benjamin Peirce, he pursued during the entire four years of his college course. This increasing interest in mathematics and physical science finds reflection in a dissertation, of his senior year, upon the publications of the British Association for the Advancement of Science. One or more of these volumes seem to have fallen into his hands and to have greatly impressed him.

His student life appears to have been a normal one, in accordance with the standards of the time. Tales of his precocious attainments, such as his translation of an ode of Horace at the tender age of 5 years and his freshman attempt at computing a comet orbit, are fairly enough offset by his ignominious failure at the blackboard when Peirce endeavored to exhibit his attainments before a visiting committee of dignitaries, and by the matter of record, that the college administration rusticated him for a considerable term because of his relation to some student pranks. The personal relations and friendships formed during this period were an abiding influence and joy throughout his later life. By parental arrangement his freshman chum was Francis Parkman, the future historian. He became corresponding secretary of the Harvard Natural History Society and, odd as it now seems, was appointed its curator for botany, mineralogy, and conchology. His interest in the biological sciences appears to have been strongly aroused for, as he long afterward told a friend who commented upon his unexpected knowledge of trees, "I narrowly escaped being a botanist instead of an astronomer." A major influence at this period was exerted by a local preacher who aroused or confirmed in him a strong moral and ethical conviction that abided through life and one phase of which found expression in his enthusiastic adherence to the Unitarian Church.

Gould was graduated from Harvard in 1844 and the immediate sequel to his college days was quite conventional; he became a teacher in the Boston Latin School and proceeded to an A.M. degree in course. But a single year sufficed to convince the young man that his purposes in life were not to be realized along these temporary lines of least resistance. He had found himself, and with clear vision and single purpose he turned toward preparation for a career in which the developement of science in his native land was a dominant purpose, a purpose that later found repeated expression in speech and print. A decade afterwards he records that in arranging his plans he had sought and received advice from Sears C. Walker, and with strong emphasis he approves the advice thus given to "study foreign languages, for thus alone can you keep pace with the progress of modern science."

To his contemporaries the plans then formed must have seemed Quixotic, for, to quote Gould himself, "I believe I may say that a single instance of a man's devoting himself to science as the only earthly aim and object of his life, while unassured of a professor's chair or some analogous appointment upon which he might depend for subsistence, was wholly unknown." Despite this lack of precedents for his chosen career Gould appears to have acted wisely and well. In July, 1845, he sailed for Europe with plans for a prolonged period of study and travel. His family connections furnished him credentials and introductions that opened wide the doors of scientific circles in the Old World. After brief periods spent under the influence of Airy at Greenwich and of Arago and Biot at Paris, he passed on to Germany, in whose academic life he seems to have found his chief inspiration, and this mainly in two institutions. He spent a year at Berlin registered as an assistant in the observatory at the time when Galle's visual discovery of Neptune, made through its modest telescope, thrilled a multitude of minds less ardent than his own. During this residence in Berlin it was his great good fortune to win the friendship and esteem of the venerable Alexander von Humboldt, then at the height of his fame and influence. Through the benevolent exercise of this influence Gould was transferred to a new environment and came into new relations that were to be decisive for his career. Prof. Carl Friederich Gauss, one of the great mathematical astronomers of all times, received the young man into his own inner circle of disciples, indeed into his own home at Goettingen, and filled his mind with enthusiasm for the problems of planetary motion then current. The first fruits of this enthusiasm are to be found in a series of some 20 papers published in rapid succession during the years 1848–1851 (see bibliography), dealing with the observation and motion of comets and minor planets, or asteroids, as they were then commonly called. Gould received from Goettingen his degree, doctor of philosophy, in 1848, his dissertation being entitled "Untersuchungen über die Gesenseitige Lage der Bahnen der zwischen Mars and Jupiter sich bewegende Planeten." The work shows small trace of its author's future power and its approval by Gauss as an adequate inaugural dissertation may perhaps be construed as evidence of the master's capacity to look beyond the immediate present.

The life at Goettingen was followed by some months of travel, from Italy to Russia, in which the young doctor, adding to his first-hand knowledge of men and things, came in especial measure under the influence of Argelander, at Bonn, and formed with him a peculiar friendship that was largely influential in determining the purposes and plans of his maturer years.

Returing to America via France, a momentary glimpse at the kaleidoscope of Gallic life revealed to Gould his friend Biot engaged in politics and, by chance, exhibited Louis Napoleon swearing allegiance to constitutional government and taking a place in the extreme left of the constituent assembly. He brought back to his home a mind well trained in the physical science of the day and filled with an enthusiasm that was to find fruitful expression in half a century of honorable and distinguished toil. But Europe had given to him much more than professional training. The genial disposition, his by inheritance, had formed on every side warm friendships that were severed only by death. Few were the astronomers of note not included in the circle of his personal friends and correspondents, and upon his numerous returns to Europe these friendships were refreshed and extended in unusual measure. He brought home also an acquaintance with and facility in the use of foreign tongues that was later to stand him in good stead. French and German were at his instant command, and to these was added later an equal command of Spanish. His Italian, while less fluent, was serviceable and his own jest, of later date, somewhat extends this tale of tongues. To a friend seeking linguistic aid and suggesting that Gould perhaps had some knowledge of Spanish, he replied with a twinkle of the eye and a gesture of the hand toward the row of ponderous Resultados del Observatorio en Córdoba, "Oh, yes; for many years I published chiefly in Spanish, and Arabic." A hasty and withal skeptical examination of the quarto volumes revealed that, in truth, their contents were mainly expressed in numerals of the Arabic notation.

The change from life in the scientific circles of Europe to the wholly different environment and conditions offered by the Massachusetts of that day was a sore trial to the young man. He knew on leaving Europe what was before him, but the reality proved even more depressing than anticipation had pictured it. His disappointment and bitterness of spirit found expression soon after his return in a letter to Humboldt, but there is in it no suggestion of altering his plans. An honorable mode of escape was opened to him a little later, as was learned long afterwards from the deceased man's letter books. Gauss offered him a professorship at Goettingen, which was declined. Renewed a little later and coupled with the promised directorship of the Goettingen Observatory, Gould hesitated, consulted his friends Peirce and Agassiz, who advised him to accept and, yielding to their judgment, he did accept the very flattering offer, but only to reconsider and withdraw the acceptance in order that he might carry out his original plans to serve science in America.

But we have overrun the chronological sequence of events. Landed in America and faced with the challenge of a wholly unconventional career, Gould found his first obligation to be the winning of his daily bread. For two years this was accomplished by teaching mathematics, French, and German at Cambridge, presumably as a coach. But this bread-and-butter pursuit was enlivened and seriously burdened by his establishment, in 1849, of the Astronomical Journal, a periodical of irregular appearance, devoted to the publication of research in astronomy. The preamble, printed over Gould's name, states that "The enthusiasm of astronomers and the liberality of friends of science in America have enabled me to commence the Astronomical Journal with the full conviction that it will be permanently supported." "In the earnest hope that the establishment of the Astronomical Journal may be hereafter referred to as an era for astronomy in America I commend it to the sympathy and cooperation of the lovers and votaries of science." The hopes thus expressed have been in substance fulfilled. The Journal has been largely influential in developing and dignifying American astronomy and its inception and early success redound greatly to Gould's credit. But its career has been very unlike that foreshadowed in the first of the preceding quotations. For nearly a dozen years Gould's unremitting effort and his pecuniary sacrifice maintained the Journal at a high level of scientific quality and prestige, conjoined to a very low level of financial stability. An occasional published note from the editor sets forth from time to time his precarious condition and in July, 1861, in the throes of civil war, when "no American is able to investigate or study now with the calmness which success requires," the editor announces that he is compelled to suspend publication, but he hopes for an early resumption. That hope remained unrealized for a quarter century, and its ultimate fruition must be told in a later part of this memoir. But even at this stage of its career the Journal had justified the enthusiastic words of his eulogist: "He inspired a new breath into American astronomy. The new atmosphere which he brought with him from Germany, where he caught the spirit of the great masters under whom he studied, became gradually transfused through the States. His enthusiasm for the introduction of better means and methods of research was caught by his compatriots, their courage in the effort to regenerate our science was sustained, and transmitted through various channels to the next and to the present generation."

The 20 years that followed Gould's return to America present him as a man of multifarious interests and activities for which a bond of union is to be found only in his own strong and versatile personality. In 1852, the failing health of his friend and mentor Sears C. Walker brought Gould into relations with the United States Coast Survey and soon afterward, as Walker's successor, into responsible charge of its longitude determinations. For this work Walker had commenced experimenting with the new electric telegraph and Gould, devoting himself with characteristic ardor to the advancement of astronomical technique, developed and applied the new device in the work of the survey until, as Loewy, his eulogist, stated to the French Academy, he had made some 15 determinations of telegraphic longitude before Europe commenced to use the method. Gould's somewhat irregular, part time, relations with the Coast Survey continued until 1867 and were brilliantly crowned, at the very end, by his execution of the first telegraphic determination of trans-Atlantic longitude ever made. His report upon this determination shows Gould at his best, with a firm grip upon essential principles but struggling against accident and adverse circumstance. He took for himself the European end of the line, and buried in the almost unbroken fog and rain of the Irish coast he waited week after week for a glimpse of a star or a swing of his magnetic needle to be made under the influence of a current closed or opened in Newfoundland. When patience found its reward in a completed observing program he turns from astronomy to physics in an attempt to utilize his new data for the improvement of electrotechnics, and also he turns to psychology in a study of the personal equation with particular reference to its lack of constancy when that virtue is most required.

The same year that marked Gould's entrance into the Coast Survey contained also the beginnings of what later was to prove to him a period of stress and trial, of recrimination and chagrin, carried through some years of apparently fruitless labor. The details of this experience are voluminously set forth in his vigorous and at times acrimonious "Reply to the statement of the trustees of the Dudley Observatory." This reply should be compared with the no less acrimonious "Statement" itself, and the unprejudiced reader of both volumes can hardly fail to be embarrassed by their irreconcilable accounts of the early history of a great institution. In substance we witness in them a lawsuit fought out of court, and the present writer's relation to a quasi legal controversy must be that of clerk rather than judge or jury.

In the decade prior to 1850, Ormsby Macknight Mitchell had built up in Cincinnati an observatory that brought fame to him and prestige to the city that had given pecuniary support to his work. Certain Albanians, i. e., citizens of Albany, in the State of New York, animated with honorable civic pride, sought to rival and perchance outdo the western contribution to science by building upon the banks of the Hudson another observatory that should not only redound to their personal credit but should make in their city a center of light and learning.

Money was needed for such a purpose and this they commenced to accumulate. Professional advice and guidance were also needed and for this they naturally turned to Mitchell, soliciting him to accept the directorship and determine the character of the institution that was to be. Mitchell listened, sympathized, and apparently entered into engagements with them that later he was loath to fulfill. Late in the year 1852, through Sears C. Walker, he approached Gould, proposing that the latter associate himself with the Albany enterprise as colleague and eventual successor to himself. The proposal was declined but in such fashion that it was more than once renewed, with increasing emphasis upon the suggestion that here was a great opportunity for the upbuilding of science in America, an opportunity that apparently was on the verge of failure for lack of a man able and willing to improve it. In the end, after months of discussion had stretched out into years, Gould, yielding, consented to ally himself with the enterprise, but in such fashion that he might retain his residence in Cambridge and his active duties with the Coast Survey and the Astronomical Journal. Through a nebulous and ill-attested agreement between the observatory trustees on the one hand and four prominent American men of science on the other, viz, Joseph Henry, Benjamin Peirce, Alexander Dallas Bache, and B. A. Gould, jr., these gentlemen undertook to act, without compensation, as a scientific council for the observatory, with Gould as their executive officer. Bache, as head of the Coast Survey, adopted the observatory as one of its stations, loaned instruments to it, and stationed at Albany officers who, while discharging their regular survey duties and utilizing for that purpose the facilities afforded by the observatory, were free to devote, and did in fact devote to it, much of their spare time. Gould was among these officers and speedily he became known as director of the Dudley Observatory, devoting to it his time and efforts, and in its service, and partly at its expense, going abroad to order suitable instruments for its equipment.

Divergent views of the value and functions of an observatory, delay, and fruitless expense in its equipment, some lack of harmony within its personnel, led in time to strained relations between the trustees and director, and the widespread financial depression of 1857 furnished a medium admirably suited to the growth of ill will. Efforts to improve the situation were not lacking. Henry, Peirce, and Bache of the scientific council, standing firm in support of their fellow member, explained to the trustees that an admittedly unfortunate situation was due to untoward circumstances for which the director was in no way blameworthy. A strong body of local sentiment, both within and without the board of trustees, stood firmly behind the director, proffering support not only to his administration of the observatory but to his other activities as well. He was urged to bring the Astronomical Journal to Albany and to take up his residence there in a house expressly provided for that purpose. Gould, accepting these proposals, moved to Albany early in 1858. The Journal had preceded him by about a year, under an arrangement and guaranty for its continued publication announced by Bache at the dedication of the Dudley Observatory. The guaranty proved to be worthless and events rapidly shaped themselves for worse instead of better. Following a hostile newspaper campaign of some months' duration, charges of incompetence, disloyalty, and sloth were made against the director by certain trustees. These were vigorously repudiated by the scientific council, which brought to the director's defense the chief if not the only technical competence available for judgment of the matter.

Inevitably Gould's relations with certain influential persons became greatly embittered and only a few months after taking up his residence at Albany, the trustees, by a divided vote, declared his relations with the observatory ended. A week later they also voted to dissolve the scientific council. The council and the director, holding that they possessed vested rights in the matter that no action of the trustees could impair, refused to yield possession of the observatory and, in effect, Gould became a recluse in his own home, fearing to leave it by day lest in his absence it should be seized by the enemy. The trustees appear to have resorted to legal process for his ejectment and then, mistrusting the law's delay, to have taken the matter into their own hands with recourse to violence. Gould's statement is that on "the 30 of January (1859) I was driven from my dwelling by a hired band of rioters, acting without form or pretense of law—a mere brute force''—scattering and destroying his papers as well as doing indignity to his person.

A somewhat voluminous literature has grown about the events here briefly summarized and concerning it two comments seem in order: (*a*) The opinion of astronomers wholeheartedly supports Gould's scientific administration of the Dudley Observatory, i. e., the essential part of the controversy, and the part upon which their judgement possesses unique technical competence. But to this consensus of opinoin there were two conspicuous exceptions. To Gould's chagrin two astronomers of note, Bruennow and Peters, took sides with the hostile majority of the trustees, and he notes that both these men are of foreign birth and training, recent comers to a new environment of which they had little understanding. (*b*) The exacerbated temper manifest in the controversy suggests the presence behind it of elements not publicly avowed. Local tradition still names as such an element Gould's faculty for mimicry and mordant characterization.

The Dudley Observatory had been an added burden to his already overtaxed pecuniary resources and during his unsalaried connection with it Gould had carried on, with compensation, a prior undertaking to reduce, discuss and save from oblivion the work of Lieut. Gilliss, United States Navy, who, in the years 1849-1852 had conducted a "U. S. naval astronomical expedition to the Southern Hemisphere." A major purpose of this expedition was to determine the solar parallax from observations of Mars and Venus, executed in Chile in accordance with a well-conceived plan. As an essential supplement to the data thus acquired Gilliss had counted upon similar observations being simultaneously made at observatories in the Northern Hemisphere and he was grievously disappointed by failure of the expected cooperation. This mishap seriously impaired the value of his laborious work and rendered inapplicable the methods planned for its utilization. By arrangement with Gilliss, Gould took over the entire body of data, the scanty northern observations as well as the more complete southern material, devised new methods for its treatment and in No. III of the four quarto volumes devoted to making public the expedition and its work he sets forth those methods and their result. The discussion is admirable and accordant with the best traditions of his German teachers but in the light of more recent knowledge it seems only to illustrate the oft-forgotten adage that bread is not made from chaff. His data were quite inadequate and his result fell farther from the truth than were the current values of the sun's distance that he sought to supplant. The compensation paid for the work, which is said to have been expended upon the Dudley Observatory, served only as a foundation for the charge of willful neglect of duty to it in seeking pecuniary gain through outside employment

The Dudley Observatory episode having become a closed incident, in 1859 Gould returned to Cambridge and took up again the threads of his former life. He turned to more sedate employment, not embittered but, as his friends said, softened and sweetened by Albany and its harrassing vicissitudes. Outside the "Reply," his own public comment on these events is singularly reserved and sober. A chance remark, made years afterward, that they "had taught him how to fight" probably does scant justice to his native quality. The first fruits of the new work, apparently executed in 1859 but not published until 1862, were his Standard Right Ascensions of Circumpolar and Time Stars, prepared for the use of the United States Coast Survey. Gould here inaugurated, for the benefit of his longitude work, a practice of fundamental importance for the astronomy of precision, viz, the introduction of systematic corrections to star catalogues. In untechnical language, he was one of the first to grasp and successfully apply the idea, now a commonplace, that the coordinates of a hundred or a thousand stars observed and published at a particular observatory are not finished data, but only raw material that may be greatly improved by collation and comparison with external evidence. The successful execution of this idea made the fortune of his star positions which almost at once were adopted and long and widely used by astronomers as standards.

In mitigation of the rigors of such serious work, Gould joined with certain young professors who, like himself, were German University trained, in setting up, under the shadow of Harvard College, bachelor quarters that speedily became the talk of the town and long remained one of its traditions. The local repute of "Cloverden" with its classic accessories and bacchanalian revels is not unduly travestied in the phrase, Gemüthlichkeit established on Plymouth Rock. The Bohemian quality of the den seems, to a generation two degrees further removed from puritanism, not to have exceeded the limits suggested by its literary offspring, the well known ballad of the "One Fish Ball."

The closing months of 1859 brought to Gould a great blow, that for some years forced him to withdraw, in considerable measure, from scientific work. His father died, leaving a mercantile business in such precarious condition that the son was forced to take immediate charge of it in order to ward off serious loss or even bankruptcy. One notes as a singular coincidence that almost simultaneously the English astronomer, Carrington, whose predilections and work bore a marked resemblance to those of Gould, was similarly summoned by a father's death to commercial pursuits which practically closed a highly promising scientific career. Not until 1864 did Gould extricate himself from a business engagement, which, though forced upon him, was assumed and prosecuted with a vigor and success characteristic of his versatile energy.

But during these years astronomical work was by no means abandoned. When the war in 1861 forced suspension of the Astronomical Journal, it opened to Gould a new line of effort. Maury, Superintendent of the United States Naval Observatory, a southerner by birth, abandoned his post and hastened to join in rebellion the forces of his native State. Behind him were left in deplorable condition the unreduced records of observations covering a considerable term of years. The last published observatory volume bore date 1859, but extended only to observations made in 1850. Capt. Gilliss, whose earlier cooperation with Gould has been noted above, took charge of the observatory after Maury's flight and, despairing of bringing up its arrears of work with the means at his disposal, he caused the fugitive records and papers to be collated, copied, and turned over to Gould for discussion, much as he had done with the records of his own Chilean expedition. The contract for this work was executed on October 9, 1861, and in the notice prefixed to the observatory volume bearing the imprint 1863, Gilliss notes that "All unpublished astronomical observations made prior to 1861, except the Zones, are ready for the press." The Zones could not be rendered useful to astronomy without further observations. With due respect to those other current obligations which were unquestionably discharged, Gould's hours and hands must have been strenuously employed in the early sixties.

Among those other obligations is one of peculiar interest and importance in Gould's life. In 1861 he married Mary Apthorp Quincy, daughter of Hon. Josiah Quincy, of Boston, a brilliant and noble woman of rare attainments whose intelligent sympathy with, and collaboration in, his purposes were a great factor in his subsequent career. The first outward manifestation of this factor in his professional activity was the erection, through her aid, of a private observatory near Cambridge, equipped with a large meridian instrument which was employed by Gould for some years, 1864–1867, in observing the positions of stars near the north celestial pole. But this contribution proved to be only the beginning of her long continued sympathy, stimulus, and aid, whose fruition is commemorated in the words prefixed by Gould two decades later to his Cordoba Zone Catalogue, "This catalogue of southern stars, the fruit of nearly 13 years of assiduous toil, is dedicated to the beloved and honored memory of Mary Apthorp Quincy Gould, to whose approval and unselfish encouragement the original undertaking was due, by whose sympathy, self-sacrifice, and practical assistance its execution was made possible, who bravely endured privation, exile, and afflictive bereavement that it might be worthily finished, but who has not seen its completion." What a pity that this tribute could not have been rendered within her lifetime.

Another interest embedded in those days of commercial activity must not be omitted. On March 3, 1863, President Lincoln approved an act to incorporate the National Academy of Sciences, naming B. A. Gould of Massachusetts as one of the 50 incorporators chosen as representative of American science. Tradition asserts that Gould was active in securing establishment of the academy. He certainly became active in its affairs from the very beginning of its corporate life. In January, 1864, at the first scientific session held by the academy he presented to it for publication an extensive and important paper entitled "Reduction of the Observations of Fixed Stars," made by Joseph Lepaute D'Agelet at Paris in 1783–1785. In this paper, published by the academy as its first memoir, Gould rescues from oblivion a meritorious series of observations made at an epoch when such work was rare, and which by lapse of time had become an important part of the material then available for the study of stellar motions. In August of the same year Gould presented to the academy its first biographical memoir, a eulogy of Joseph S. Hubbard, the first of its incorporators to be removed by death.

Following the completion of his commercial career, Gould suddenly appears in an unexpected rôle for which his prior training seemed to himself of doubtful adequacy, viz. actuary to the United States Sanitary Commission, charged with accumulating from the military and naval service of the United States extensive data relative to the physical character and quality of the men composing it. The commission's statistical bureau, of which Gould took charge in July, 1864, was a very considerable organization whose personnel contained more than a sprinkling of names subsequently famous. Its immediate duty was to collect, tabulate, and discuss vital statistics, e. g., the distribution among the troops, of age, stature, nativity, color of eyes, length of bone, pulmonary capacity, etc., and in Gould's words its "action was controlled by a constant regard to those hygienic and physiological laws which are already known, and by an anxious desire to discover and apply such other laws as might affect the welfare and success of our soldiers." Gould's energy and organizing power made amends for the scant familiarity with those "known laws" which he publicly confesses and deplores; and the "Statistical Volume," Volume III, issued by the commission, gives abundant illustration of the astronomer seeking to apply to new problems in a new field such familiar tools as empirical equations and the method of least squares.

Formidable obstacles to the work of his bureau speedily developed, apparently through professional reluctance to communicate valuable data to a rival organization, and the actuary found himself cut off first from the records of the Surgeon General's office and a little later, by direct order of the Secretary of War, from the records of The Adjutant General, United States Army. Despite the barriers thus opposed to him Gould succeeded in collecting, organizing, and publishing a great body of data whose value and influence are still held by competent scholars to be of the first importance.

It was while engaged in this work that Gould's attention and purpose were captivated by the beginnings of what was to become the *magnum opus* of his life. That part of the heavens visible from Europe had been surveyed and charted by astronomers, among whom his own masters and friends held a conspicuous place. Something of the same kind had been done by his friend Lieut. Gilliss for the region surrounding the south celestial pole, but between this area and that covered by the northern surveys lay a broad expanse of sky which, if not an absolutely virgin field, was at least one known only in the most fragmentary way. For its systematic exploration and the cataloguing of its stars Gould possessed both the will and the technical competence. As the project grew in his mind from a dream into an ardent purpose, he was assured that his Massachusetts friends were prepared to put at his disposal considerable sums of money for its achievement. The scheme involved, necessarily, his own expatriation for a time during which he should erect somewhere in the Southern Hemisphere a temporary observatory and should in two or three years make there the needed observations and then bring home his data for such study and treatment as should prove needful to bring forth their results and to fill the last great gap in the exploration of the sky. For information and counsel in the matter he turned to his friend Sarmiento, then minister of the Argentine Republic, resident in Washington. Were the local conditions in Argentina satisfactory for such a project? Would its Government welcome such a scientific expedition? What would be its status after reaching that country, etc.? The response was most encouraging. The Argentine Government would not only welcome the undertaking, it would adopt it as its own child, erect and maintain its observatory, not for a term of years only, but indefinitely, as a national scientific foundation. But the negotiations thus briefly summarized were spread out over many months, during which Gould's relations with the Sanitary Commission and with the Coast Survey were terminated and during which he commenced ordering from Europe, upon his personal responsibility, the instruments required for the proposed work.

Meanwhile there came into the science of astronomy a new method of research with which Gould became early identified and with whose development he is closely associated. Lewis Rutherfurd, of New York, a pioneer in photography, had applied that art to the heavens and, overcoming very considerable difficulties by means of improved technique, he had obtained excellent large-scale photographs of limited areas of the sky. Much impressed by these photographs, Gould volunteered, in February, 1866, to investigate their possible utility as a new method of astronomical research. Rutherfurd had already designed and constructed apparatus for measuring the positions of the star images on the plates, and upon Gould devolved the task of investigating the new tools as well as the subject-matter to which they should apply, and of pushing both tools and plates to the utmost limit of attainable precision. A preliminary account of his first conclusions, based upon photographs of the Pleiades taken in March, 1866, was presented to the National Academy of Sciences in August of the same year, but much further labor was required before definitive results, from the photographs for the Praesepe group as well as the Pleiades, could be realized. After long delay, intended to secure to Rutherfurd the opportunity for prior publication, these final results were published by the academy in 1888, as a part of its memoirs for 1870. Here, in Gould's supplement to Rutherfurd's work, was shown for the first time that the photographic plate, when developed after exposure to the stars, gives not merely a picture of the sky but an accurate reproduction of it adapted to measurements of the highest precision. Mueller, one of the masters of modern astrophysics, characterizes this work in the words "Durch diese Arbeiten, welche zum ersten Male an einem grösseren Material die Anwendbarkeit der Photographie zu exacten Messungen am Himmel bewiesen, hat sich Gould auch in der Geschichte der Astrophysik einen hervorragenden Ehrenplatz verdient."

The scientific work accomplished by Gould in the 22 years following his first return from Europe must be designated by any just critic as distinguished in character and remarkable in amount. Consequent to this record, the year 1870 found him a man of middle age, established position and repute, but with his major work not yet seriously entered upon. An index to his outlook upon life at this period may be found in two notable addresses. In one of these, upon the physical character and constitution of the sun, delivered as a series of lectures before the Peabody Institute of Baltimore, he shows, as nowhere else, his interest in and familiarity with the new phase of astronomical research then coming into vogue which we now call astrophysics. That he did not actively engage in this new line of research was due to no lack of sympathy or appreciation of its promise. His address as retiring president of the American Association for the Advancement of Science, delivered at the meeting of 1869, is largely devoted to an exposition of his outlook upon the larger intellectual and spiritual interests of life. The "conflict between religion and science" filled the air of that day with its clamor, and Gould improved the opportunity offered by his position in American science to set forth earnestly and vigorously his conception of the relations between the intellectual and the spiritual life. Upon questions of this kind no man may pronounce definitive judgment, and the interest that still inheres in the address is not to be sought from this side. It is, rather, an *apologia pro vita sua*, an expression of the intellectual side of his own spiritual life.

Five years had now elapsed since his first approach to the Argentine envoy with the inquiries above noted. Sarmiento meanwhile had returned to his own land as its president and, for the development of its educational system, he had inaugurated a policy of emphasizing the natural sciences, with stress upon the element of research. Two years after this statesman assumed his high office, at his invitation Gould sailed for the Argentine, via Europe, to execute the projects that had been taking shape in his mind since 1865. Narrowly escaping entanglement in the Franco-Prussian War of 1870, he arrived at Buenos Aires as the southern winter was changing into spring and found his destination still far away. Proceeding by boat up the La Plata to Rosario, and thence northwestward by a newly constructed railway across the pampas, he found in Cordoba, the site chosen for his work, a mediaeval Spanish city of 30,000 people, set down in the new world but perpetuating in it the life and ideas of a bygone time. Capable of supporting life in a primitive but fairly comfortable fashion, the place was almost wholly devoid of accessories for a scientific establishment. Mechanical facilities of every kind, light, power, machinery, and skilled labor were almost unknown, and local assistance was of small avail save for the aid given by one or two Cordobans who had been educated in Europe. Foreseeing these conditions, Gould had made provision against them by ordering from home and from Europe not only the instrumental equipment required for his work, but much of accessory supplies, extending even to the framework of his proposed observatory. Most important of all, he had organized and sent on by ship direct from Maine to Argentina a party of four young men to be his assistants and collaborators in the proposed work. While they were not technically trained astronomers, Gould notes with much appreciation that a college education had prepared each of them for the rapid development of efficiency in his new evironment.

Gould's early estimate that three years would suffice for the accomplishment of his observing program was soon made obsolete. War in Europe, pestilence and quarantine in America, produced extraordinary delay in receipt of his shipments. The five American astronomers found themselves beneath the southern stars but with no instruments for observing them, and with small prospect that any such equipment could arrive and be installed for many months to come. With characteristic vigor Gould rose to the emergency. Once before he had faced something of the same kind when the long delay in mounting the instruments of the Dudley Observatory had caused him to study the northern heavens with the naked eye and to set down in catalogue form the approximate position and degree of brightness of each star that should later be observed when the appropriate instrument was available. He now resorted to a similar idea for the virgin southern sky but with a difference of purpose and from a new view point that mark his own development in the intervening years. At Albany he had insisted that while the natural history of the sky may possess some interest, it is not the proper and serious work for an astromomer; "the study of the *motions* of the heavenly bodies is nevertheless the sole problem of astronomy." (Reply to the statement, etc., p. 95.) In accordance with this principle the naked eye work at Albany was a mere skirmish preparatory to a real campaign of observations that should be undertaken later. *Per contra* the Cordoba work was conceived as a serious problem in itself. It was to be a photometric work wherein certain empirical standards of stellar brightness set up by others among the northern stars should be extended into the southern sky by means of a carefully arranged program of observations with the naked eye or opera glass and in terms of these standards, revised and corrected if need be, there should be determined with all possible precision the brightness of every southern star visible to the naked eye. His own myopic vision might suffice for the work at Albany but he deemed it inadequate for that at Cordoba. The thousands of tedious observations required for this work were therefore executed by his associates while Gould planned, superintended, and inspired the work from beginning to end.

The final results of this work were published, under the special title Uranometria Argentina, in Volume I of that splendid series of Resultados del Observatorio Nacional Argentino en Córdoba, the first 15 volumes of which present the chief results of his life and work in South America. No attempt can here be made to abstract their contents but we may note that the Uranometria, completed in 1874 but not published until 1879, commanded the immediate and enthusiastic appreciation of astronomers throughout the world as a notable contribution to their science. At one stroke, Gould had raised our knowledge of the aspect of the southern sky to a parity with that which in the northern heavens had been attained by the labor of many astronomers through many years. He had rearranged the boundaries of its constellations as well as classified their content and with his new data had formulated and studied a wide range of problems extending from technical photometry to the structure of the universe.

The National Academy of Sciences took the unusual step of expressing through formal resolution its appreciation of this work accomplished by its absent member, and the Royal Astronomical Society (London) in 1883 bestowed upon Gould its gold medal in recognition of the work. In presenting this medal the president of the society justly remarked that while the Uranometry "will be accepted for many years as the chief authority upon questions of * * * magnitude * * * it is certain from its very success to * * * incite to efforts which must ultimately lead to its being replaced by something * * * yet more accurate." Within our own generation we witness the partial fulfillment of this forecast. Gould's photometric methods have given way to others more precise which, however, verify the substantial accuracy of his work within the limits to which it could pretend. Some of his conclusions, such as the probable variability of most stars, and parts of his cosmogony must probably be modified or abandoned, but such is the law of progress and despite such change the Uranometria Argentina will long remain a landmark in the astronomy of the nineteenth century.

But we have overrun the course of events. Slowly, and under the stress of obstacles that sometimes looked like opposition, an observatory was built in the outskirts of Cordoba. Long delayed instruments arrived, were mounted into place and, two years after Gould's arrival in South America, a beginning was made upon the chief purpose of his expedition, the zone observations. Just as topography may be rapidly sketched upon a map after a sufficient number of well-defined reference points have been accurately plotted upon it, so in the sky when fundamental reference stars are available the zone observations furnish a facile method of interpolating among them *ad libitum* the hitherto unknown positions of other stars. But Gould found himself in the position of the geographer whose reference points are few and ill determined. The southern sky in that day was nearly void of material suited to this purpose and he must therefore determine for himself the positions of his fundamental stars while in the act of using them for reference. Thus there came about a great extension of the work originally planned and its division into three fairly distinct categories: (1) The accurate determination of the positions of a large number of fundamental stars, a program in which his own observations were to be largely supplemented by a collation and discussion of all available material that could be found in the work of others; (2) the zone observations, these were first reduced with provisional positions of the fundamental stars and afterward laboriously computed a second time when better data had been obtained for the reference points; (3) the construction of a Durchmusterung for the southern heavens, i. e., a second zone catalogue less accurate but more extensive than the first in which there should be found a complete muster roll of every star in the southern sky brighter than a given limit. The observations required for this program extended over many years and in making them, although ably assisted by his colleagues, Gould himself took a major part, involving more than a million independent judgments made with his eye at the telescope. The reduction and publication of this work required an even longer period than its observation, but the printer's "copy" for 15 bi-lingual volumes, Spanish-English, of Resultados was completed under Gould's own care and the volumes passed through the press, although the last of them barely reached his eye before it closed in death. These volumes must remain as Gould's chief monument. They worthily continue and complete the brilliant introduction furnished by the Uranometria Argentina and it is difficult to foresee an epoch in which they will cease to be the chief foundation upon which is built a knowledge of stellar motions in the southern heavens.

The execution of such a program brought with it through sheer lapse of time a change of personal relations to environment. The astronomical expedition, conceived as a scientific raid for the exploitation of a vacant field, became transformed almost into a missionary enterprise for transplanting and permanently establishing northern science in a southern field ready and eager to receive it. The camp became a residence with permanent quarters for the staff and a home for the director's family. The hearty cooperation of Mrs. Gould brought within the cultured influence of this home not only the observatory staff and their immediate neighbors but much of what was best in the social and official life of Argentina. Personal friendships here established paved the way not only to public support of the observatory but to a rapidly developing circle of relations in which Gould became an unofficial adviser and guide to the development of physical science in Argentina, a relation which flourished over a dozen years and more, up to the time when, with completed program, he returned to his native land.

In one respect Cordoba proved a sore disappointment. Its sky, while sometimes marvelously clear, revealing to the unaided eye stars of unprecedented faintness, was, upon the whole, no more free from clouds than that of Boston. In 1870 the data by which this condition might have been foretold did not exist. South American climatology was still in the embryo and one of the first extensions given to Gould's scientific program was the creation of a weather bureau and meteorological service for the Argentine. The Government, responding cordially to his advances in the matter, entrusted to him the establishment and development of such a service. Starting under conditions the reverse of favorable, with a competent personnel almost wholly lacking and with conditions of transportation so crude that the shipment of even a thermometer to a remote station was a hazardous undertaking, there was built up by slow degrees a modern meteorological bureau. Up to the time of his final departure from South America Gould retained active charge of this service, trained his own successor, one of his young American aids, and transmitted to his able hands not only an efficient bureau but a well-developed climatology for America south of the equator.

Almost immediately after his arrival in Argentina Gould was appointed by its Government to verify the standards of weight and measure actually in use throughout the Republic and to this duty there was added a large amount of work in determining the geographical positions of State capitals and in connecting by direct exchange of time signals the trans-Atlantic longitudes of the east and west coasts of South America. With a keen interest in the use and extension of the metric system Gould served Argentina as its representative on the International Commission for Weights and Measures and in similar matters made his influence felt in humbler bodies such as science clubs and organizations of engineers and surveyors.

It was perhaps with foresight of these other similar opportunities and demands that, just before leaving home, Gould, at the mature age of 46, allied himself with the order of Freemasons, a body with which he maintained active connection during the remainder of his life. At Cordoba he served as worshipful master of the Lodge of the Southern Cross and during the last decade of his residence abroad he acted as an official intermediary between the Freemasonry of North and South America. These relations must have rendered substantial aid to his South American career for, serving the Argentine Government under four different administrations, Gould maintained excellent relations with all of them and found in all a generous measure of support for his scientific work that seems to have been realized with increasing difficulty by his successors. He testifies to the cordial support given him by the Argentine Government at a time of war at home and abroad, and to the uniform sympathy and courtesy of a people strange to his modes of life and thought. While the extent to which these relations were aided by his Freemasonry must remain a matter of conjecture, that they were not its sole end and purpose is shown by his subsequent career at home where an admiring commentator notes with marked approval that "he served his lodge from its humblest office to the highest." He received with much pleasure his complimentary election to the thirty-third degree of the Scottish Rite, became deputy grand master of the grand lodge of Massachusetts, and declined to become a candidate for the office of grand master of the same lodge only because he felt himself ill adapted to the office. This lack of adaptation was doubtless because public speech was a burden to him and was undertaken only under compulsion. As a lad he had not been permitted to "speak his piece" at the college commencement "for lack of rhetorical ability," and his masonic brother notes with perhaps a touch of glee, as one who had caught great Jove nodding, "his rare and diffident attempts to speak in lodge * * * anything less oratorical can not well be imagined."

Gould's relation to his assistants and his feeling for them is illustrated in the following condensed excerpts from an unpublished letter of February, 1884, which also brings into relief his own strong convictions of immortality: "A flash of lightning took from us one of the finest and noblest young men I ever knew, Chalmers W. Stevens, one of my mainstays whom I loved as a younger brother or son, and whose devotion to the work has been intense. I had promised him six months leave of absence and in May he was to start. Yesterday we buried him in the Protestant Cemetery lately opened here. The concourse was very large for he was a universal favorite. And tears flowed very freely. To-day I have had the terrible duty of writing to his old father in New Hampshire that the son he was so proud of is not coming. It would not in the least surprise me were they to meet in the other world before they could have met in this."

The spirit here shown may be regarded as an exceptional manifestation called forth by a tragic event. But even in the more ordinary routine of life at Cordoba Gould's relation to his immediate environment, the observatory staff, contained much that was cordial and stimulating albeit mixed with metal of a different quality. Diverse though not irreconcilable impressions of the man and master find expression after the lapse of many years in the words of two of his assistants. To one of these "He was a difficult master to serve; his methods were often indirect. He did not develop a loyal feeling among us, while I was there, rather the reverse," and there are suggestions of sarcasm as a lash in frequent use. Quite different are the words of another: "I believe that Dr. Gould accomplished systematically and intelligently all that was possible under the circumstances. He was very hard working and painstaking, methodical in the care of books, papers, records, and generally inspired his assistants with an excellent disposition to do everything possible."

Black sheep there were among his assistants who plundered or sought to plunder from their colleagues both prestige and pelf. But happily these were of alien race and every American assistant proved loyal to his trust. They frequented the director's home and shared its sunshine and its showers. In sorrow they sympathized in the bitter bereavement that came to that home in 1874 through the drowning of the two older Gould children, girls not yet in their teens. While on a birthday outing one of the girls, playfully venturing into the river, Rio Primero, not far from their home, was caught and swept away by its swollen torrent. The sister and the nurse, hastening to her aid, were similarly engulfed and the disaster was complete even before word of it could be brought to the near-by parents. Three children, Alice Bache, Benjamin Apthorp, and Mary Quincy, survived this terrible disaster and all were still living in 1921. But the solace they brought to Gould's later years could never completely efface the shock given to the parents by the tragic death of the older girls. Under its depressing effect Gould returned to Boston late in 1874 for a brief vacation in which to recuperate his forces. He was received with open arms by his old friends and townsmen and at a public banquet given in his honor he made an address in explanation of his work and purpose in South America, from which some parts of the present memoir have been taken.

He returned to the Argentine with the shadow still heavy upon him and with an ever-growing burden. Nearly 10 years later, following Stevens' tragic death, he writes to a former colleague in the Sanitary Commission: "It will be harder than ever for me to keep on now in the dreary separation from my children and home. But there are two grand fellows left me. I am sure they will stand by and I mean to stick to my colors while strength permits. That the need of help is sorer than ever you will well understand." A great loss that had newly come into his life finds reflection rather than expression in these words. During a vacation home in 1883, Mrs. Gould passed away and on his return to Argentina his children were left in New England for training under the influences that had nurtured him. The increasing loneliness of these years was in some measure relieved by the very extensive correspondence which he maintained with a wide circle of friends and fellow scientific workers in the Northern Hemisphere. The collection and publication of this correspondence, if feasible, would be an admirable contribution to the history of astronomy in the nineteenth century.

But as the hours grew darker the end of his exile was near at hand and in 1885 he severed his official relations with Cordoba and turned homeward, a broken man with shattered nerves, but with interest in life unshaken and with the power and will to work still strong within him. Not all that he had planned to do under the southern sky was complete but the omissions were few and inconsiderable. His major work, relating to star positions, was finished even to the printer's "copy." Some proposed investigations involving stellar spectra had perforce been crowded out of his program, but in the midst of his official duties and despite their pressure he had found time to begin his proposed private work in astronomical photography; its completion was reserved for future leisure.

The work done upon the Rutherford photographs, in the late sixties, led Gould to borrow the lens that had produced these plates and to take it with him to South America for similar work upon the southern sky. But the pressure of duties incident to his early residence in Cordoba left no leisure for collateral work and the photographic apparatus long rested undisturbed in its packing box. When finally opened the lens was found broken across the middle with no clue to suggest how or when the accident had occurred. Prolonged and partially successful attempts at its repair were finally abandoned and a new lens ordered. But much time had been lost, and even after the new lens had tardily arrived and was put to work Gould's feelings were outraged by the treachery of an assistant, privately employed by him for the photographic work. Nevertheless, by 1885 some 1,400 photographs of southern star clusters had been obtained with the new lens, and the plates were brought back with him for measurement and study. This work, extending over the remaining decade of Gould's life, was, by the care of friends, published after his death, in the noble quarto volume that bears the title "Photographic Observations of Star Clusters from Impressions Made at the Argentine National Observatory. Measured and Computed with Aid from the Argentine Government, by Benjamin Apthorp Gould, 1897." The work is devoted to an accurate determination of the positions of stars in certain regions of the sky where they are crowded together in unusual degree. It lays the foundation for problems of stellar motion that are still far from solution, and as such foundation it is worthy to stand as its author's last contribution to astronomical science. At a much later date, all of these Argentine photographs were sent for further discussion to Prof. E. C. Pickering.

It is perhaps a misnomer to call the Cordoba photographs Gould's last work unless there be bracketed with such statement mention of a very different phase of his activity subsequent to 1885. Carrying out a long-cherished purpose, in 1886 he resuscitated the Astronomical Journal and announced in the preamble to its seventh volume: "The publication of the Astronomical Journal was discontinued in 1861, with great reluctance, yet with undoubting hope that the suspension would be not only temporary but brief. In August, 1869, the arrangements for its reestablishment had been fully matured when they were interrupted by circumstances known to astronomers. The delays thus occasioned have been unexpectedly long, but after the lapse of 25 years all impediments seem to be at last removed, and no reason is apparent why the resumption may not now be regarded as permanent." It must have been with a feeling of profound satisfaction that Gould penned these lines and his faith has been justified by the event. Under his editorial care, supplemented by that of his long-time pupil, friend, and colleague, S. C. Chandler, the Journal flourished for a decade, and to the present day his successors have conducted it in his spirit for "the advancement rather than the diffusion of astronomical knowledge."

Again taking up his residence in Cambridge, Gould found himself in the succeeding decade a prominent citizen of the larger community, Boston, and a public character in its civic and social life. His return was celebrated by a public dinner in his honor in which Boston's best participated by speech as well as by presence and at which the venerable Oliver Wendell Holmes recited a poem, written for the occasion, whose opening lines, despite their lurking humor, seem fairly to represent the prevailing temper:

Once more Orion and the sisters Seven
  Look on thee from the skies that hailed thy birth.
How shall we welcome thee whose home was Heaven
  From thy celestial wanderings, back to earth?

The scientific staff of the United States Coast Survey sought to have Gould placed at the head of that organization, but in vain. His remaining years were to be spent in the home of his youth, and there, supplementing his extended scientific and professional relations, he speedily became interested and active in many local organizations that collectively must have imposed large demands upon his time, e. g., in addition to his active participation in Masonry, already noted, he became an organizer and first president of the Colonial Society of Massachussetts, president of the American Metrological Society, vice president of the Bunker Hill Monument Association, vice president of the Massachusetts Society of Cincinnati, an active member of the American Antiquarian Society, etc. It was during this later period of his life that Gould gave considerable attention to the pseudoscience of astrology. This activity, however, seems to have found small public expression and connotes, presumably, nothing more than pure curiosity concerning a phase of human interest in the sky that never outgrew the chaos of primitive ideas.

In the summer of 1896 he met with a slight accident in the streets of Boston, whose effects, while not in themselves serious, persisted in the partial incapacity of one foot. He treated the matter lightly but on November 26, 1896, as he left his room to go and join in the festivities of a Thanksgiving dinner at the home of his youngest daughter, the foot failed him, he fell down a flight of stairs and received a shock from which he never rallied. Death ensued within a few hours.

Quite naturally his departure was the occasion for many a tribute to his life and work and the widely varied character of these tributes testifies to his many-sidedness. From his local associates in organizations of the type noted above, I select a few that are typical of many: "His erudition upon the subject of the early settlers of this community was a source of surprise to those who knew him only as a scientific man." "He was a delightful companion, being endowed with conversational gifts of a rare quality." "He was ever ready with fitting anecdote, apt quotation, or witty rejoinder." He was one "ever ready to enliven his talk with a merry jest but whose profound religious convictions could not fail to impress themselves upon all whom he met." "He was fond of poetry and when in the mood would often cap a sentiment with a quotation." Others comment upon his remarkable memory, retentive to an extraordinary degree, of many things other than history and poetry. Perhaps none of these tributes more aptly illustrates the social side of his character than do his own words to a local organization, that so long as he was its president "a good dinner and good wine should never be wanting as an adjunct to" its meetings.

To his professional work and scientific achievements tribute is paid in numerous journals and through the transactions of academies and learned societies that had, in life, enrolled him in their membership, *honoris causa.* The complete list of these and other like honors is too long for reproduction here but typical among them are:

The Royal Society, London;
The Royal Astronomical Society, London;
Académie des Sciences, Institut de France.
Bureau des Longitudes, Paris;
K. Akademie der Wissenschaften, Berlin;
K. Akademie der Wissenschaften, Wien;
K. Gessellschaft der Wissenschaften, Goettingen;
Académie Impériale des Sciences, St. Petersburg; etc.,

to which should be added the order Pour le Merite, Prussia, an honor rarely bestowed upon a foreigner.

While such expressions of affectionate esteem are pertinent to a judgement of the whole man, it is the purpose of this memoir in chief part to set forth and insist upon the more serious and sterner parts of his character. To present him as a man of clear intelligence and strong will, *vir tenax propositi,* whose life was given whole-heartedly to one purpose early defined and never abandoned, the upbuilding of science in his native land. With such an outlook upon life, there is inevitably associated a firmness of conviction regarding matters small as well as great, that may be courteous but must be inflexible. There goes with it, also, a certain insistent demand for recognition of personal achievement that sometimes prompted Gould to lay a heavy hand upon the presumptuous or careless wight who ventured to attribute to another the product of his own mind and pen. Varying phases are these, of one primal impulse, a sense of duty, a categorical imperative, that ruled his life.

To the record of this career there must be appended one further item. Through the subsequent action of a daughter, Miss Alice Bache Gould, there was created and vested in the National Academy of Sciences a trust fund of $20,000 to be known as the Benjamin Apthorp Gould fund, the income from which is devoted, in perpetuity, to aid research in those branches of astronomical science to which the father's career was related. His works do follow him.

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The following bibliography is for convenience divided into four sections, viz:

A. Major works, for the most part independently printed.

B. Minor articles, usually contributed to periodical literature.

C. Notices of new books.

D. Obituary notices of astronomers.

The titles under the last two categories, C, D, for the most part relate to articles contributed to the Astronomical Journal by Gould as its editor. For dates subsequent to 1890 they are commonly unsigned, and in view of S. C. Chandler's activity in aiding Gould, some doubt may be entertained as to the real authorship of the later titles.

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EIGHTH MEMOIR.

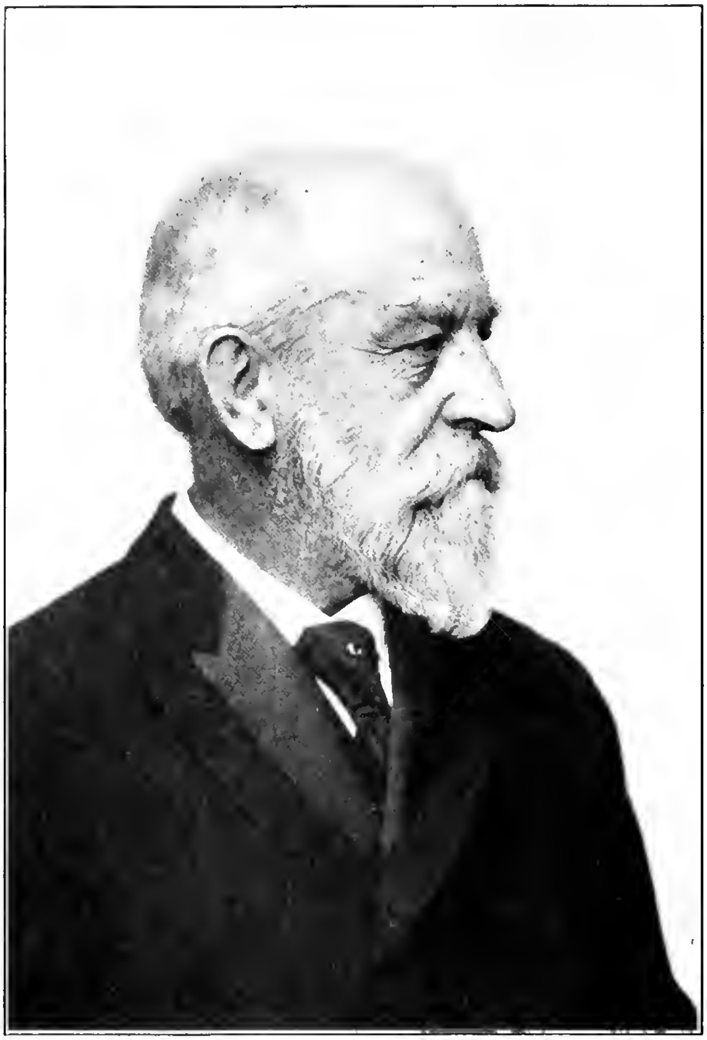
BIOGRAPHICAL MEMOIR HENRY PICKERING BOWDITCH

1840-1911.

BY

W. B. CANNON.

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1922.



H. P. Bowditch

HENRY PICKERING BOWDITCH.

By W. B. Cannon.

Henry Pickering Bowditch was born in Boston April 4, 1840. Scientific interest and ability were manifest in both the maternal and paternal family lines. Through his mother, Lucy Orne Nichols, a woman of rare fortitude and unselfish devotion, he was related to John Pickering (a son of Col. Timothy Pickering, Washington's Secretary of State), who was a student of and an authority on Indian language. On the maternal side, also, he was related to the well-known astronomers, Edward and William Pickering, and to the mathematician, Benjamin Mills Pierce. His paternal grandfather, Nathaniel Bowditch, was a well-known mathematician who at one time followed the sea—self-educated, accurate and careful, author of "The American Practical Navigator," and translator of La Place's "Mechanique Céleste." The father, Jonathan Ingersoll Bowditch, was a Boston merchant, a man with a scientific turn of mind, who continued to edit the Practical Navigator, and who on the basis of his father's work published a set of useful nautical tables. He was interested in meteorology, and if occasion had been favorable would probably have devoted his life to scientific pursuits. He is said to have brought up his children, of whom he had five besides Henry, in a strict and uncompromising discipline.

BOYHOOD AND EARLY EDUCATION.

Life in Boston in the middle of the nineteenth century had more of the characteristics of a small town than of a city. The common was a playground for the boys, and Henry Bowditch skated on the Frog Pond in winter, "cut" behind sleighs, played "I spy," and engaged in the sports that a vigorous normal lad would naturally enjoy. When he was 13 years old the family moved to an estate in West Roxbury, situated on a hill from which there were beautiful and extensive views of Boston and the surrounding territory. Then the region was in the country, and riding and tramping were the common activities. Jamaica Pond was near and enabled the boy to become a good swimmer and diver. He and a young friend built a rowboat and he became an adept at managing it. His resourcefulness at that time is indicated by his success, when he had been blown offshore without oars, in getting to land by using the rudder as a paddle.

After his primary education he entered the school managed by Mr. Epes S. Dixwell, where he was prepared for college. The five other members of his class were Oliver Wendell Holmes, jr., Charles Greenough, Thomas B. Wales, Samuel F. Emmons, and Franklin Weld. He entered Harvard College in 1857.

About the time of his entering college he was enough interested in anatomy to clean the bones of one of his father's horses which had died, and later to set up the complete skeleton, properly articulated. His medical career, however, was not decided on till late in his college life, or after graduation—a delay in determining his future which was very disturbing to his father. After graduation, in 1861, he entered the Lawrence Scientific School in Cambridge and started studying chemistry and natural history. The call to arms became too strong to resist, however, and he gave up his studies for service in the war.

EXPERIENCE IN THE WAR, 1861–1865.

In November, 1861, he joined the First Massachusetts Cavalry (Company G, Second Battalion) as second lieutenant. On January 13, 1862, the regiment sailed from New York for Port Royal. On June 28 Bowditch was commissioned first lieutenant and saw active service in the Battle of Secessionville. At the Battle of Fredericksburg, December 13, his regiment was part of the reserve. He participated in General Stoneman's raid in April, 1863, and on May 13 was commissioned captain, Company E. Thereafter he was in the battles of Stevensburg, Aldie, Upperville, Culpeper, Rapidan, and Bristoe. His regiment was on important guard duties at Gettysburg. During the engagement at New Hope Church, November 27, 1863, he was shot in the right forearm while leading a charge. A furlough during his convalescence from this wound permitted him to return to Boston. On February 15, 1864, he was honorably discharged from the Army, but promptly reentered it as major in the Fifth Massachusetts Cavalry (colored). He took part in some of the earliest movements against Petersburg and entered Richmond with Weitzel on April 3, 1865.

Maj. Henry L. Higginson has described Henry Bowditch as he appeared during the war—"a handsome, refined, and homebred looking youth, with a fondness and faculty for keeping face clean and clothing neat when those attributes were a rarity * * * an upright and fine officer, often reserved and even unbending in his manner, but unflagging in his faithfulness and unflinching in his courage." In a conversation with Maj. Higginson, after the Battle of Antietam, Bowditch confessed that he had no liking for Army life, and that he longed for the time when he could devote himself to scientific studies.

MEDICAL EDUCATION.

On June 3, 1865, he resigned his command. He reentered the Lawrence Scientific School and resumed his study of comparative anatomy under Prof. Jeffries Wyman. In later years he frequently referred to Wyman's stimulating influence on his scientific development. Continuing his interests and labors at the scientific school between terms, he finished the requirements of the Harvard Medical School. As his graduating thesis, he presented a review of observations on the physiological action of potassium bromide, some of them personal. This thesis was published at the request of Prof. E. H. Clark as a "valuable addition to our knowledge." In 1886 Bowditch received the A. M. degree, and in 1868 the M. D. degree from the University.

PHYSIOLOGICAL STUDY IN PARIS.

In the late summer of 1868 he went to Paris to study. In a letter of February 12, 1869, he wrote, "I wish I could see a real good opening for a purely scientific career. Dr. Wyman and Dr. Holmes (Oliver Wendell Holmes) both advised me to study science and let practice go, but pure science in our country is rather hard to live on." At the beginning he appears to have had the idea that he might combine scientific interests and medical practice. A notebook kept during the first months in Paris has repeated references to clinics and to the great clinicians, Charcot, Broca, and Louis. He had planned, however, to work with Brown-Séquard, who had lived in Boston and Cambridge and was well known to Wyman. Brown-Séquard was encouraging, but failed to provide a place for Bowditch to work in. He therefore turned to Claude Bernard and to Ranvier, spending three days a week in physiology and the other three in microscopy. His letters home mentioned with enthusiasm the interest he found in his scientific work and the pleasures of his association with Ranvier. John Collins Warren, William James, and Charles Emerson were also in Paris at this time and together with Ranvier and other acquaintances they formed frog-hunting parties which were the source of much amusement and the occasion for establishing close friendships. After five months he wrote, "I have been devoting myself lately almost entirely to the purely scientific part of my profession, which centainly has much greater attraction for me than the more practical portion." This tendency seems to have been closely watched at home, for on March 1 his father sent him a letter urging him to follow his desires for a career in science. On March 18 the son, after expressing his gratitude, continued: "My only hesitation arose from the feeling that in following pure science I should probably not be able to support myself so soon as in taking a more practical branch. But now, being reassured in this point, I shall push on and aim at getting as thorough a physiological education as possible * * *. Dr. Wyman's letter, which I received a few weeks ago, contained very strong advice for me to study pure science. He seemed to think that something was certain to turn up." In the light of later events a few lines from a letter to his mother at this period are interesting: "I have been feeling very happy at the prospect of devoting my whole time to scientific pursuits. I have been building all sorts of laboratories and medical schools in the air. In this labor I have been materially assisted by Coll. Warren (John Collins Warren), who is quite convinced that something ought to be done to raise the standard of scientific education in our community. I mean, of course, particularly medical science."

In March, 1869, he met the German physiologist, Kuhne, who, on request, laid out a career of physiological study, including a few months with Max Schultze, a year with Carl Ludwig in Leipzig, some time with Virchow in Berlin, and a final period with Helmholtz. The plan was an attractive one and Bowditch decided at once to undertake at least the first part of it.

PHYSIOLOGICAL STUDY IN LEIPZIG—MARRIAGE.

On May 9, 1869, he arrived at Bonn and there remained until midsummer studying microscopic anatomy under Schultze and Rindfleisch. In September he settled at Leipzig and at once entered into the activities of the physiological laboratory of Prof. Carl Ludwig. It was without doubt the most stimulating and interesting center of biological research in the world at that time. Ludwig himself was an ingenious and fertile investigator in a wide range of problems, and had a most attractive personality. Men drawn to him at first by his discoveries were held by the beauty and force of his character and became loyal friends and followers. Students gathered about him from all parts of the world. There Bowditch met Lauder Brunton of Scotland, Ray Lankester of England, Mosso of Italy, Kronecker of Germany, Ustimowitsch of Russia—all of whom became close friends. A club made up of this group dined together daily and talked over their laboratory experiences and other matters of interest. Ludwig was a constant delight to them. He had recently invented the kymograph for the registration of records of physiological processes on a moving surface. The time and the period of electrical stimulation were marked on the surface by hand. Young Bowditch invented a means of doing this automatically. In a letter written on November 7, 1869, he told of this event. "Prof. Ludwig is a very amiable and agreeable man. He must be between fifty and sixty years old, but he retains his youthful enthusiasm and a remarkable faculty of finding pleasure and amusement in trifling matters. I arranged a little apparatus yesterday attached to a metronome for the purpose of marking time on a revolving cylinder covered with smoked paper (an instrument much used in various physiological experiments), and it was real fun to see how delighted the professor was with it."

In May, 1869, Charles W. Eliot was elected president of Harvard University. In December he proposed that Bowditch return to the United States and deliver a course of university lectures on physiology during the second term of 1870-71. This Bowditch declined to do, because it would require him to give up the last and most valuable six months of his proposed period of study in Germany. A letter from his uncle, Henry I. Bowditch, a few weeks later strongly urged him not to be "wheedled into coming home"—a supporting opinion which he much appreciated.

With the exception of time spent with members of his family on trips to Italy in March and April and to England in July, Bowditch continued at work in the Leipzig Laboratory, finding "the exhaustive way in which questions are treated by the German investigators" "very satisfactory" and contrasting "very strongly with the French method." In November, 1870, he went to Munich for a month to listen to a course of lectures by Prof. Carl Voit on nutrition and metabolism —"very interesting and important," as he wrote. On returning to Leipzig he began purchasing apparatus for use in his own laboratory when he should be established in Boston or Cambridge again.

In April, 1871, President Eliot offered him the position of assistant professor of physiology at the Harvard Medical School and invited him on his return home "to take part in the good work of reforming medical education." His uncle had warned him to be cautious about accepting a subordinate position and to insist on his "rights." But young Bowditch accepted without conditions, explaining, "on general principle I think it is best to take it for granted that people are going to do the right thing."

In August he put together in an "essay" the results of the year's investigation and handed it to Prof. Ludwig, "who seemed quite well pleased with it." A few days later he left Leipzig, Ludwig accompanying him to the station, seeing him into the cars, and kissing him "very affectionately" on taking leave of him. Thus ended an experience which had a profound effect on Bowditch's scientific interests, and which did much to impress on him and his American students the methods and standards of the Leipzig school.

From Leipzig Bowditch went to Oberammergau to witness the Passion Play. He was accompanied by his Russian colleague, Ustimowitsch, and by Miss Selma Knauth and her mother, Leipzig friends whom he had known for many months and at whose house he and other American students had received a delightful hospitality. He intended to proceed from Oberammergau to Munich "and from there straight to Paris," but on August 16, at Munich, he became engaged to Miss Knauth and his plans were changed. On September 9, at Leipzig, with Ustimowitsch as groomsman, he was married, and on September 14 he and his wife sailed from Liverpool for the United States.

So many and so varied were Dr. Bowditch's activities during the years of his service in Boston that it will be impossible to give a clear chronological account of them. Instead, the various aspects of his labors will be dealt with separately.

SERVICES TO PHYSIOLOGY.

On his return to Boston there was no physiological laboratory for Bowditch to work in. The rooms in the old Medical School Building on North Grove Street were crowded. Two small rooms in the attic were made over, however, and in them was placed the apparatus which had been brought back from Germany. This was the first physiological laboratory for the use of students in the United States.

These rooms might perhaps be better designated the first laboratory for experimental medicine established in this country, for every phase of experimental medical work was represented there within a few years after its establishment. Charles S. Minot carried on investigations in general biology, J. Ott and R. W. Lovett in experimental pharmacology, J. C. Warren in experimental pathology, G. Stanley Hall and W. F. Southard in experimental psychology, O. K. Newall in experimental surgery, and W. P. Lombard, J. J. Putnam (assisted by William James), C. S. Minot, G. M. Garland, C. H. Williams, J. W. Warren, F. H. Hooper, and F. W. Ellis in physiological researches. The hospitality of the laboratory was unbounded; indeed, some of the first careful work on bacterial cultures in this country was done there by H. C. Ernst. With Dr. Bowditch's enthusiasm and inspiration almost every scientific interest of a complete modern medical school was stimulated. From the start the emphasis was on productive scholarship. In the preface to the first collection of papers published from the laboratory the announcement was made that the contributions were presented in a volume, "not from any exaggerated idea of their value and importance, but with the hope that by calling attention to the facilities offered in the laboratory for original research a greater number of workers may be encouraged to attempt the investigation of the many physiological problems now pressing for a solution."

The Leipzig Laboratory was characterized by the simultaneous pursuit of a variety of problems. It was characterized also by the attempt to explain physiological facts in physical terms and by the use of physical methods. Thus Dr. Bowditch had come to know "the many physiological problems" and had learned ways of attacking them. The employment of physical apparatus gave play to his inventive faculties. As already noted, one of the first things he did at Leipzig was the contriving of records of time and stimulation periods on the kymograph to accompany the physiological tracing—a device said to have first directed Ludwig's attention to the young American's abilities. The invention of the "Bowditch clock" to mark various periods time was another product of his Leipzig experience. In the Harvard Laboratory a new form of induction apparatus, with the secondary coil turning at various angles to the primary, and permitting in brief compass variation of intensity of the induced current, a new form of plethysmograph to register changes in the volume of organs, a new apparatus for artificial respiration, a novel animal holder, a cannula for observing the vocal cords, and a special arrangement of unpolarizable electrodes were evidences of his ingenuity. Apparatus, however was always a means to an end and never became a central interest for him.

Two papers were published on the basis of work done under Ludwig's direction. The first, on peculiarities of the irritability of cardiac muscle, has become a classic in physiological literature. In this contribution are pointed out two fundamental characteristics—the "Treppe," or step-like increase of contraction, in response to a repetition of uniform stimuli, which is accounted for by the effect of activity itself in causing greater responsiveness in the tissue; and the "all-or-none law," i. e., the contraction of cardiac muscle to a maximal extent, at the moment, independently of the strength of stimulation, or no contraction whatever. The former observation has been proved to be generally true of irritable structures and is at the basis of "warming up" for action; the latter has been extended in recent years to the contraction of the fibers of skeletal muscle and to the passage of impulses along nerve trunks. The second paper was concerned with the interference between accelerator and inhibitor nerves on the heart as influenced by variations of arterial blood pressure.

Interest in the physiology of cardiac muscle was continued in the laboratory at the Harvard Medical School, and resulted in a demonstration of the incapacity of the apex of the frog's ventricle to show a spontaneous rhythm after being isolated from the base, though normally nourished and though remaining irritable to external stimuli.

Wyman had called attention to the ability of ciliated epithelium to exert a force by no means inconsiderable. This observation Bowditch made the subject of an investigation and by having the ciliated cells move weights up an inclined surface he calculated that in a minute they did an amount of work equal to lifting their own weight 4.25 meters. When he demonstrated this effect in Leipzig at one of his visits to Ludwig it aroused much interest among the group of investigators there.

Another line of interest developed in the Harvard Laboratory was concerned with the nervous control of blood vessels. As early as 1874, Bowditch and Minot published a paper showing that chloroform has a much more profound effect than ether in depressing vasomotor reflexes. Later Bowditch and Warren undertook an extensive investigation of the influence of different rates and strengths of peripheral stimulation on the contraction and relaxation of blood vessels. This study, which has received much attention, showed that by varying the nature of the stimuli it was possible to produce constriction, or constriction followed by dilation, or dilation alone—rapid stimulation favoring constriction and later dilation. This mode of separating vasoconstrictor and vasodilator effects was extended by means of experiments on degenerated nerves. It was found that whereas immediately after nerve section a given stimulus caused pure constriction, the same stimulus applied to a nerve which had been severed four days previously induced a pure dilation. These results have suggestive values which have not yet been fully appreciated. Similar reversals of effect were reported by Bowditch in relation to etherization. Thus the glottis may be constricted or dilated according to the degree of etherization and the strength of the stimulus applied to the recurrent laryngeal nerve. Likewise in the frog extension of the leg and abduction of the toes, as a result of exciting the sciatic, will give place, under ether, to flexation and abduction.

With Garland, Bowditch investigated the effect of the respiratory movements on the pulmonary circulation, and came to the conclusion that expansion of the lungs diminishes the size of the pulmonary vessels, and that collapse of the lungs has the opposite effect, the changes being more marked on the venous than on the arterial side.

The functioning of the nervous system was for a time a central interest in Bowditch's thinking. "What conception can one form of the physical or chemical changes which take place in those white glistening bands which are for us the only channels through which knowledge of the physical universe can be obtained and which also enable us to impress upon the world around us the evidence of our conscious personality?" Bernstein had concluded that a nerve fiber could be exhausted by tetanic stimulation for 5 to 15 minutes. Widenski, however, had not been able to demonstrate exhaustion during stimulation for several hours. Using curare as a temporary block to nerve impulses, Bowditch stimulated the peripheral end of the cut sciatic from one and a half to four hours and as the effect of the drug wore off saw the muscle respond. Thus new evidence was obtained of the indefatigability of the nerve trunk—a fundamental fact in the physiology of the nervous system.

Another research, on conditions modifying the knee jerk, conducted in cooperation with Warren, brought out important new facts regarding the interaction of influences in the nervous system. Voluntary contraction of another part of the body had been used by clinicians for some years as a means of reinforcing the patellar tendon reflex. In this research it was shown that not only voluntary effort but also afferent stimuli applied to different parts of the body could affect the degree of response, and furthermore that the reinforcement occurred only during a fraction of a second and was commonly followed by a period of depression, lasting a second or two, in which the jerk was diminished or abolished. Thus activity in one part of the nervous system may first exalt and then depress the activity in another part.

The foregoing review of Dr. Bowditch's contributions to physiology shows the variety of interests which he entertained and the suggestive character of the work which he performed. It was typical of his papers that they dealt very little with speculative features. This was not due to lack of imagination, for many of the reports of his work promised further pursuit of the subject, showing that he saw the interesting problems hinted at by the results that were obtained.

Aside from engaging in physiological research and stimulating young men to engage in it, Dr. Bowditch for years wrote for the *Boston Medical and Surgical Journal* semiannual reports on the progress of physiology. In these reports he summarized the results of a group of investigations on one or more broad topics, and commented upon them. It was a practice which served to keep his interests extended and to suggest to him new lines of study and research.

He was one of the principal founders of the American Physiological Society, in 1887, and succeeded S. Weir Mitchell in 1888 as its second president. He was reelected president during the years 1891–1895, and served for many years besides as a member of the council. The traditions of the society, particularly its character as an association to encourage research, are largely the result of his initiative. His attendance at its meetings was regular, and his example and his genuine appreciation of new work as it was reported were a wholesome stimulus to young men beginning physiological investigation.

In 1877, when Michael Foster started the English *Journal of Physiology*, Bowditch was consulted and agreed to serve as one of the American editors. Until 1898 the publications from the Harvard Laboratory appeared in that *Journal*. When the activities of American physiologists became sufficiently great to warrant the establishment of an American journal, Dr. Bowditch gave support and encouragement to the efforts of Dr. W. T. Porter, a member of his departmental staff, in establishing the *American Journal of Physiology*, and was on its first editorial board.

SERVICES TO PSYCHOLOGY.

For many years, and especially in his later life, Dr. Bowditch was interested in the physiology of the senses, an aspect of physiology which has since been taken over largely by the experimental psychologist. In 1881 he published, in cooperation with W. F. Southard, an investigation into the relative accuracy of our knowledge of position in space as obtained by sight and by touch. Evidence was adduced showing that direct vision gave the most accurate special knowledge, with touch second, when tested by the hand which had been experienced in locating the object. For details of this interesting paper, such as the influence of time, etc., the reader should consult the original.

With G. Stanley Hall, Dr. Bowditch made a study of certain illusions of motion, e. g., the influence on the observer of watching a revolving spiral, the "waterfall effect," the apparent rotation of concentric circles when subjected to a "rinsing" movement. These curious phenomena were tested by modifications of the figures and were given explanations. The attention to the physiology and psychology of vision, which this and the previous research initiated, persisted to the end of Dr. Bowditch's scientific career. When other activities consumed most of his time, he still kept abreast of the literature of this field.

With a small group of colleagues in Boston he took up psychical research and aided in founding and for several years in managing the American branch of the Society for Psychical Research. His open-mindedness was revealed in this action and was characteristic, but his experience finally rendered him extremely skeptical as to the reality of telepathy and other alleged psychical phenomena.

SERVICES TO ANTHROPOMETRY.

At a meeting of the Boston Society of Medical Sciences, September 24, 1872, Dr. Bowditch exhibited diagrams showing the rate of growth of a small number of boys and girls near the age of puberty that differed from Quetelet's Belgian figures, in that the average height of the girls was greater than that of the boys at about the thirteenth and fourteenth years, a relation that was thereafter reversed. Dr. Bowditch's suggestion that more extensive data, especially related to the influence of race and climatic conditions on growth, would be interesting was the occasion for a vote authorizing such a study in Boston school children (1875). This novel undertaking was regarded as basal for similar studies elsewhere, under different climatic circumstances, and with different foreign elements predominating in the school population. To only a small degree has the opening thus made been utilized in other communities. The main points brought out by Bowditch's pioneer work were (1) that until 11 or 12 years of age boys are taller and heavier than girls of the same age, then girls begin to grow rapidly and for two or three years surpass boys of the same age in both height and weight, whereupon boys begin to forge ahead of the girls who have nearly completed their full growth; (2) that children of American-born parents are taller and heavier than those of foreign-born (Irish) parents; (3) that children of American parentage in selected schools are superior in height and weight to corresponding children in the public schools; and (4) that these same children (in the selected schools) are superior to English boys in public schools and universities, particularly with regard to weight. Six important new lines of study were indicated at the end of the report (which was issued by the State board of health in 1877) in case similar examinations were made in other communities.

It was suggested that the difference between the growth of the native and the foreign born (point 2, above) might be due to more favorable living conditions in the former group or to differences of race and stock. To throw light on this problem the data were retabulated according to the occupation of the parents and the results published in a supplementary report in 1879. Although the classifying of occupations could not be accurate, the results justified the cautious conclusion that probably the mode of life, as a factor in determining the size of growing children in Boston, is at least equal to, and possibly even greater than, that of race.

In 1889 was published Galton's "Natural Inheritance," in which he elaborated his scheme of "percentile grades" as a means of displaying the results of statistical inquiry and facilitating a comparison between various sets of observations. In a paper on the "Physique of Women in Massachusetts" Dr. Bowditch, in 1890, called attention to the advantages of this scheme, and in 1891 he published a review of his data on the growth of school children, based on the application of Galton's method. One of the new points thus brought out was that the period of acceleration, which is so prominent a phenomenon in the growth of children, occurs at an earlier age in large than in small children. For other inferences and for the discussion the reader must consult the original paper. The conclusions, of course, were based on data from children measured at different ages and involved the assumption that large, small, and medium-sized children remained in those groups as the years passed. Dr. Bowditch recognized the possibility of error in this assumption and urged the importance of securing reliable observations made at frequent regular intervals on the same children during the period of adolescence. We should then be able, he declared, "to draw fairly accurate conclusions as to the normal range of variation in percentile rank during the period of growth and to determine how far the rate of growth in the earlier years of life is to be regarded as an indication of the size to be subsequently attained." This suggestion is now being realized and within a short time we should have normal standards of development derived from observations through a series of years on large groups of children.

Another hint offered by Galton that bore fruit in Bowditch's activities was the use of composite photographs as a method of recording typical or generic features. In a popular article published in 1894 he reproduced some of the results of his own studies. At the close of it he pointed out various interesting applications of the method which might be made even by the amateur photographer.

In 1881, before the section on children's diseases of the American Medical Association, Bowditch presented a communication calling attention to the loss of weight in growing children just antecedent to the onset of acute or chronic illness. He urged the importance of further studies to determine the relations between growth rate and disease, with the hope that the data thus accumulated might be useful in preventive medicine as applied to childhood.

A set of rules regarding the mode of collecting information at autopsies, which was prepared by Dr. Bowditch and Dr. F. A. Harris in 1882, was further evidence of his interest in anthropometry. In this field, as in physiology itself, his labors were varied and were most suggestive. In many respects the lines of work laid down by him have not been much extended since his pioneer work was done, and offer now as many valuable hints for further investigation as they did when he wrote.

SERVICES IN THE PROTECTION OF MEDICAL RESEARCH.

Beginning in 1896, when the antivivisectionists made a vigorous effort to obtain legislation restrictive of animal experimentation in Massachusetts, Dr. Bowditch became an ardent defender of freedom of research within the law. In association with H. C. Ernst and others he appeared repeatedly before legislative committees both in Boston and in Washington, giving reasons for opposing bills directed toward restricting the activities of medical investigators. In an important address before the Massachusetts Medical Society in 1896, he summarized these reasons as follows: "(1) That the men in charge of the institutions where vivisections are practiced in this State are no less humane than those who desire to supervise their actions, while they are, at the same time, vastly better informed with regard to the importance of animal experimentation and the amount of suffering which it involves; (2) that no abuse of the right to vivisect has been shown to exist in these institutions: (3) that the governing bodies of these institutions possess both the will and the power to put a stop to such abuses should they arise: (4) and that the existing statutes furnish sufficient protection against cruelty in vivisection as well as against cruelty in general." His hostility to *any* restrictive legislation some of his friends found difficulty in understanding. It was based on two considerations; first, as stated above, that the existing anticruelty laws are adequate to punish any experimenter who is wantonly cruel in the course of experimental procedures; and second, that the passage of restrictive legislation in England had not lessened but had increased the efforts of the antivivisectionists. In other words, the aim of these agitators is complete abolition of the use of animals for medical advance—a result which, as he sanely regarded it, would be disastrous to the welfare of both man and the lower animals themselves. In the legislative hearings on this subject his manifest honesty and singleness of purpose added weight to the evidence he brought forward and to the opinions he expressed. The struggle to preserve freedom of medical investigation in this country has been carried on along lines which he followed and by the open and frank methods which he employed.

SERVICES ON COMMISSIONS ON THE ALCOHOL PROBLEM AND SANITATION.

As early as 1872, Dr. Bowditch read before the Boston Society of Medical Sciences a discussion of alcohol as a nutritive agent. He there raised the question whether in morbid conditions, when in large amounts it does not induce narcotism, it may not have nutritive values which it does not offer to the healthy organism. This early interest in the pharmacological action of alcohol, as well as an interest in the social problems attending its use, he maintained for many years. In 1893 he and John Lowell and John Graham Brooks were appointed by the Governer of Massachusetts as a commission to investigate the Gothenburg and Norwegian systems of licensing the sale of intoxicating liquors. An extensive report of their examination of these systems was rendered in 1894.

Dr. Bowditch was a member of the Committee of Fifty to investigate the liquor problem and was on the subcommittee on the physiological and pathological aspects of the problem. With Dr. C. F. Hodge he made an extensive report, in 1903, on the statements given in textbooks and by eminent physiologists both in the United States and in Europe regarding the physiological action of alcohol.

In 1874, Bowditch served with C. W. Swan and E. S. Wood, on a commission appointed by the mayor of Boston to examine and report upon the comparative desirability, on sanitary grounds, of the rivers near Boston which might serve for additional water supply.

SERVICES TO MEDICAL EDUCATION.

Until 1865, instruction in physiology at the Harvard Medical School was given by Oliver Wendell Holmes, Parkman professor of anatomy and physiology. It consisted of remarks on function during anatomy lectures and of a relatively small number of lectures on physiology itself at the end of the course. From 1865 to 1870, Dr. Josiah S. Lombard aided in the physiological teaching, and during the year 1870-71, Dr. William T. Lusk, as lecturer in physiology, presented the subject and illustrated it with numerous experiments. This subordinate position of physiology in the medical curriculum was changed when Bowditch returned from European study in 1871. The Parkman professorship was restricted to anatomy, and though Bowditch had the title of assistant professor he had full charge of physiological instruction and at once instituted an admirable course of lectures and demonstrations. He continued in active service for 35 years. In 1876, he was appointed professor, and from 1903 until his resignation in 1906 occupied the newly established George Higginson professorship of physiology in the Harvard Medical School.

In the teaching of physiology Dr. Bowditch's instruction was marked by wide learning, clear discussion of controverted questions, cautious inference when convincing facts were not at hand, and by orderly exposition. His lectures were unusually well illustrated by methods which made lasting impressions. A notable contribution to educational procedure was the sending of students to the original sources for material for physiological theses which were read before the class. The conferences at which these theses were presented and the weekly quizzes which Dr. Bowditch conducted were delightfully informal and conversational. Although welcoming with open mind the introduction of the laboratory method of teaching physiology in the later years of his service as a professor, he warned against too great a reaction from purely didactic methods of instruction "lest useful as well as useless things be swept away," and declared that "a good teacher with a bad method is more effective than a bad teacher with a good method."

Looking back on 27 years of experience he was so impressed by the vast increase of knowledge of medical science and of diagnostic and therapeutic procedures that he urged, in 1898, as president of the American Society of Naturalists, certain reforms in medical education. Again in 1900, as president of the Congress of American Physicians and Surgeons, he returned to the problem presented by the immense mass of information which medical schools are attempting to crowd into students during the four-year course, and in an address on "The Medical School of the Future" ventured certain predictions. Because the future medical school must offer advanced instruction in all subjects, and because this will be more than any student can reasonably learn, an elective system will be adopted. This involves, as he had previously shown, drawing a distinction between essential subjects which every student should know, and desirable subjects which certain students should know, i. e., provision for required and for elective studies. Besides this feature of future medical instruction, greater emphasis on practical experience, concentration of attention on one principal subject at a time, with arrangements for natural sequence of these subjects, and such examinations as will test the student's permanent acquisition of usable medical knowledge, were emphasized as probable characteristics of the way in which the teaching of medicine will develop. Twenty-one years have passed since this address was given. During that time the pressure on the medical student has increased still further, so that the problem discussed by Dr. Bowditch has become more acute than ever, and medical teachers are laboring to seek the relief which he sought. To what degree his suggestions will prove to be wise is not yet clear.

SERVICES TO THE COMMUNITY, TO GENERAL SCIENTIFIC ORGANIZATIONS, AND TO THE UNIVERSITY.

In spite of his large interest in medical research and education, Dr. Bowditch maintained throughout his life useful relations with public affairs nonprofessional in character. From 1877 to 1881 he was a member of the Boston school committee. In 1886 he was president of the Massachusetts Infant Asylum. He was also president of the Boston Children's Aid Society and helped to broaden its scope and importance. Between 1895 and 1902, as a trustee of the Boston Public Library, he was active in favoring the dissemination of good literature. He served on the joint special committee on education and health of the American Social Science Association, the function of which was to consider public schools in their relation to public health.

In 1872 he was elected a fellow of the American Academy of Arts and Sciences. During the year 1877 he was its recording secretary, and from 1881 to 1883 a member of its council. For 22 years he served on the library committee. In his address as vice president of section F (biology) of the American Association for the Advancement of Science he summarized the evidence which he and others had obtained regarding the nature of the nerve impulse. To the affairs of the National Academy of Sciences, to which he was elected in 1887, he gave his time generously and helpfully. He was actively interested from the beginning in the promotion of the International Physiological Congresses which brought together every three years physiologists from all parts of the world. From its foundation in 1886 until 1906 he acted as trustee of the Elizabeth Thompson science fund and to him belongs much of the credit for its successful administration.

It will be recalled that when Bowditch was in Europe in 1870 President Eliot invited him to return to the University "to take part in the good work of reforming medical education." In the pioneer work of developing a graded course of instruction and in the other reforms which the new president struggled to institute he found Dr. Bowditch a staunch supporter. After the resignation, in 1883, of Dr. Calvin Ellis, who had been dean of the school during the years of its transformation into a true university department, Dr. Bowditch was appointed dean and served in that capacity for 10 years (until 1893). During that period important changes were introduced in the medical department. Bacteriology was recognized as a regular study, a novel venture under Bowditch's leadership. The four years' required course was adopted, another forward step which the Harvard Medical School was among the first to take. A further significant innovation was the calling of outstanding men from other universities to assume positions in the school—Dr. W. H. Howell came from Michigan to be associate professor of physiology and Dr. W. T. Councilman came from Johns Hopkins to be professor of pathology.

As already stated, young Bowditch wrote to his mother from Paris in 1869, when he first had the prospect of a purely scientific career, "I have been building all sorts of medical schools and laboratories in the air." He took a leading part in the planning of the new building started on Boylston Street in 1881, and his deanship coincided with the first 10 years of occupancy of that building. In 1899 and 1900 Dr. Bowditch initiated in the faculty the movement for the new buildings of the Harvard Medical School, and for securing the land for neighboring hospitals. During the next few years he cooperated with Dr. John Collins Warren, his friend of Paris days, in raising the funds needed to complete the great project. The group of splendid structures, which were completed in 1906, together with the hospitals now surrounding them, are a monument to the vision and faith and devoted efforts of these lifelong companions.

GENERAL CHARACTERISTICS, HONORS, LAST YEARS.

Everyone who came in close contact with Dr. Bowditch was impressed with his rare combination of sure and sober judgment, vigorous will, and readiness for action—qualities which made him a natural leader. His imagination was fertile with ingenious and effective ways to secure the accomplishment of worthy ends. He was eminently single-minded; the matter in hand was always the important matter to be attended to. Persons who knew him well for many years recall that he seldom spoke of the past, almost never of his experiences in the Civil War, and rarely of his earlier researches. The forward look to the fulfillment of plans already started was typical of him to the last.

The qualities of energetic leadership were tempered by unfailing courtesy, fairness, and good will. His conversation was not witty and lacked the light touch, but he had a keen sense of fun, and his hearty laugh was rewarding to the humorous fancies of his fellows. These lovable traits brought to him the friendship and lasting devotion of the foremost men of medical science, as well as of his students and his associates in his various interests. The Bowditch Club, an organization of active medical investigators in Boston, started during the late nineties and, continuing until after his death, was a tribute not only to his eminence in science but to his genial and wholesome spirit. Friendship was to him a blessing to be cultivated. He rejoiced in having his friends with him at his beautiful home near Jamaica Pond in Boston, and in his summer camp, or in going to be with them. Comrades of his Leipzig days visited him thus, as well as Sir Michael Foster, Prof. Mosso of Turin, Prof. Gaskell of Cambridge, England, and Prof. Waller of London; and he frequently renewed association with them in Europe.

His interest in the physiology of vision may have been related to the fact that he was himself red-green color blind. He had no appreciation for music and could not sing, nor play any musical instrument. It is said that he had little insight into any but the realistic qualities of pictorial art. He loved outdoor life. Skating, mountain climbing, and kite flying were among his diversions. He was skillful at the lathe and in glass blowing. His inventiveness and his manual skill were put to use frequently in the laboratory and also in the rough life of the Adirondack camp. The Bowditch chair, a remarkably comfortable piece of furniture, was the outcome of these abilities applied to side interests.

Numerous honors came to him in this country and abroad. Election to the National Academy of Sciences has been mentioned. He was also a member of the American Philosophical Society and of many other scientific bodies. The Royal Society of Medicine and Natural Science of Brussels and the Academy of Science of Rome enrolled him among their members. The University of Cambridge made him doctor of science in 1898; and Edinburgh (1898), Toronto (1903), Pennsylvania (1904), and Harvard (1906) gave him the degree of doctor of laws.

When the new buildings of the medical school were dedicated in 1906, the disease, paralysis agitans, which five years later proved fatal, had already made serious inroads on his health. Gradually his strength and his ability to take part in outside activities became more and more limited. Aware of the hopelessness of his condition, he surrendered with patience and fortitude to the confinement which was forced upon him. Almost to the last, however, he welcomed the visit of friends, and manifested a keen interest in the affairs with which he had been associated in his active years. On March 13, 1911, he quietly passed away.

Dr. Bowditch's traits and achievements bring into prominence the transmission of exceptional qualities through the generations. His grandfather was a man of unusual originality and force. His father's scientific interests were maintained along with a business career. A brother, Charles P. Bowditch, like the father, though engaging in business pursuits, was keenly alive to scientific matters and made important contributions to American archeology. Five daughters and two sons survive in the line of Henry P. Bowditch to carry on the family characteristics.

There is an intellectual inheritance which may be transmitted from person to person outside of family ties. The stimulating eagerness for research received from Ludwig his students carried far and wide. Bowditch brought the spirit to the United States. The manifold services demanded of him and regarded by him as duties, that have been referred to in the foregoing pages, encroached upon his time and prevented him from devoting himself, as he otherwise might have done, to physiological research. The conflict between scientific study and administrative activities seems to have disturbed him, for it is recorded that occasionally in the late years of his life he would ask a friend whether his life would not have been of greater service if he had devoted himself exclusively to experimental physiology. The question is a difficult one to answer. It is true, however, that he was not drawn away from research until he had transmitted to others the inspiration he had drawn from Ludwig and the Leipzig group. Thus in the line of intellectual inheritance he could claim, among his own direct successors, William James, James J. Putnam, G. Stanley Hall, Warren P. Lombard, Walter B. Cannon, Joseph W. Warren, and many others whom his enthusiasm and his imagination and his sterling honesty and love of truth had influenced.

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