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OF

OTHNIEL CHARLES MARSH

1831–1899

BY

CHARLES SCHUCHERT

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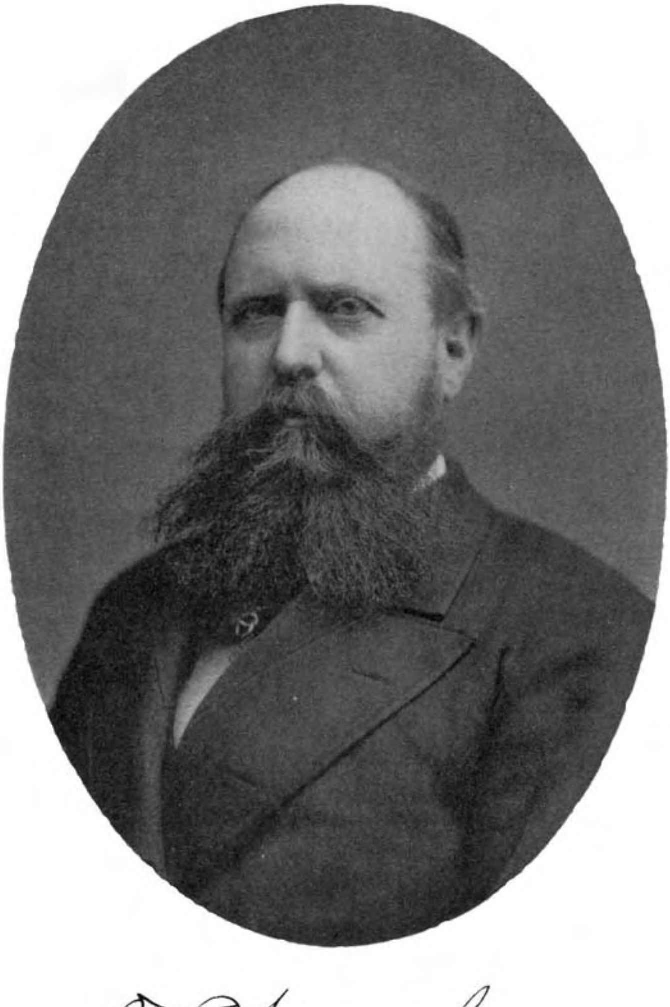
O C Marsh

OTHNIEL CHARLES MARSH[1]

1831–1899

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Othniel Charles Marsh, for twelve years president of the National Academy of Sciences, was born to Caleb Marsh and Mary Gaines Peabody on October 29, 1831, in Lockport, New York, and died in New Haven, Connecticut, on March 18, 1899. One of the three founders of the science of vertebrate paleontology in America, his career furnishes an outstanding example of the indomitable spirit that drives men on to a determined goal. His motto might well have been, "What I have, I hold." He asked no quarter, and gave none. At home around a camp fire or in an army tent, formal as a presiding officer or in society, at times austere and autocratic, at others a raconteur of note, he left a lasting impression on his chosen branch of science.

Summarizing his work statistically, it may be said that between 1861 and 1899 he published about 300 papers, reports, and books. Of new genera he described 225, and of new species, 496; of new families 64, of suborders 8, of orders 19, and of subclasses 1.

Of his work on vertebrate fossils in general, Osborn says that he "carried out the most intensive field exploration known to science and published a large number of preliminary papers, which fairly revolutionized our knowledge."

ANCESTRY AND TRAINING

John Marsh of Salem, the first of his name recorded as emigrating from England to America, is believed to have reached

[1] In the preparation of this memorial, the writer has been aided greatly by the excellent sketches of Professor Marsh written by George Bird Grinnell, Charles E. Beecher, and J. L. Wortman. Still further insight into his background and character was furnished by the many family letters preserved in the archives of the Peabody Museum at Yale University, and by the twenty-six bound volumes of Marsh correspondence. The memorial has also had the benefit of criticism by Professor Richard S. Lull, who was for many years in charge of the Marsh collections at Yale. It is the writer's hope soon to expand the memorial into a book on Professor Marsh.

the Massachusetts Bay colony in the year 1634. A cordwainer by trade, he was very fortunate in his marriage, taking to wife in 1635/36 Susanna, eldest daughter of the Rev. Samuel Skelton, the latter a graduate of Cambridge and the "spiritual father" of Governor Endicott, at whose solicitation he came to Salem in 1629 and there organized the first church of the Puritans. Zachary, the eldest of John and Susanna Marsh's eleven children, in turn left a family of nine, and it is this line that has most interest in the present connection, because John Marsh, of the sixth generation from Zachary, and his wife, Mary Brown, were the parents of Caleb Marsh, born in South Danvers (now Peabody) on November 8, 1800.

On his mother's side, Professor Marsh's ancestry can be carried back much further, the name Peabody (or Pabody) reputedly originating early in the Christian era. Lieut. Francis Peabody, the first of the American family, came to New England from Hertfordshire in 1635—a "husbandman," 21 years of age. He lived first in Ipswich but in 1638 became one of the original settlers of Hampton, and moved to Topsfield in 1650. Like John Marsh, he picked a helpmate from a distinguished family, the daughter of Reginald Foster (or Forster), whose kin were honorably mentioned in "The Lay of the Last Minstrel" and in "Marmion". Thomas, their descendant of the fifth generation, born in 1762, married Judith Dodge of Rowley in 1788, and became the father of Mary Gaines Peabody, Professor Marsh's mother, on September 3, 1807.

It is interesting to note the purity of the English stock that lay back of the subject of this memorial. The families that are represented by Professor Marsh's eight greatgrandparents can each be traced back to the early days of the colonies without break, and several of them are known for many generations in England; and in none of the marriages so far traced does there appear any name indicative of other than English blood. The families were: Marsh, Brown, Foster, and Buxton, on the one side, and Peabody, Gaines, Dodge, and Spofford on the other.

The early years of the nineteenth century found the two households with which we are concerned living in the village of South Danvers. John and Mary Marsh, with their seven children, shared a comfortable home, kept from ready money by the father's tendency to acquire still more land, but with definite educational traditions that sent the boys to nearby academies and at least two of them to college—John [2] to Harvard, Ezekiel to Bowdoin and then to Andover and Yale for theology. In the Peabody home, there was at first little surplus beyond living necessities, because the father had died by accident in 1811, leaving his widow to find food and shelter for eight children, the youngest of whom had been in the world only two years. Judith Dodge Peabody was made of stern stuff, however, and she had stalwart help in her sons, especially George, then aged sixteen, who was to have one of the most astonishing careers in American finance. By the time the younger girls were ready for schooling, George was providing the family with a comfortable living, and it was at his request that his sisters Mary and Sophronia were sent to Bradford Academy, which Caleb Marsh had also attended.

The Peabody family moved from Danvers to a neighboring town some time during this period, but Mary's friendship with Caleb Marsh reached the stage of an engagement in the early part of 1826. A letter was sent to Baltimore, asking her brother's consent to the marriage, and enclosing an extract of a letter from Caleb, which was concerned with the very necessary question of what the young couple were to live on. George Peabody agreed to give his sister as much as Caleb should receive from his father, so the two seemed assured of a comfortable amount on which to start life together.

Caleb and his family felt that his opportunities for making a living would be better in the new country to the west, and with that idea in mind the young man accompanied his brother John to Michigan. However, the farm that Caleb finally bought for his matrimonial venture was in Lockport, New York, on Chestnut Ridge, three miles east of the village and one mile from the Erie Canal, on the north side of the old Post Road to Albany; it had 114 acres of land, two "convenient houses", three large

[2] The Dr. John Marsh whose interesting story has been told by George D. Lyman in his book, *John Marsh, Pioneer*, Scribner's, 1930.

barns, and a very fine orchard, the price being $2000. Later he bought an additional 100 acres or more.

To this Lockport farm Caleb brought his young wife shortly after their marriage on April 12, 1827. No sorrow seems to have clouded their first years together except the loss of their first child at birth early in 1828, a loss soon softened by the coming of a daughter, Mary, in August 1829, and of a son, Othniel Charles, on October 29, 1831. There were temporary reverses of fortune such as fall to the farmer's lot, but no major catastrophe until August 1834, when the young mother, apparently recovering normally from the birth of her fourth child, was taken down with cholera and died within fourteen hours. Her husband, grief stricken, hurriedly sold his farm and went back with his two elder children to his old home in Danvers. In 1836 or early 1837 he was remarried, this time to Mary Lattin, daughter of a well-to-do Lockport man. He was engaged for a while in the shoe business in Haverhill, but shared the fate of many in the depression of 1837, and a few years later returned to Lockport, taking Othniel with him.

Of Othniel's early days, we have but little information. As the eldest boy, he was expected to be his father's mainstay in the farm work, but he preferred to range the countryside, hunting the small game then still abundant in the Lockport region, and becoming an expert shot with a rifle. While he and his stepmother seem to have been on friendly terms, nevertheless the new brood of children, which had increased to six by 1852, the recurring financial troubles, Caleb's inability to cope with them, and his consequent lack of equability, all helped to drive the wedge deeper between father and son. The boy went to school apparently in the winter only, but by 1848 he had acquired sufficient knowledge to allow him to attend Wilson Collegiate Institute at Wilson, New York, where his conduct and progress during the years 1848-1850 were reported by the principal to be "satisfactory". In 1850 he was a pupil in the Lockport Union School, and in that year he tried school teaching, but gave it up because of "headaches"—probably due to near-sightedness. However, he made money enough to enable him to follow a long-cherished wish and go back East; and the next year his doings at the family homestead in South Danvers are recorded in a diary. This diary, it must be admitted, shows surprising immaturity for a young man of twenty, and yet the year 1851-1852 was the turning point in Marsh's life. Coming of age, he received a settlement, at least in part, of the property held for him since his mother's death (proceeds of the marriage dowry given her by her brother George), and with it, he decided to go to Phillips Academy at Andover, Massachusetts.

He entered the Academy before the turn of the year, and there he found the environment that brought to the fore qualities hitherto dormant. Not at once, however: the first year he did not exert himself, but the second year he settled down to work in earnest. His comparative maturity gave him an advantage over the other boys, and he found within himself a zest for learning. Even more significant, he very shortly developed a talent for leadership. He was at Andover five years, graduating valedictorian in July 1856; according to a statement quoted by Grinnell, "He had made a clean sweep of all the honors of Phillips Academy—there was no desirable honor which he did not get while there."

He had not been in Andover long when George Peabody extended him a helping hand, and in May 1856 Othniel carefully framed a letter to his uncle, expressing his gratitude for past opportunities, and asking permission to enter Yale College. The first actual meeting between the two took place later in that same year, and what George Peabody saw was evidently to his liking, for Marsh entered Yale College in September 1856.

At Yale, Marsh's progress was less brilliant than at Andover, but he was graduated in 1860 (at the age of 28) with a High Orations stand in the Classical Course, eighth in a class of 109. He was elected to Phi Beta Kappa, and he also received a Berkeley Scholarship, awarded for excellence in certain of the classics, and carrying with it the proviso that the recipient must remain at Yale as a graduate student for one to three years. Although his rank as a "Scholar of the House" was thus founded on the classics, Marsh had no intention of following these branches further. Before his graduation he had written his uncle that he wished to fit himself for "a Professorship of Natural Science in Yale or some other College", and had received the latter's consent. Certainly it was quite in keeping with George Peabody's own career to be willing to foster high ambition when he saw it!

It might be profitable at this point to consider what forces had been shaping Marsh's mind toward science. First among them was doubtless his country upbringing and his great love for the outdoors, expressed in his compositions at the Wilson Collegiate Institute. At the time when the Erie Canal was being excavated, in 1823, and when it was being widened, about 1843, the Lockport region became famous the world over for its Niagaran (Silurian) fossils, and this rich fauna attracted a retired army officer, Col. Ezekiel Jewett (1791-1877), who is said at that time to have been "unsurpassed in America as a field paleontologist." It is known that young Marsh came under the influence of Colonel Jewett some time after 1843—the colonel had a summer school in geology at Lockport in 1843-1847—and learned from him how and where to collect fossils, and especially minerals. By the time he went to Andover, in 1851, he already had a mineral collection of some dimension, and he added to it during five summer trips to Nova Scotia. An interesting item, in view of subsequent events, is the statement in his Andover diary that in April 1855 he called on Benjamin F. Mudge, then curator of the natural history society in Lynn, to see his minerals and to get help in identifying some of his own. During his first two years at Andover, he was in the English Department, which offered some courses in natural science, but with his decision to go to college, made in the spring of 1853, he had perforce to shift to the Classical Course.

After his graduation from Yale College, Marsh turned at once to science, then developing rapidly at Yale under the two Sillimans, George J. Brush, and James D. Dana; and it was under the guidance of these men, and especially of Professor Brush, that he spent two years of study in the young Sheffield Scientific School. As the second year drew to a close, he had to decide what should be the next step toward the professorship that had become his goal. Evidently the idea of study abroad had been in his mind for some time—doubtless placed there by

Brush, who had studied in Germany—for he wrote his uncle on June 9, 1862: "If the plan of completing my studies in Germany, which you once so kindly approved, still meets with your approbation, I should like to go in September next." Mr. Peabody readily assented, and letters of introduction given Marsh by Professor Dana indicate that he was planning to study particularly analytical chemistry and mineralogy.

Marsh started for Germany in November 1862, stopping in London to visit his uncle, to see the International Exhibition, and to look at some fossils in the British Museum that he wished to compare with certain vertebrate remains discovered on his second visit to Nova Scotia some years earlier, and forming the subject of his first paper on fossil vertebrates, "Description of the Remains of a New Enaliosaurian (*Eosaurus acadianus*)", published in July 1862. A copy of this paper had been sent to Sir Charles Lyell for publication in the *Proceedings* of the Geological Society of London, and it was communicated to that Society in December by Lyell himself. In the following year, Marsh was proposed for membership in this leading geological society by Lyell, a signal honor for so young and untried a worker.

Marsh matriculated at Berlin University as a student of mineralogy and chemistry under G. and H. Rose, respectively, and of microgeology under Ehrenberg. In the spring of 1863 he moved on to Heidelberg, to work under Bunsen, Blum, and Kirschoff. During this spring, also, he had a momentous meeting with his uncle while the latter was taking the "cure" at Wiesbaden. This conference was concerned not only with Marsh's hoped-for career, but with Mr. Peabody's "future plans and donations," regarding which the two had had "a long talk" in England the year before. When it was over, Marsh was able to write the elder Silliman that his uncle proposed to give Yale the sum of $100,000 (later increased to $150,-000) for a museum of natural science.

After a summer spent in Switzerland, Marsh went back to Berlin in the fall of 1863, and spent the entire academic year in the study of paleontology, at Professor Dana's suggestion; by this time it had been made clear to him that a position in the

Sheffield Scientific School was a probability. The summer of 1864 he devoted to further excursions in Switzerland, and in October he entered the university at Breslau to study with Ferdinand Roemer (who had done much geologic work in Texas and Tennessee), Grube, and Goeppert, returning to Berlin in the spring.

Marsh's formal appointment to the professorship of paleontology in the Sheffield Scientific School—the first such chair in America—was made at Commencement, July 24, 1866. His connection with the Scientific School continued until 1879, when he was transferred to Yale College. According to Grinnell, "he did not wish to make his professorship a teaching one, and preferred to serve Yale without salary in order that his time might be devoted to research and exploration."

MARSH'S PERSONALITY

George Bird Grinnell, naturalist and writer, was one of Professor Marsh's students, a fellow explorer with him on two Yale expeditions in the Rocky Mountain country, and a close friend to the end of Marsh's life. Charles E. Beecher, who succeeded Marsh at Yale, worked in the same room with him for ten years as his assistant, had the full confidence of his superior, and probably understood him better than most other persons, besides knowing more of his later history. The memorials written by Grinnell (1910) and Beecher (1899)[3] form the basis for the following account, supplemented by the writer's own knowledge of Marsh, gained from daily intercourse with him during the year 1892 and occasional meetings during the last six years of his life, and from a study of the thousands of letters received by Marsh, his many notes relating to his own career, an abundance of newspaper clippings, and finally, the nearly three hundred scientific papers that he published.

Marsh's early life as a farmer's son had developed for him a strong frame and a robust body. Never seriously ill at any time in his life, we find him nowhere dwelling on the hardships of life or the dangers and fatigue of field work in his pioneer

[3] Cited, together with other sketches of Professor Marsh, at the end of the bibliography which accompanies this memoir.

days in the Rocky Mountain region. He stood about 5 feet, 10 inches, in his shoes, was stockily built, broad-shouldered, and erect. In early life he probably weighed around 160 pounds, and in later years about 175. In middle life his nose, mouth and chin were average in character, his face round, his complexion fair and of a healthy color. His hair and eyebrows were sandy in tone, with a beard tending toward red. He had widely spaced blue eyes that were somewhat nearsighted—a defect that led to his rejection by the Army in the Civil War days; he wore eyeglasses only while reading and writing, however, and none of his many portraits show him with such. His forehead was high, and a scantiness of front hair caused it to appear even unduly so; with middle life he became slightly bald. As a youth he wore a flowing mustache, but almost all his later portraits show a well dressed full beard.

Although possibly inheriting through his mother many of the traits that were to make him prominent, Marsh grew up without the softening influence that she might have exerted, and his favorite sister, Mary, died while he was in Andover. With his somewhat domineering father he did not get on well. Moreover, as he remained a bachelor, he had no family ties to hold him in check. Self-reliance he possessed to an extraordinary degree, and it naturally led to a self-centering of his life and ambitions. Out of it came, also, Beecher says,

"an absence of the complete exchange of confidence which normally exists between intimate friends. Even where perfect confidence existed, he seldom revealed more about any particular matter than seemed to him necessary or than the circumstances really demanded."

By anyone meeting Marsh for the first time, and especially anyone asking for information in his line of research, the caution of the man must have been instantly felt—possibly even a slightly suspicious attitude until he had made sure that he knew the whys and wherefores of the meeting. Although access to him was easy, the critical visitor soon saw the marked self-confidence that comes with wealth and position. It was but natural that he should be proud of his ancestry, especially of his relationship to George Peabody, who had made his career possible; and he was very proud indeed of his unique professorship at Yale, as well as of his high standing among the leaders of science. The next things to impress the visitor were minor physical peculiarities, such as the blinking of his searching, nearsighted eyes, and the seeming impatience shown in his nervous, half-articulated "What? What's that?" On longer acquaintance one came to appreciate that his chief characteristic was his feeling that "the work of the hour is of prime importance," and that all those around him should be as interested in it as he was. His ambition to stand at the top is apparent from his Andover days onward, and once he had decided what road to follow, he never wavered in his determination to be one of the highest savants in science and to build up at Yale one of the world's largest foundations in paleontology. He fully accomplished all these wishes.

We get a good insight into Professor Marsh as he appeared to his Yale colleagues in the following excerpt from President Timothy Dwight's *Memories of Yale Life and Men:*

"In his personality, Professor Marsh was, as we may say, a man quite by himself. He was intelligent, with a manly intelligence, and a careful student, patient in his researches. But at the same time, as a collector and discoverer, he had the irrepressible zeal which is characteristic of an enthusiast. Every new thing in his own sphere of investigation which revealed itself—everything which had in it the promise of a revelation—gave him happiness and stirred him to fresh activity. He would press forward with all energy, and any needed outlay of effort or means, to secure what it might have to give him. When he had made it his own, and found it of true value, he hastened with joyful ardor to relate his good fortune to his friends, as if he had possessed himself of a hidden treasure. . . .

"In his attitude and in his manner of expressing himself, a certain formality was characteristic of him. Especially was this manifest in cases where he sought an interview with others on matters of business, or on subjects of interest with respect to his own particular work. The slight and somewhat peculiar hesitation in his utterance rendered this formality more conspicuous. I was always struck with this singularity of manner when he called upon me. . . . Whatever the object might be, the manner of the man was the same. It was as if we had been two ministers of state having little acquaintance with each other, who had met for the settlement of some great question of public concern. All was serious with a dignified solemnity, and measured with a diplomatic deliberateness. . . . Such idiosyncrasies made the man the more interesting. They certainly gave him an individuality which distinguished him from others."

Grinnell says that Marsh was a keen judge of men, could instantly select the one he felt would be of most use to him, and was seldom at fault in his estimate of character; that he was efficient and shrewd, with a touch of cunning, and an aggressive leader. Though not an easy writer, "he took great pains to express himself clearly and in correct English."

With the desire to know how Marsh appeared to his European contemporaries, the writer asked this question of Sir Arthur Smith Woodward, of London, whose father, Henry Woodward, was probably the closest of Marsh's friends on that side of the ocean, and from him received the following reply:

"Professor Marsh visited England usually in alternate years, and he had a large circle of friends both in this country and on the European continent. I first met him in 1884 in my second year as an assistant in the Geological Department of the British Museum (Nat. Hist.), and thenceforth I regarded him as one of my best friends. In 1890 I stayed with him in his 'wigwam' (as he termed it) at 360 Prospect Street, New Haven, and I was always closely associated with him during his visits to England. He was absorbed in palaeontological research; and in London he spent most of his time in studying the fragmentary fossil remains of reptiles and mammals in the British Museum for comparison with the much finer specimens which he had at his disposal in America. He visited other cities for the same purpose, and thus had much influence on the progress of vertebrate palaeontology in Europe. . . .

"Like other great men, Marsh had his failings; and close association with him soon revealed both his unrestrained jealousy and his love of popular adulation. His early rivalry with Cope and his later rivalry with Osborn were never-ending subjects of conversation. Flattering newspaper notices pleased him, and I remember he was delighted when the English journal *Punch* published a little picture of him discoursing on the newly discovered skull of *Triceratops* to the British Association at Leeds in 1890. . . .

"Marsh was a remarkably keen observer, and he was quick to see the inferences which might be drawn from the facts before him. He was also one of the foremost systematists of his time, and contributed greatly to the classification of reptiles, birds and mammals. . . . I am convinced that in all essentials Marsh's fundamental contributions to vertebrate palaeontology were his own, and stimulated by his boundless enthusiasm for our science."

In his Academy days, and at Yale College, Marsh learned to be an easy mixer, and his diary shows that this was true not only among his classmates but also among his instructors; during his vacations he was constantly traveling about, calling on his relatives, on the curators of museums, on local collectors of minerals, and on others whom he had heard of as interested in natural history. This ease in meeting people, and especially notables, stood him in good stead in both America and Europe. The sunny side of his make-up was nearly always uppermost; in Huxley's words, he was "a wonderfully good fellow, full of fun and stories of his western adventures."

Marsh was also very fond of entertaining, and liked to give dinner parties in his finely landscaped home on Prospect Street, which was in reality but another museum in which to display his many trophies, his orchids, his paintings, and his endless examples of Japanese art. Here also he had as a guest, for several days in 1883, the great Sioux leader, Chief Red Cloud, whom he presented to several hundred of the distinguished citizens of the town.

It is a little difficult for a biographer, writing after this lapse of time, to understand fully the trail of hostility that Marsh left in many quarters. Beecher testifies that he was

"normally restive under restraint, and met all opposition with power and fearlessness. Having practically created the modern science of vertebrate paleontology in America, he resented any encroachment upon the particular fields of research in which he was engaged. This attitude frequently developed feelings of hostility in other investigators, and often alienated him from co-workers in his Department of Science."

Grinnell puts the same idea a little differently, thus:

"His fossils were priceless in his eyes, and he guarded them with extremest care. A man of less enthusiasm or more liberal mind might have turned over certain subjects to able assistants; Marsh's failure in this respect caused in several cases a rupture of friendly relations. . . . He had one or two unfortunate experiences with visitors; hence was somewhat suspicious. . . . Marsh's peculiarities were many, some of them being so marked as to give his enemies an opportunity to speak ill of him, which sometimes resulted in grave injustice."

Looking back through his career, Marsh appears to the writer to have been a sort of Jack the Giant Killer, for he was forever attacking errors, humbugs, and impostors. He began this in

1861, when he exploded the Nova Scotians' hopes for their gold mines, and in 1862 he corrected no less a savant than Louis Agassiz in regard to a certain feature in *Eosaurus*. Six years later, on his first trip to the West, certain so-called "human" remains found nearly 70 feet beneath the surface in western Nebraska were shown by him to belong to three-toed horses and associated animals; and huge footprints supposed to have been left by giants in ancient Nevada, turned out, under his searching examination in 1883, to be those of a well-known species of extinct ground sloth.

The richest exposure in which he figured was undoubtedly that of the Cardiff Giant in 1869. This was "a gypsum man, ten and a half feet long, nude, virile and unabashed," dug up in the dark of an October night in Onondaga County, New York, and widely shown at fifty cents a head. State Geologist James Hall, inspecting it undisturbed for "a full quarter of an hour," publicly stated it to be "the most remarkable object yet brought to light in this country and although perhaps not dating back to the Stone Age, . . . nevertheless deserving the attention of archeologists." The perpetrators of the hoax were getting rich, when Professor Marsh, suspicious of this gypsum giant from his native state, unearthed its real history with the help of a man from Iowa who, dissatisfied with his share of the profits, declared that he "got up" the giant from a block of Iowa gypsum, and that it was then shipped to Cardiff, New York, hauled by night to its burying place, and "resuscitated with full attention to all necessary details." After his inspection of the giant at Syracuse, during which he made sure that it was composed of gypsum, a substance that is soluble in water and therefore could not have retained, after burial, the polished surface that the statue displayed, Marsh wrote a letter to a newspaper friend exposing all that he had learned, and thus exploded the most uproarious hoax ever "launched upon the credulity of a humbug-loving people" (Clarke, *Life of James Hall*, 1921).

One of the two hardest battles of Marsh's life was his struggle in 1875 with the unscrupulous politicians of the "Indian Ring" at Washington, which started when he sent to President Grant, following a promise made to Chief Red Cloud, a printed exposé of disreputable frauds that were being practiced upon the Indians at the Red Cloud Agency in Nebraska; and which ended with the cleaning out of the Agency and added the final straw to a load of evidence that had long been accumulating against certain members of the Interior Department. Many of the partisan papers of the time showered the professor with scurrilous language, but so far as Marsh was concerned these attacks had the same effect as water on a duck's back, and in no wise turned him from his determination "to clear out the varmints."

The most protracted and bitter fight of Marsh's life, that against his great rival, Professor Edward Drinker Cope of Philadelphia, broke out in 1873, when he began to point out in print the latter's attempt at antedating papers containing descriptions of new forms of vertebrates. Years of acrimony between the two climaxed on January 12, 1890, when Cope, through a newspaper writer in the New York *Herald*, burst forth with a full-page charge against the doings of Marsh and of Major J. W. Powell, Director of the United States Geological Survey, which was met a week later by a long blast of counter-accusation from Marsh. Of this exchange, Osborn says, in his life of Cope (1931):

> "Cope attacked after a truly Celtic fashion, hitting out blindly right and left with little or no precaution for guarding the rear. . . . Marsh's reply was thoroughly of a cold-blooded Teutonic, or Nordic type, very dignified and, under the cover of wounded silence, reluctantly breaking the silence of years."

During the two closing decades of the last century, nearly all the vertebrate paleontologists in the United States became partisans in this warfare, either openly or otherwise. Reverberations of the quarrel reached the Senate in 1892, when the Geological Survey was under fire because of Major Powell's advanced ideas about irrigation; and it thus became one of the factors that led to the 30 per cent cut in the Survey's annual appropriations (50 per cent in paleontology), and to the consequent discharge of many geologists, aside from Marsh, who had had nothing whatever to do with the controversies.

MARSH AS A COLLECTOR

According to Beecher, it was as a collector that Marsh was seen at his best, and the collections that he amassed during the last thirty years of his life

"form a lasting monument to his perseverance and foresight. . . . He not only had the means and the inclination, but entered every field of acquisition with the dominating ambition to obtain everything there was in it, and leave not a single scrap behind. Every avenue of approach was made use of, and cost was often a secondary consideration. The nine-tenths, when attained, were only an additional stimulus for securing the remaining one-tenth."

This preëminence of Marsh as a collector went beyond the amount of material that he acquired, because the improvement that he made in the technique of collecting was of equal importance. In 1892, when the writer was at work as a preparator of invertebrate fossils in the Yale Museum, he saw masses of rock and bone coming in from the field daily, bandaged and held together by gunny sacking that had been cut in strips, saturated with plaster of paris, wrapped over the fossils before they were lifted out of the ground and again on the under side when they could be turned over. He saw these packages, small and large, opened little by little by the skilful "bone-setters", with no disturbance of the much fractured specimens. As each part was opened, thin shellac or liquid glue was poured into all the crevices, or the parts were lifted one after another and reset in plaster of paris, so that when they dried out, the pieces were held firmly in place. He was fascinated by this resurrection of ancient bones and their preservation in all their structural glory for the edification of paleontologists. Having heard that Marsh was the inventor of the process, the writer asked him one day how this came about. Marsh replied that he got the idea from having seen medical men set broken bones in splints and hold them together with strips of cloth soaked in plaster of paris. This may be true, but rumor has it that the first step in this method was invented by S. W. Williston. In the late summer of 1877, he and M. P. Felch were trying to take up a badly fractured and much weathered *Diplodocus,* and finally, in despair, Williston wrote Marsh on September 21: "Will it do to paste strips of strong paper on fractured bones before removing? . . . These strips are put on with ordinary flour-paste and can be removed I think easily." There is still extant in the Peabody Museum a bone bandaged in this way by Williston and Mudge in 1877. This seems to indicate that the former was the initiator of the bandaging method, and it would be but a step from strips of paper with flour paste to the more secure strips of sacking soaked in liquid plaster of paris. Marsh may have suggested the improvement; in any event, by 1880 this surgical device was in use by all his collectors.

At the time when he began to collect vertebrates, Marsh went on to say, the material that had been described was nearly always of a fragmentary nature, and usually consisted of teeth, broken jaws, and other isolated bones. The truth of this statement is evident at once to anyone who looks through the early publications. As Marsh said, this was the age when the usual method was to drive the pick under the bone, pull it up, rake all the pieces together and dump them into a sack, with the pious hope that the preparators would be able to fit the puzzle together. How much better Marsh and his "bone-hunters" came to do their collecting may be seen from a perusal of the plates in, for example, his monographs on the toothed birds (1880), the Dinocerata (1885), and the dinosaurs (1896), and in his many papers that give lifelike restorations of extinct reptiles and mammals.

John Bell Hatcher, the most extensive collector of Marsh's many field men, speaks of "Marsh's well known aversion to dealing with fragmentary or relatively unimportant material and seeking after the 'choicest plums' as he used frequently to express it." In another place, he adds:

> "Where a generation ago the extinct vertebrate life of America was but poorly represented in our museums by imperfect series of teeth and isolated bones, we are now able to study many of these extinct animals from more or less complete skeletons. For these improved conditions we are mainly indebted to the late Professor Marsh, either directly by reason of the vast collections acquired by him, or indirectly through the improved laboratory and field methods developed by him and his assistants."

The steady stream of vertebrate fossils that poured from the West into the Yale Museum during the years 1870–1873 came as the result of a brilliant idea on the part of Marsh—brilliantly planned and brilliantly executed—in short, the organization of four expeditions into the western territories, the personnel of which was made up mainly of recent graduates or undergraduates of Yale College and the Sheffield Scientific School, who not only did their share of the actual collecting, but paid most of the expenses of the trips. A fifth expedition, in 1874, though rich in yield, was made up of tested collectors and army men. After that date, Marsh did most of his collecting through individual paid collectors and their assistants, directed by correspondence and by occasional trips to the field.

Marsh himself said that at one time or another between 1870 and 1898, and for short or long periods of service, he employed "several hundred" helpers of various types. Included in this category were soldier escorts and their officers and guides, cooks, teamsters, "bone-diggers" and their assistants, and also his laboratory aids. There is no record of those who were thus employed for short times, but more than one hundred persons are represented either by letters or by names in the accession and account books. Of these, at least fifty were employed before 1882, and the remainder during Marsh's connection with the United States Geological Survey; and of the latter, thirty-five were collectors on the federal payroll. The collector *par excellence* was J. B. Hatcher; other efficient ones were B. F. Mudge, Arthur Lakes, M. P. Felch, W. H. Reed, S. W. Williston, Fred Brown, E. Kennedy, D. Baldwin, Gus Craven, Leander S. Davis, Sam Smith, and H. T. Martin. In the years between 1870 and 1892 the vertebrate fossils arrived at New Haven in an endless stream of boxes and packages of all sizes, and at times in carload lots, the accession books recording about 3000 shipments.

The use of his personal fortune and of the funds put at his disposal by the United States Geological Survey made it possible for Marsh to bring together what was probably the greatest collection of Mesozoic and Cenozoic vertebrate skeletons ever amassed by one individual. Cost was never his first consideration—he was after big results. He told the writer that his pet specimen, the giant sauropod dinosaur *Brontosaurus excelsus*, had cost him $20,000, and that he had spent on his collections as a whole not less than $200,000 of his own money. In addition, he spent for the United States Geological Survey about $150,000.

With regard to the improvements in collecting technique brought about by Marsh, we have the testimony of J. L. Wortman, who was in a position to note the changes in methods, since he was long assistant to Cope and later a member of Osborn's large staff in the American Museum of Natural History. In his memorial of Marsh, he says:

"The record of his discoveries is one of almost continual triumph in the bringing to light of new and strange forms of life that had inhabited the western hemisphere in the distant past. . . . The methods of collecting and preparing these fossils for study and exhibition which he has introduced in the course of his long experience form the basis very largely of all similar work in almost every palaeontological laboratory of the world, and it is a matter of common remark that nearly all the noted collectors and preparateurs have received their training under his immediate influence."

Of Marsh's vertebrate collection, presented by him to Yale University in 1898, Wortman said in 1900 that it was

"without doubt the finest and most complete of any in the world, and, when properly installed and exhibited, will make a monument in every way worthy of the greatness of the man who dedicated his life and his fortune to its formation. The influence of his work for advancement in this department of knowledge has probably no equal in any country."

At the same time that Marsh was building up his great collection of fossil vertebrates, he was bringing together, from all parts of the world, skeletons of recent animals to be used for comparative studies. The collection of recent osteological material thus assembled was in Marsh's time one of the most complete in America.

MARSH'S CONTRIBUTIONS TO THE EVOLUTION THEORY

Darwin's epochal work, *The Origin of Species*, did not appear until November 1859, and, since it is well known that Professor

Dana was a creationist until long after that date, it is more than probable that Marsh's attention was not directed favorably toward evolution until his student days in Germany. That he was thinking about it, however, is evident from his paper of 1862 on *Eosaurus*, in which he says that, inasmuch as these bones occur in Paleozoic strata,

"they add another to the arguments that have been brought against the so called 'Development Theory'; and they show with how great caution we should receive the assertions, so frequently and confidently made on negative evidence alone, of the exact date of the creation or destruction of any form of animal or vegetable life."

Marsh made his first visit to England in the fall of this same year, and at this time or shortly thereafter he met Charles Lyell and Thomas Huxley, the latter of whom, he tells us, was "a guide, philosopher, and friend, almost from the time I made choice of science as my life work". We also know that as early as 1865 he had been at the country home of Darwin. In any event, by 1874 he was an out-and-out evolutionist, and in his memorable Nashville address of 1877 he states that evolution is the "key to the mysteries of past life on the earth," and that "to doubt evolution is to doubt science, and science is only another name for truth". In his address of the following year, he adds that Darwin's *Origin of Species* had in two decades "changed the whole course of scientific thought . . . Darwin spoke the magic word—'Natural Selection,' and a new epoch in science began."

The demonstration of the truth of the evolutionary theory can come only through the study of fossils, and Marsh's well preserved and carefully collected material played a large part in the establishment of the hypothesis. It was, indeed, his specimens from the region to the east of the Rocky Mountains, where there exists an unrivaled record of dinosaurs, birds, and mammals, that helped to take the entire question of evolution out of the realm of hypothesis and to demonstrate that it is a living truth.

Marsh's first major contribution to the evidence for the evolution theory was his discovery of birds which, by their possession of teeth and other reptilian characters, proved the genetic relationship between these two groups of animals that had been foreshadowed by Huxley. It was, however, his magnificent collection of fossil horses, and his accurate and careful tracing, from these, of the progress of the horses through geologic time, that tended to give him a greater reputation than any of his other discoveries.

It has been well said that the living horse is probably the most perfect organic machine for swift running so far developed, and that it displays throughout its organization a most exact and finished adaptation to this purpose. It has, however, taken Nature about fifty million years to perfect this mechanism. The evolution of the superfamily Equoidea "affords the best known illustration of the doctrine of evolution by means of natural selection and the adaptation of a race of animals to its environment" (W. D. Matthew 1913). This evolution begins in the Rocky Mountain country during the Age of Mammals (Cenozoic) in *Eohippus* (= *Hyracotherium*), only 11 inches tall, and proceeds by various genetic lines through 15 genera and some 215 different forms into the *Equus* of today.

Even previous to 1865, no fewer than ten kinds of fossil American horses had been described. Nevertheless, as Marsh tells us in his Nashville address:

> "I heard a world renowned Professor of Zoology [in Germany] gravely inform his pupils that the horse was a gift of the Old World to the New, and was entirely unknown in America until introduced by the Spaniards. After the lecture I asked him whether no earlier remains of horses had been found on this continent and was told in reply that the reports were too unsatisfactory to be presented as facts in science. This remark led me, on my return, to examine the subject myself, and I have unearthed [many] species of the horse tribe . . . and it is now, I think, generally admitted that America is, after all, the true home of the horse."

In his paper on the fossil horses of America, appearing in 1874, Marsh said:

> "The large number of equine mammals now known from the Tertiary deposits of this country, and their regular distribution through the subdivisions of this formation, afford a good opportunity to ascertain the probable lineal descent of the modern horse. The American representative of the latter is the extinct *Eq. fraternus* Leidy, a species almost, if not entirely identical with the old world *Eq. caballus* Linn., to which

our recent horse belongs. Huxley has traced successfully the later genealogy of the horse through European extinct forms [1870], but the line in America was probably a more direct one, and the record is more complete. Taking, then, as the extremes of a series, *Orohippus agilis* Marsh, from the Eocene [Bridger] and *Eq. fraternus* Leidy, from the Quaternary [Pleistocene] intermediate forms may be intercalated with considerable certainty from the thirty or more well marked species that lived in the intervening periods. The natural line of descent would seem to be through the following genera: *Orohippus*, of the Eocene; *Miohippus* and *Anchitherium* of the [Oligocene and] Miocene; *Anchippus, Hipparion, Protohippus* and *Pliohippus*, of the Pliocene; and *Equus*" of the Pleistocene and Recent.

"The most marked changes undergone by the successive equine genera are as follows: 1st, increase in size; 2nd, increase in speed, through concentration of limb bones; 3d, elongation of head and neck, and modifications of skull. The increase in size is remarkable. The Eocene *Orohippus* was about the size of a fox. *Miohippus* and *Anchitherium*, from the Miocene [Oligocene] were about as large as a sheep; *Hipparion* and *Pliohippus*, of the Pliocene, equalled the ass in height; while the size of the Quaternary *Equus* was fully up to that of the modern horse.

"The ancient *Orohippus* had all four digits of the manus well developed. In *Miohippus* . . . the fifth toe has disappeared, or is only represented by a rudiment, and the limb is supported by the second, third, and fourth, the middle one being the largest. *Hipparion* . . . still has three digits, but the third is much stouter, and the outer ones have ceased to be of use, as they do not touch the ground. In *Equus*, the last of the series, the lateral hoofs are gone, and the digits themselves are represented only by the rudimentary splint bones. The middle, or third, digit supports the limb, and its size has increased accordingly. The corresponding changes in the posterior limb of these genera are very similar, but not so manifest. . . . This reduction in the number of toes may, perhaps, have been due to elevation of the region inhabited, which gradually led the animals to live on higher ground, instead of the soft lowlands where a polydactyl foot would be an advantage."

Between 1868 and 1892 Marsh issued thirteen papers relating to fossil horses. His genera, arranged in the order of their description, are: *Orohippus* (1872), *Miohippus* and *Pliohippus* (1874), *Mesohippus* (1875), *Eohippus* (1876 = *Hyracotherium* Owen), *Epihippus* (1878), and *Helohippus* (1892, a synonym of *Orohippus*, as is *Orotherium* 1872).

By 1876, Marsh knew at least thirty kinds of American horses, and most of these he showed Huxley on the occasion of the latter's visit to America. The great scientist was met by Marsh on his arrival in New York and stayed a week in New Haven as his guest, examining Marsh's general collection, which he wished to see before delivering his course of lectures. Marsh said of this circumstance later:

"One of Huxley's lectures in New York was to be on the genealogy of the horse, a subject which he had already written about, based entirely upon European specimens. My own explorations had led me to conclusions quite different from his, and my specimens seemed to me to prove conclusively that the horse originated in the New World and not in the Old, and that its genealogy must be worked out here. With some hesitation, I laid the whole matter frankly before Huxley, and he spent nearly two days going over my specimens with me, and testing each point I made. He then informed me that all this was new to him, and that my facts demonstrated the evolution of the horse beyond question, and for the first time indicated the direct line of descent of an existing animal. With the generosity of true greatness, he gave up his own opinions in the face of new truth, and took my conclusions as the basis of his famous New York lecture on the horse."

If more striking testimony to the value of Marsh's contributions to the evolution theory is needed, it is at hand in a holograph letter treasured in the Peabody Museum archives, which reads:

"Down, Kent, August 31, 1880.

"My dear Prof. Marsh,—

"I received some time ago your very kind note of July 28th, and yesterday the magnificent volume [Odontornithes]. I have looked with renewed admiration at the plates, and will soon read the text. Your work on these old birds and on the many fossil animals of N. America has afforded the best support to the theory of evolution which has appeared within the last 20 years.[4] . . .

"With cordial thanks, believe me,

"Yours very sincerely,

(Signed) CHARLES DARWIN."

MARSH AND STRATIGRAPHY

When Marsh was receiving his training in geology in the late fifties and early sixties, the stratigraphy of the marine formations was as yet very much generalized, and of the freshwater deposits there was hardly any known chronology at all.

[4] In other words, since the publication of *The Origin of Species* in 1859.

The time had not arrived when lake and river deposits could be distinguished clearly from those of the seas. Besides, there was little information that was reliable about the genetic sequence of the land plants and the animals found fossil in continental strata. It was but natural, therefore, that Marsh, while a student in Germany, should have been greatly influenced by the dictum of Professor Goeppert of Breslau, who told his classes "to doubt the value of fossil plants as indices of the past history of the world" (Marsh 1898), and that he should unfortunately have retained this opinion throughout his career. It was this prejudice that led him late in life into the grave error of thinking that continental deposits of Jurassic age are present throughout the Atlantic Coastal Plain from Martha's Vineyard and Block Island south into Virginia, despite the fact that the paleobotanists of the United States Geological Survey, on the basis of large floras described by Fontaine and Ward, had shown these deposits of the Potomac group to be of Lower Cretaceous age.

When Marsh began his researches on the Tertiary deposits of the Great Plains east of the Rocky Mountains, it was the general belief that these strata had accumulated in vast lake basins. The first edition of Dana's *Manual of Geology* (1862) held that these formations were of lacustrine and brackish-water origin, laid down in bodies of water that had been of long endurance and that had covered great areas with thick deposits. These erroneous ideas about lake deposits did not begin to break down until the last decade of the nineteenth century. Therefore in Marsh's papers treating of the Cenozoic stratigraphy of the Great Plains we read of "ancient lake basins," and that "the existence of several large fresh water lakes in the Rocky Mountains region, during Tertiary time, is now well established." The lakes, he said, were of Eocene (Wasatch, Bridger, Uinta, Green River, etc.), Miocene = Oligocene, and Pliocene ages. Even as late as 1885, in the monograph of the Dinocerata, he says that these animals are "found in a single Eocene lake basin in Wyoming. . . . This lake basin . . . slowly filled up with sediment, but remained a lake so long that the deposits formed in it, during Eocene time, reached a vertical thickness of more than a mile." That rivers in a semiarid climate lay down their sediments over widespread flood plains did not come to be general knowledge among stratigraphers until the present century.

In none of Marsh's publications do we find that he ever actually measured or described in detail a stratigraphic sequence. He was content to note the formation in which the fossils occurred and rarely did he mention the subdivision of the formation. He left to the geologist all this most desirable stratigraphic detail, as well as the naming of the formations, since it was his ambition to develop only the biologic sequence which would show the direction evolution had taken. As a rule, his named zones were very broadly conceived.

In his description of new species of fossil vertebrates, Marsh rarely gave exact information as to their geologic level or detailed geographic position, his usual citation being "Upper Eocene of Wyoming," "the Coryphodon beds, or lowest Eocene of Wyoming," "the Miocene of New Jersey," "the Pliocene of Idaho," "the Ceratops beds or the Laramie of Wyoming," "the Atlantosaurus beds of the upper Jurassic in Colorado," and so on. For this lack of detail he was severely criticized by his colleagues, and the statement was often made verbally that his reason was that he did not want others to go to his collecting places and get specimens of his species. In his monograph on birds with teeth, he is more specific than usual as to the geologic horizon; these remarkable Kansas birds, he said, occur "in the Middle Cretaceous [which] corresponds to the strata named by the writer the 'Pteranodon beds' . . . included in subdivision number three in Meek and Hayden's section."

As we have seen, Marsh very rarely attempted stratigraphy from the viewpoint of geology. On the other hand, he was a good biostratigrapher from the standpoint of evolution as seen in the succession of vertebrate life. He was quite correct in holding that vertebrate fossils are of the greatest value in determining the stratigraphic sequence of fresh-water deposits. We may illustrate his principle by the following quotation regarding the evolution of the horse, taken from his paper of 1898:

"Near the base of the Eocene the genus *Eohippus* is found, representing the oldest known member of the horse tribe. Higher up in the Eocene *Orohippus* occurs, and still higher comes *Epihippus*, near the top of the

Eocene. Again through the Miocene more genera of horses, *Mesohippus, Miohippus,* and others, follow in succession, and the line still continues in the Pliocene, when the modern genus *Equus* makes its appearance. Throughout this entire series, definite horizons may be marked by the genera, and even by the species of these equine mammals, as there is a change from one stage to the other, both in the teeth and feet, so that every experienced paleontologist can distinguish even fragments of these remains, and thus identify the zones in which they occur."

Accordingly, it was Marsh's aim to name the successive vertebrate life zones after "the largest and most dominant vertebrate form which characterized them." By this method he had by 1896 named sixteen vertebrate life zones above the Paleozoic, as follows: Triassic, 1; Jurassic, 3 (Hallopus, Baptanodon, and Atlantosaurus); Cretaceous, 2 (Pteranodon and Ceratops); Eocene, 4 (Coryphodon, Heliobatis, Dinoceras, Diplacodon); Oligocene, 3 (Brontotherium, Oreodon, Miohippus); Pliocene, 2 (Pliohippus and Equus); Pleistocene, 1 (Bos). Many of these post-Triassic life-zone terms are still in use for the Rocky Mountain region. Osborn in 1929 proposed a different scheme for the same region, with sixteen life zones.

MARSH AND THE UNITED STATES GEOLOGICAL SURVEY

In view of Marsh's spectacular success in his earlier years as a collector of vertebrate fossils, and the rapidity with which he produced published results, it was only natural, when the reorganized and combined geological and geographical surveys were placed under the direction of Major Powell, that the latter should turn to Marsh for paleontological help. Moreover, through his Yale influence, through his wide personal acquaintance with important men, and through his long connection with the National Academy of Sciences, Marsh could also be very helpful to the Survey in easing the annual appropriations bill through Congress. According to Beecher:

"After repeated solicitations and with promises of material aid in the way of publication and collections, Marsh in 1882 accepted the appointment of Vertebrate Paleontologist to the United States Geological Survey.

This position he held to the time of his death, although the field work for the survey was terminated in 1892. His connection with the Survey gave him increased facilities for publication and for prosecuting explorations in the West."

During the ten years that Marsh was chief of the federal section of Vertebrate Paleontology, the Powell Survey was liberal in allotments for his work, and he was given about $15,000 each year to pay salaries for himself and his numerous assistants—collectors (about 35), preparators (9), scientific aids (8), and artists—and for field and laboratory expenses, including large freight bills.

The monograph of the Dinocerata was published by the Survey in 1886, and those of the vertebrates of the Denver Basin and on the dinosaurs of North America in 1896, but none of the five other monographs projected was completed. The material for them had been collected, most of the plates (about 215) and many text figures had been made, and preliminary descriptions of the genera and species had been published, but the final detailed accounts and the philosophical and phylogenetic problems were left largely untouched. As Beecher said, Marsh "planned his life work on the basis that immortality is here and not in the hereafter. It seemed difficult for him to realize the limitations of human existence and worldly accomplishment."

The material results of the ten years' service given to the federal Survey by Marsh and his staff amounted to seven carloads of vertebrate fossils. Shipments totaling two carloads (255 large boxes) were sent to the United States National Museum in 1886, 1891, 1896, and 1898. The final sending, made in 1899 after Marsh's death, filled five freight cars (529 boxes). Walcott, referring to the cessation of Marsh's relations with the Survey, said in 1900 that the value of these collections

"will be upwards of $150,000. . . . The transfer of these great collections to Washington without the loss of any material, either through imperfect recording or through misunderstanding as to the ownership of specimens, reflects the greatest credit on the business-like methods and the integrity of Professor Marsh."

PRESIDENT MARSH OF THE NATIONAL ACADEMY OF SCIENCES

Professor Marsh was greatly elated over his election to membership in the National Academy of Sciences at the April meeting of 1874 in Philadelphia, which was announced to him in a congratulatory telegram by John Strong Newberry. He was then forty-three years old, in the eighth year of his professorship at Yale; and the number of his papers describing striking new discoveries in the fossil fields of the West was just short of fifty. The geologists in the Academy at that time were a strong and influential group, including as they did Cope, Dana, Guyot, James Hall, Hayden, E. W. Hilgard, Hunt, Leidy, Lesley, Lesquereux, Meek, Newberry, Pumpelly, W. B. Rogers, and Worthen. Prior to his election, he had made one personal appearance before the Academy, by invitation, when he read a paper at the Northampton meeting in September 1868 on "human" bones found in a well in Nebraska, which had turned out to be those of an upper Miocene (Loup Fork) horse and other contemporary mammals. In the spring following his election he read his second paper, on "Size of the Brain of Extinct Mammals," and in his twenty-five years of membership, he read in all eleven papers before the Academy.

Marsh became an officer in the Academy in 1878, when he was elected vice-president. Alexander Bache, the founder-president, elected in 1863, had not lived to complete his six-year term, and Joseph Henry, who had succeeded Dana as vice-president in 1866, served as acting president until 1868, when he in turn was elected president, and was re-elected in 1874. Following Henry as vice-president had been William Chauvenet (1868-1870) and Wolcott Gibbs (1872-April 1878). At the spring meeting of 1878, Gibbs gave way to Marsh as vice-president, and on May 13, 1878, President Henry died and Marsh thus became the Academy's acting president four years after his election to membership. He held this office until the spring meeting of 1879 when, with the election of W. B. Rogers to the presidency, he resumed his status as vice-president. Curiously, however, the third president, like the other two, was not destined to fill out his elected term. Rogers died in 1882, and once more Marsh was acting president. In April 1883, Wolcott Gibbs was elected to succeed Rogers, but as he could not serve, the presidency was given to Marsh. As a result of this odd chain of circumstances, Marsh was no stranger to the Academy's administrative duties when he became its presiding officer. That he took his duties seriously is evident when he tells us that in his seventeen years of administrative service he did not miss a single stated meeting of the forty called, nor was he absent from any of the meetings of committees of which he was a member. No other member of the Academy, either before or since his time, had as long or as strenuous a service as its presiding officer.

In 1881, the Academy had been in existence for eighteen years, and during this time no fewer than 649 papers had been read at the scientific sessions. Of these papers, only five had been published by the Academy, and President Rogers felt that the organization had not received the recognition by the scientific world that would have come if the papers of each year had been published promptly by the Academy. He proposed that they should be brought together and transmitted with the annual report to Congress, but nothing came of this move. During Marsh's presidency, the plan of issuing a volume of papers each year or two became fairly well established, six volumes (in eight parts) appearing up to 1895; and during his term there was no lapse in the publication of the annual reports.

As a presiding officer, Marsh exercised the same amount of care that he bestowed on his private affairs, and he was an active and efficient leader. Testimony as to this is included in a statement from Professor Russell H. Chittenden, a member of the Academy since 1890, who, at the writer's request, wrote down the following recollections:

"As president of the Academy during a period of twelve years, 1883–1895, Professor Marsh through his strong personality exerted an influence on the meetings of the Academy which resulted in a dignified formality in keeping with its high standing. Somewhat stern in appearance, rather punctilious in intercourse with his associates, and with a stiffness of bearing frequently misunderstood, Marsh nevertheless possessed an innate courtesy and kindness of heart which softened his apparent hardness and made him a friend and colleague to be respected and admired.

"His interest in the Academy was deep and sincere. By many means, both direct and indirect, he sought to promote its standing with the administration at Washington, even suggesting to the President specific ways in which the Academy could be of service to the Government. Whenever possible at the annual meeting in Washington he arranged for a formal call of the Academy on the President at the White House, this at a time when there was laxity in this custom. In these and other ways he used his office to enhance the standing of the Academy as an efficient servant of the Government of the United States."

Between 1881 and 1883, Marsh had much to do with placing the administration of the Academy's trust funds on a secure basis. As he said in his address to the Academy on April 19, 1889:

"The Academy may justly congratulate itself on the possession of its trust funds for the promotion of original research in science. Three of these, for discoveries in astronomy alone, are recent gifts to the Academy, and already the Draper, Smith, and Watson gold medals, the first fruits of these donations, have been awarded, and promise to do much to encourage future study. The acquisition of these gifts made it necessary for the Academy to secure from Congress the authority to receive and hold trust funds in aid of scientific investigations, and this was accomplished in June 1884."

The first award of a medal took place in 1886, when Samuel P. Langley was given the Henry Draper medal. In the following year the Watson medal was awarded to B. A. Gould. The J. Lawrence Smith medal was presented for the first time on the evening of April 18, 1888, in the lecture room of the U. S. National Museum, the recipient being Professor H. A. Newton. This meeting was made still more memorable by the presentation of the second Draper medal to Professor Edward C. Pickering. In Marsh's time ten medals in all were given.

In 1883, the Academy began the practice of sending delegates to other learned societies and to universities, both in this country and in Europe, Marsh being delegated in 1892 to represent the Academy at the tercentenary of the University of Dublin.

As is well known, the one thing that sets the National Academy apart from other scientific organizations in America is its relation to the Government. The Academy's historian, F. W. True, states this in the Jubilee volume of 1913 in these words:

> "Other scientific organizations were founded whose membership was drawn from all parts of the country, whose scope covered all branches of scientific research, and whose transactions reflected credit on their membership and on American science, but none could claim recognition as the scientific adviser to the Government."

The Academy was founded for this purpose, and its constitution was framed with this in view. Nevertheless, in the fifteen years previous to Marsh's administration, although committees had been called on twenty-seven times by the various Government bureaus for reports on technical matters, Congress itself had turned to the Academy but twice, once in 1869–1870 when the Academy was directed to draw up plans for the scientific operations of the *Polaris* expedition to the Arctic, and once in connection with the Transit of Venus Commission in 1874. During Marsh's official terms (vice president or acting president 1876-1883, and president 1883-1895), the Academy was asked for advice by Congress three times, indirectly by Congress once, and by the departments thirteen times. The work of all these committees is described in the Jubilee volume. From Marsh's time up to the Jubilee year (1896-1913), there were but five calls, a falling off of direct service that is ascribed by True to "the increase of large scientific organizations in the country, the growth of public opinion relative to scientific matters of more or less practical importance, and the development of the scientific bureaus of the Government."

Regarding this relationship of the Academy to the Government, Marsh said in 1889:

> "The question has arisen, shall the Academy, in addition to the duty of giving advice when asked, volunteer its advice to the Government? Members of the Academy have urged this course at various times in the past, and during the present session the question came up again for decision. My own opinion on this subject, after careful consideration, is against such action. The Academy stands in a confidential relation to the Government, as its scientific adviser, and in my judgment it would lose both influence and dignity by offering its advice unasked.
>
> "In appointing the committees on the part of the Academy, I informed them that the proper province of the National Academy is not merely to

make a technical examination in any case, but especially to bring out the scientific principles involved in the investigation, as a basis for future use."

Probably the most important, and certainly the most controversial, affair that came before the Academy in Marsh's period of administration was the reorganization of the various geological surveys, which was referred to the Academy by an act of Congress approved June 20, 1878, under the title, "On a Plan for Surveying and Mapping the Territories of the United States". This was concerned with the relative merits of military or civil control of public enterprises centering around the surveys of the public domain, and the discussion of it, begun as early as 1869, had become animated, acrid, and widespread. The Academy's solution of the problem was to have far-reaching results, not only for American geology in general, but for Marsh himself, whom that curious chain of circumstances hitherto noted had brought to the acting presidency of the Academy at this particular time.

The state of affairs that led up to this request by Congress has been described by George P. Merrill, in *The First One Hundred Years of American Geology* (1924), thus:

"The period of the Civil War had brought to light a considerable number of men for whom the piping times of peace, even when varied by Indian outbreaks in the West, afforded insufficient opportunities. They were men in whom the times had developed a power of organization and command. They were, moreover, men of great physical and moral courage. It was but natural, therefore, particularly when the necessity for military routes in the West and public land questions were taken into consideration, that such should turn their attention toward western exploration. . . . Willing workers were abundant and Congress not difficult to persuade into granting the necessary funds. Hence expedition after expedition was organized and sent out, some purely military, some military and geographic, with geology only incidental, and others for the avowed purpose of geological and natural history research."

As a result of this condition, there were functioning in 1874 six separate surveys of the western territories—two geological surveys under the Engineer Corps of the Army and two under the Department of the Interior, a land-parcelling survey under the latter department, and the United States Coast and Geodetic

Survey under the Treasury Department—all with little or no attempt at mutual collaboration, more or less overlapping, and consequent wasteful expenditure of time and of public funds.

The discussion finally became so acute that Congress decided reform must be brought about, and set it in motion with the following act:

"And the National Academy of Sciences is hereby required at their next meeting to take into consideration the method and expenses of conducting all surveys of a scientific character under the War or Interior Department, and the surveys of the Land Office, and to report to Congress as soon thereafter as may be practicable, a plan for surveying and mapping the Territories of the United States on such general system as will, in their judgment, secure the best results at the least possible cost; and also to recommend to Congress a suitable plan for the publication and distribution of reports, maps, and documents, and other results of the said surveys."

When this act was approved on June 20, 1878, Marsh was in Europe. Upon his return in August, after consulting members of the Academy Council and others, he at once set about fulfilling the wish of Congress. In his own words, as given in his annual report for that year:

"I was required to appoint a special committee to consider the subject. The report of the committee, when completed, could in accordance with the constitution of the Academy . . . be transmitted directly to the government, and afterward to the Academy at its next stated session. Inasmuch, however, as the subject to be considered was of great importance, I thought it better to have the report submitted first to the Academy before transmission to Congress.

"In the appointment of this special committee it was obvious that I could not properly select as members any of those who had taken part in the controversy between the then existing government surveys; which contention, it was said, had resulted in the passage of the law for the proposed reorganization. Again, the subjects to be considered by the committee pertained to mensuration, geology, and natural history, and I therefore selected those who were familiar with these branches of science."

The committee appointed by Marsh was made up of the following Academicians: James D. Dana, William B. Rogers, J. S. Newberry, W. P. Trowbridge, Simon Newcomb, and Alexander Agassiz. Their appointment, True says,

"led to a protest by General Humphreys, Chief of Engineers, who asserted that 'a properly constituted committee should have had among its members those officers in the Government service whose duties consisted in part or in whole in making geodetic, topographic, or other scientific surveys in the different departments of the government.'"

Marsh then went on to say:

"As the surveys under the War Department and the Interior Department were the special subjects for investigation, I addressed letters to the Secretary of War and the Secretary of the Interior informing them that a committee of the Academy had been appointed to consider the matter, and requested any information as to their plans or wishes in regard to the scientific surveys under their departments they might think proper to lay before the Academy. In reply, the Secretary of War sent a communication from the acting Chief of Engineers of the Army, and the Secretary of the Interior sent reports from the Commissioner of the General Land Office, from Prof. F. V. Hayden, and from Maj. J. W. Powell, all of which were carefully considered by the committee."

The committee deliberated some three months, then handed in a report of about 2000 words which was brought before a special meeting at the autumn session of the Academy in New York City, November 6, 1878, "and after a full discussion of three hours was adopted with only a single dissenting vote". Acting President Marsh then transmitted the report to the President of the Senate and to the Speaker of the House of Representatives.

The report recommended the recombination of the various surveys into three: 1. Coast and Geodetic Survey, "whose function will embrace all questions of position and mensuration"; 2. U. S. Geological Survey, to determine "all questions relating to the geological structure and natural resources of the public domain"; 3. Land Office, to control "the disposition and sale of the public lands": all three organizations to be within the Department of the Interior.

When the report was printed, the chief opposition to it came, as was to be expected, from the War Department, and especially from General Humphreys, Chief of Engineers, but despite this the House Committee on Appropriations incorporated the whole plan proposed by the Academy in a bill (House Res. 6140) which was duly reported to Congress. The final action by Congress, however, accepted only that portion of the plan relating to the establishment of a single geological survey under the Department of the Interior, and appointed a commission to consider the codification of laws relating to the survey and disposition of the public domain, leaving the matter of the mensuration surveys for the present in abeyance.

Another important recommendation of this report, adopted by Congress, was that

"All collections of rocks, minerals, soils, fossils, and objects of natural history, archaeology, and ethnology, made by the Coast and Interior Survey, the Geological Survey, or by any other parties for the Government of the United States, when no longer needed for investigations in progress shall be deposited in the National Museum."

This provision was added by Marsh.

Among the reports made by Academy committees to various departmental bureaus during Marsh's terms of service, one of the most discussed was that on glucose, presented in 1882 by Remsen, Chandler, and Barker, which covered 77 printed pages. With this report Marsh had nothing to do directly, but he was in frequent correspondence with the committee during its deliberations.

Marsh's presidency of the Academy came to an end in April 1895, when he refused re-election for a third term. In his farewell address, on April 19, he said in part:

"In conclusion, allow me to congratulate the Academy on the substantial progress it has already made, the sure foundation on which it now stands in its relations to the Government, and its high position in the ranks of the scientific societies of the world. . . . I am especially grateful for the unanimous vote of thanks by which you have set the seal of your approval on my services as vice-president and president of the Academy during the last seventeen years."

It was Marsh's wish that "the influence of the Academy should be scrupulously reserved for the promotion of noble ends." At his death in 1899, it was found that he had bequeathed to the Academy in his will the sum of ten thousand dollars "for promoting original research in the natural sciences," a sum that was later increased to twenty thousand dollars by the trustee of his estate.

MARSH'S WORK IN VERTEBRATE PALEONTOLOGY

The Astonishing Dinosaurs

Of all land animals that ever lived, none was more remarkable than the dinosaurs, and they were certainly the most wonderful creatures discovered in Marsh's time. They were the masters of the warmer parts of the continents during the Mesozoic era, and for about one hundred and thirty million years they were the rulers of all life. The Age of Reptiles saw their rise, culmination, decline, and extinction.

In general form, dinosaurs were more like mammals than any other class of animals, not sprawling as do most reptiles, but standing well up on their legs; nevertheless, they were the most specialized of all reptiles. Most significant was the smallness of their brains. It mattered not whether the head in these giants was a foot or eight feet in length, the sensory center weighed but a few ounces, or at most two pounds, in bodies that in some forms weighed as much as forty tons. Truly, the long Age of Reptiles was characterized by low mentality and brute strength.

Isolated bones and partial skeletons of carnivorous dinosaurs are now known to have been found as early as 1820 in the Upper Triassic strata near East Windsor, Connecticut; and in 1824 one of the duck-billed dinosaurs, *Iguanodon*, was described from the late Jurassic deposits of England, although the relationships were then unknown. Curiously, the numerous so-called "bird tracks" of the Connecticut Valley did not attract much attention until 1835, and it was many years later before these highly varied foot impressions were proved to be the tracks of dinosaurs. By 1841, enough different kinds of dinosaur remains were known to show the leading British anatomist, Sir Richard Owen, that these animals were different from all other known reptiles, and he proposed the name Dinosauria ("terrible reptiles") for them, regarding them as an order.

In this country, bones and teeth of small sauropod dinosaurs were found in 1858 in the Lower Cretaceous near Bladensburg, Maryland, and a single tooth of a different type was found about this same time by Hayden in the Judith River region of Montana. Still later, remains of *Iguanodon*-like dinosaurs were recovered in the marl pits of New Jersey farmers and elsewhere along the Atlantic border.

The possibility of the Great Plains as a major source for dinosaur remains may have suggested itself to Marsh on his first transcontinental trip, in 1868, when he was shown a sauropod bone found near Lake Como, Wyoming; but at that time he was apparently too much engrossed in other things to follow up the discovery. Late in 1870, in the marine strata of the Upper Cretaceous of western Kansas, he found the greater part of a small dinosaur skeleton that he named *Hadrosaurus* (now *Claosaurus*) *agilis*. It was of the same general type as those from the New Jersey marl pits, but only one or two other specimens of this species have been found since. A few years later, Cope brought back from the Judith River region of Montana a long series of dinosaur teeth (21 species), indicating that dinosaurs had been present there in abundance, and that some of them had reached considerable size. From that time on, Marsh was on the alert for dinosaurs, and he kept himself posted as to new finds through the newspapers of the time and through correspondence with military officers and scouts stationed at the frontier posts east of the Rocky Mountains. Partly as the result of this vigilance, there were two periods in his career when the dinosaurs of the Great Plains were on the march to New Haven in carload lots. The first of these "migrations" was of late Jurassic forms, and it began in 1877 and lasted strongly until 1886; the other, of late Cretaceous forms, began in 1888 and continued until 1892. These discoveries were so remarkable that the story may be told in some detail.

Late in the spring of 1877 Marsh received a most welcome letter from Arthur Lakes, an Englishman teaching school at Denver, stating that he and Captain H. C. Beckwith, U. S. N., were digging out, at Morrison, Colorado, the bones of a gigantic animal which they wished to sell. As Cope had also been informed of this find, Marsh rushed one of his experienced collectors, Professor B. F. Mudge, to Lake's quarry, and bought all the bones (including even the few remains that had been sent to Cope for inspection), announcing in July 1877 the discovery of "a new and gigantic dinosaur", which he named *Titanosaurus* (later *Atlantosaurus*) *montanus*. This striking new discovery was widely heralded in the newspapers of Denver and elsewhere, and other collectors were quickly at work. Mudge was sent to Canyon City to inspect another promising locality, and after his report, Marsh transferred Samuel W. Williston, one of Mudge's most alert students, from western Kansas to Colorado. Williston went to work with a will on September 21. It was only a short time, however, before he wrote Marsh that Cope's man, O. W. Lucas, was getting "by far the best lot of fossils," and that another man was out prospecting all the time for Cope. Young and impatient, Williston also set out to find "better bones," and by October 27 had gone as far north as Morrison. This battle of prospectors continued until Williston was ordered by telegram to go at once to Como, Wyoming, to look at still a third "bone-yard". From this place he wrote Marsh on November 14 that he had struck pay dirt with a vengeance, that well preserved bones could be had there "by the ton. . . . Canyon City and Morrison are simply nowhere in comparison with this locality. . . . I shall commence work . . . about 250 yards from the northwest shore of Como Lake."

The finding of these many dinosaur localities in Wyoming and Colorado finally led to the employment by Marsh of dozens of "bone-diggers", and during the years 1877 to 1886, Marsh and the United States Geological Survey spent there upward of $10,000 a year. In the course of these ten years about 134 small packages, mainly with mammal teeth, and at least 480 large boxes of dinosaur bones came from Como alone; in addition, Marsh received about 270 boxes of dinosaur bones from Canyon City, and 230 from Morrison. All in all, the late Jurassic formations—Marsh's Atlantosaurus beds—yielded him not less than 1115 boxes, large and small, of dinosaur remains. Out of this material he described 21 new genera and 41 new species, truly the richest harvest of dinosaurs ever garnered by a single paleontologist. Among them were the largest members of the order, *Brontosaurus* and *Diplodocus*, the carnivorous horned

Ceratosaurus, and also the most bizarre of dinosaurs, *Stegosaurus*.

The swamp-living sauropods, ponderous quadrupedal dinosaurs of world-wide distribution in late Jurassic time, included the largest land animals that ever lived, in fact, "greater than was supposed possible in an animal that lived and moved upon the land". One of the mightiest of these, the "thunder saurian," *Brontosaurus excelsus*, was described by Marsh from the most perfect sauropod skeleton ever dug up, found by Reed near Como. When the bones were discovered, Marsh states, the huge skeleton "lay nearly in the position in which the bones would naturally fall after death." In August 1883 he presented a lifelike restoration of this skeleton, the first to be published of any dinosaur, and this illustration, together with many other drawings based on his work, has gone into many textbooks. The *Brontosaurus* skeleton, as now mounted in the Peabody Museum of Yale University, is 67 feet long and 16 feet high at the hips, and the animal is estimated to have weighed nearly 30 tons in the flesh. The head is less than 2 feet long, "smaller in proportion to the body than in any reptile hitherto known," and the astonishingly small brain weighs less than one pound, while the enlarged neural ganglion in the sacrum is about three times as large. An Indian elephant ("Rya"), by contrast, had nearly 11 pounds of brain to 4 tons of body weight. A slenderer and lighter sauropod associated with *Brontosaurus* was *Diplodocus*, which had a length of nearly 80 feet to the end of its long whiplike tail.

The overspecialized stegosaurs of the late Jurassic of Wyoming and Colorado, first described by Marsh in 1877, were provided with a mighty armor composed of huge plates and long spikes, which Marsh placed in a single row down the back and tail. This curious armature, Marsh says, "could not have been anticipated and would hardly have been credited had not the plates themselves been found in position." Now, however, nearly all vertebrate paleontologists agree that these plates were arranged in two alternating rows along either side of the dorsal processes of the vertebrae, while the tail spikes were opposite, in pairs. These plates and spikes appear to have been for defense against the terrible carnivores of the time. *Stegosaurus* was more than 18 feet in length and about 10 feet tall; the beaked head was only about 17 inches in length, with a brain 5 inches long and weighing 2½ ounces or less, to control 10 tons of animated flesh.

Marsh's second period of dinosaurian discovery was concerned with the horned ceratopsians, whose evolution was recorded in about 3500 feet of late Cretaceous strata.

The Ceratopsia were again huge and ponderous dinosaurs, ranging up to 23 feet or more in length and up to 8 feet in height, with skulls from 4 to 8 feet long. The brain in these huge heads was not over 6 inches long and "smaller in proportion to the entire skull than in any known vertebrate." The jaws were provided with a sharp cutting beak, and in *Triceratops* there was a strong horn on the nose, a pair of very large pointed horns on the top of the head, and a row of sharp projections around the margin of the posterior crest. This huge, expanded crest, which overshadowed the back of the skull and neck, was evidently of secondary growth, a practical necessity for the protection of the neck and even more so for the attachment of the powerful ligaments and muscles that supported the great head.

The region from which nearly all the best ceratopsians come is an area about 15 by 35 miles in the east-central part of Converse [now Niobrara] County, Wyoming. In this area Hatcher, with the help of O. A. Peterson, W. H. Utterback, A. L. Sullins, W. H. Burwell, and Charles E. Beecher, worked for most of four years, shipping to Marsh more than 300 large boxes, containing 31 "big skulls" and several fairly complete skeletons of horned dinosaurs, besides much other material among which were more than 5000 small mammal teeth and jaws. The largest ceratopsian skull shipped was No. 24, which, with its box, weighed 6850 pounds. The amassing of this great amount of material was, as Osborn says, one of the greatest achievements of Hatcher's remarkable life.

In the revision of the Ceratopsia made by Hatcher and Lull in 1907, we learn that of the 13 genera proposed by Marsh, Cope, Lambe, and Lull, but 6 were left in good standing within the group, Marsh losing 2, Cope 4, and Lambe 1. Lull's memoir of 1933 recognizes 6 genera, 3 of which belong to Marsh.

In addition to the ceratopsians, Converse County yielded other dinosaurs, duck-billed and ostrich-like forms, both bipedal running types. The duck-bills (*Claosaurus* = "trachodonts") were characteristic animals of late Cretaceous time the world over, and lived along the shores of rivers and lakes. The front of the mouth had no teeth but the jaws had a horny cropping beak as in birds. Marsh's best material in this group came from Wyoming, where two entire skeletons were found, each with a length of about 30 feet and a height of 15 feet.

Marsh's work on the Dinosauria is recorded in 55 papers and books. These were issued between 1872 and 1899, and most of the results of the first 50 papers are summarized in his quarto monographs, *The Dinosaurs of North America* (1896) and *Vertebrate Fossils of the Denver Basin* (1896). In these publications Marsh named and described 80 new species (2 lost to Leidy),[5] and these he classified in 34 new genera, of which 27 are still in use (1 each lost to Leidy, Cope, and Johnston, and 4 to himself), in 7 new suborders, and 3 new orders—surely an astonishing record for one man to make in less than thirty years. Even more valuable than the descriptions is the perfection of much of the material left to posterity, since among the several hundred individuals studied by Marsh many are represented by almost complete skeletons. All this material is now in the United States National Museum, or in the Peabody Museum of Yale University.

In 1895, Marsh was not disposed to accept the view that the Dinosauria belong to two or more distinct groups, each of independent origin, because of "the very limited information we now have in regard to so many dinosaurs known only from fragmentary remains." The tendency among more recent authors, however, is to abandon the term Dinosauria, since it surely includes reptiles of two phylogenetic lines.

[5] The taxonomy followed throughout this paper is that used by O. P. Hay in his catalogues of fossil vertebrates, with one or two exceptions.

Flying Reptiles

Late in November 1870, after an especially successful day's fossil hunting in the chalk bluffs of the Smoky Hill River in western Kansas, Marsh was returning to camp with his soldier escort, when he espied from the saddle a fossil bone. The lateness of the day made it impossible for him to explore the rock further, but he saw that the bone "was hollow, about six inches long and one inch in diameter, with one end perfect and containing a peculiar joint that I had never seen before." Placing the bone in his "softest pocket," he re-examined it in camp and thought it might prove to be the tibia of a gigantic bird. Back in New Haven, with figures of other material for comparison, he saw that the bone was from the wing finger of a pterodactyl, the first remnant of these flying reptiles to be found in America, but of a much larger species than any known European form. He at once asked himself how great must have been the wing expanse of this animal when alive, and concluded that it "would be about twenty feet . . . truly a gigantic dragon even in this country of big things."

In June 1871, Marsh hurried back to the Smoky Hill River country and to the spot where he had found the bone the previous autumn. Dismounting, he found the impression of the very bone he had collected, "and following it up with great care, I obtained the upper end of the same bone." To his great joy, further digging turned up another joint which fitted onto the first one, and directly he "uncovered still another bone, and at last the whole series that supported the gigantic wing of the ancient dragon." These he measured roughly and determined that "this first found American dragon was fully as large as my fancy had painted him."

As all pterodactyls known up to 1876 were provided with teeth, Professor Marsh must have been greatly surprised to learn that his Kansas forms had none at all. In view of the fact that they showed characters so widely different from all other forms in the Old World, he proposed a new order for the American types this same year, calling it Pteranodontia, and the family, Pteranodontidae, from the typical genus *Pteranodon*. The nearly perfect skull and jaws of *P. longiceps*, he says, "are more like those of birds than of any known reptiles," and the head of *P. ingens* was no less than 4 feet long. The tail was slender and short, and the posterior limbs, though small, were well developed.

In the decade beginning with 1871 Marsh described and named, of the order Pterosauria, 3 new genera (1 a synonym), and 8 new species (1 preoccupied) from the Cretaceous of Kansas, and 1 new genus and 1 new species from the Jurassic of Wyoming. After 1876, so many extraordinary fossils crowded in upon him that he never was able to write a detailed account of his pterodactyls. This was well done later on, however, by Williston, in eleven papers published between 1891 and 1911, and by George F. Eaton in his *Osteology of Pteranodon*, 1910. From the latter memoir we learn that the spread of wing in the usual run of pteranodons was between 11 and 16 feet, but that the largest, *P. ingens*, shows a breadth of 22 feet, 3 inches, and single large bones indicate a probable maximum of 26 feet, 9 inches. The bones are a marvel of lightness, and Williston estimates that the entire animal, when alive, did not weigh more than 30 pounds. This combination of great wing expanse and extreme lightness of body was of much interest to Secretary Langley of the Smithsonian Institution in his pioneer aviation studies, and it was at his request that F. A. Lucas, of the Museum staff, made a reconstruction of *Pteranodon*.

In addition to his American finds, Marsh also secured one of the most perfect pterodactyls ever unearthed in Europe. This was found in 1873 by Martin Krauss in the late Jurassic lithographic limestone of Eichstätt, Bavaria, and there was great rivalry as to who was to have the specimen, which was of the long-tailed type with an abundance of teeth. Marsh cabled his friend, Prof. H. B. Geinitz, to secure this remarkable fossil for him, paying about $1000 for it and other Solenhofen fossils. It is now one of the gems of the Peabody Museum. It belongs to the genus *Rhamphorhynchus*, and Marsh gave it the specific name *phyllurus*. The bones of the skeleton, he says,

"are nearly all in position, and those of both wings show very perfect impressions of *volant membranes* still attached to them. Moreover, the extremity of the long tail supported a separate vertical membrane, which was evidently used as a rudder in flight."

Marine Lizards (Mosasauria)

Another group of reptiles to which Marsh made a considerable contribution was the mosasaurs, descendants of carnivorous land reptiles that at some time in the early Cretaceous, and at some place as yet unknown, had invaded the realm of the seas. So common that they were supreme rulers of the Upper Cretaceous seas, they grew to lengths of 30 and exceptionally of 40 feet, with skulls as long as 5 feet, and with backbones made up of more than 100 vertebrae. "On one occasion," Marsh says, "as I rode through a valley washed out of this old ocean bed, I saw no less than seven different skeletons of these monsters in sight at once." By 1880 he had at Yale bones representing not less than 1400 individual mosasaurs, collected, for the most part, by Williston, who became the leading authority on the group. Marsh himself, in eight brief papers, described 7 new genera (2 lost to himself and 2 to Cope) and 18 new species.

Birds with Teeth

The remains of birds are among the rarest of fossils. Their bones, other than those of leg and wing, being very frail, are soon destroyed by the atmosphere, by being crushed, or in other ways; and the buoyancy of their bodies, when afloat, causes the winds and waves to carry their cadavers shoreward where they are sure to be devoured by carnivorous or scavenging animals.

At the outset of his fruitful career in paleontology, Professor Marsh was well aware of these facts, and he was constantly on the hunt for bird remains. His first single bones he secured from New Jersey, in deposits considered at the time to be of Cretaceous age but recently placed in the Eocene; describing them in 1870 as 3 new genera and 5 new species of aquatic birds, he regarded them all as representatives of families now living.

In December of that same year, in the course of the first of his western explorations with a party of students, Marsh found a bird tibia in the Niobrara (Cretaceous) chalk of western Kansas, and it whetted his appetite for better material. The next year's party, hunting in the Smoky Hill region of the same state, was primed to look for fossil birds; and on November 29 Marsh wrote Professor Dana from San Francisco that among their season's trophies was the headless skeleton of a great bird, found by himself, and parts of four other individuals, found by his students; "on my return," he adds, "I shall describe this unique fossil under the name *Hesperornis regalis*," a promise which he made good in the *American Journal of Science* for January 1872.

The following summer Mudge was collecting in the Smoky Hill country, and Marsh, aware of this, wrote him on September 2 to inquire about his results. Mudge, well disposed toward Marsh from former acquaintance, "practically presented" him with a box of his fossils, regarding which Marsh wrote him on September 25 that "the hollow bones are part of a bird, and the two jaws belong to a small saurian. The latter is peculiar, and I wish I had some of the vertebrae for comparison with other Kansas species." Under this belief, the specimens were described by Marsh as pertaining to different animals, the avian bones being named *Ichthyornis dispar* in October 1872, and the "saurian" bones receiving the appellation *Colonosaurus mudgei* the following month. Not until further preparation of the specimens had revealed a skull and additional portions of both jaws did it become apparent that all the bones belonged to one animal, and that animal a *bird with teeth*. This remarkable discovery was announced in February 1873, in a preliminary paper in which the author modestly remarks that "The fortunate discovery of these interesting fossils . . . does much to break down the old distinction between Birds and Reptiles, which the *Archaeopteryx* has so materially diminished." Williston later spoke of these fossils as "by far the most important specimens of these early years [of Marsh's career], if not the most important of those succeeding," and Osborn in 1931 remarked that they constituted "the most important single palaeontological discovery" of Marsh's life.

In his more extended description of *Hesperornis regalis* in May 1872, Marsh considered it to be related to the Great Northern Diver *(Gavia immer)*, a reference that was later completely abandoned, as a result of the discovery, by T. H. Russell of the Yale party, of a nearly perfect skeleton of the same bird, including parts of the head and teeth—"an ample reward for the hardships and danger we incurred." When the great Cretaceous diver had been cleaned of all the adhering chalk, it was seen to be a bird 6 feet long and larger than any other known aquatic form, fossil or living. "The maxillary bones are massive," Marsh wrote, "and have throughout their length a deep inferior groove, which was thickly set with sharp, pointed teeth."

These astonishing discoveries were brought into even greater prominence in 1880, when Marsh produced his first monograph, a *magnum opus* entitled *Odontornithes: A Monograph on the Extinct Toothed Birds of North America*, a publication which was said by Henry Woodward, the English paleontologist, to surpass "any which have already appeared devoted to paleontology." This book, a sumptuous royal quarto with 201 pages of text, 40 woodcuts, and 34 lithographic plates, was published as one of the reports of the United States Geological Exploration of the Fortieth Parallel, under the direction of Clarence King, and also as Memoir 1 of the Peabody Museum of Natural History. The text was a most detailed description, bone by bone, of nearly entire skeletons of five species of toothed birds: *Hesperornis regalis, H. crassipes, Ichthyornis dispar, I. victor* (the two last named have curious biconcave vertebrae), and *Apatornis celer*. These descriptions were based upon about fifty different individuals of *Hesperornis* and seventy-seven of *Ichthyornis*—testimony to the care and patience with which Marsh's collectors combed the Kansas chalk for this rare material. "Never before," said Sir Archibald Geikie in his review of the monograph, "has it been possible, we believe, to reconstruct so perfectly so ancient an organism." The plates, which include a full-size restoration of *Ichthyornis* and one of *Hesperornis* half-size, were marvels of reproduction, "combined [with] an artistic finish which has made each plate a kind of finished picture." In defense of such elaborate plates, Marsh says in another paper (1885) that his aim was

"to do full justice to the ample material . . . and where possible, to make the illustrations tell the main story to anatomists. The text of such a

Memoir may soon lose its interest, and belong to the past, but good figures are of permanent value."

Aside from the above monograph, Marsh published fifteen pamphlets and notes on fossil birds between 1870 and 1880, to which he added but eight short articles during the next twenty years. In these twenty-four publications he described 1 new subclass of fossil birds, 2 new orders, 16 new genera (2 are synonyms: *Colonosaurus=Ichthyornis*, and *Lestornis=Hesperornis*), and 43 new species (3 are synonyms, 1 lost to Cope). Of these species, 1 occurs in the Jurassic *(Laopteryx priscus)*, 15 in the Cretaceous (12 in the Niobrara, 1 in the Claggett, 2 in the Lance), and 24 in the Cenozoic.

In *Odontornithes*, Marsh says: "The Struthious characters seen in *Hesperornis*, should probably be regarded as evidence of real affinity, and in this case *Hesperornis* would be essentially a carnivorous, swimming Ostrich." This conclusion "did not meet with general acceptance . . . and before long the Ratite affinities of *Hesperornis* were seldom alluded to in scientific literature." When Williston in 1896 described a specimen of *Hesperornis* with some of the feathers in place, Marsh commented that "these feathers are the typical plumage of an Ostrich," and rejoiced that this find proved "beyond dispute" that the nearest affinities of the Odontornithes were with the Ratitae. However, ornithologists of the present day still see no genetic connections here.

In his Nashville address, Marsh stated:

"It is now generally admitted, by biologists who made a study of the vertebrates, that birds have come down to us through the Dinosaurs. . . . The case amounts almost to a demonstration, if we compare, with Dinosaurs, their contemporaries, the Mesozoic birds. The classes of Birds and Reptiles, as now living, are separated by a gulf so profound that a few years since it was cited by the opponents of evolution as the most important break in the animal series, and one which that doctrine could not bridge over. Since then, as Huxley has clearly shown, this gap has been virtually filled by the discovery of bird-like reptiles and reptilian birds. *Compsognathus* [once thought to be a bird but shown by Gegenbaur, Huxley, and Marsh to be a dinosaur], and *Archaeopteryx* ["the most reptilian of birds"] of the Old World and *Ichthyornis* and *Hesperornis* of the New, are the stepping stones by which the evolutionist of today leads the doubting brother across the shallow remnant of the gulf once thought impassible."

At present, systematists would say that there is not much else besides feathers to distinguish birds from reptiles.

Marsh in 1880 regarded the Odontornithes, or birds with teeth, as a subclass, which he divided into three orders: (1) Odontocolcae, for the *Hesperornis* type; (2) Odontotormae, for the *Ichthyornis* type (in modern classification these are of the order Carinatae); and (3) Saururae of Haeckel, for *Archaeopteryx*. That these oldest types of true birds

"should differ so widely from each other points unmistakably to a great antiquity for the class . . . but the reptilian characters they possess are convergent toward a more generalized type. No Triassic birds are known. . . . [When they are found], if we may judge from Jurassic Mammals and Reptiles, the next classes above and below Birds, the avian forms of that period would still be birds, although with even stronger reptilian features. For the primal forms of the bird-type, we must evidently look to the Paleozoic; and in the rich land fauna from American Permian we may yet hope to find the remains of both Birds and Mammals."

This hope has not yet been realized.

Lucas (in Zittel, 1902 ed.) holds that the birds are "descended without question from reptiles, their affinities with that class are so intimate that Huxley included them both under the common designation of Sauropsida." He objects, however, and correctly, to this merging of birds with reptiles.

Alexander Wetmore, in his *Systematic Classification for the Birds of the World, Revised and Emended* (1934), agrees with Marsh's views as to the systematic relations between the Mesozoic birds and the more recent ones. He refers the Jurassic reptilian birds to the subclass Archaeornithes (ancestral birds), while placing the Cretaceous toothed birds in the subclass Neornithes (true birds), in the superorder Odontognathae (New World toothed birds), and in the orders Hesperornithiformes *(Hesperornis* and *Hargeria)* and Ichthyornithiformes *(Ichthyornis)*. While this places them near the ostriches (superorder Palaeognathae or struthious birds) among recent birds, they are not considered as closely allied to that group.

Doctor Wetmore, after kindly reading the above section, made the following comment:

"Marsh's discovery of the toothed birds in the fossil deposits of Kansas though made at so early a day still ranks as one of the outstanding discoveries in palaeornithology in North America. And to his original studies little that is new has been added, except to refute Marsh's belief that these Cretaceous species were closely allied to the living ostriches. In point of fact the toothed birds seem set apart by themselves from all living forms.

"In view of the very definite specialization of *Hesperornis* and its allies for an aquatic existence, and of *Ichthyornis* for life in the air it seems strange that no cursorial type has yet been discovered in Cretaceous deposits, though birds of this kind are found well developed in the Tertiary."

Mammals in General

Originally, Marsh intended to devote most of his time to the study of fossil mammals, but when he began to get the well preserved skeletons of gigantic dinosaurs, he became more and more overwhelmed by the extraordinary evolution shown in this phylum of reptiles, of which very little was known to paleontologists in the seventies. Accordingly, his projected monographs on the Mesozoic mammals, the horses, and the brontotheres failed to materialize, although the handsome one on the Dinocerata appeared in 1885 (author's edition).

Marsh treats of fossil mammals in eighty-five different publications, and his most productive years for describing them were the seventies. In these papers he describes as new 255 species and 120 genera; 38 of the species and 43 of the genera are known to be synonyms. Their variety is so great and their history is so intricate that of most of them little can be said in this memoir. In the list following, these mammals are grouped by orders, and those marked with an asterisk will be presented in more detail. Figures in parentheses indicate synonyms.

Subclass Allotheria. Mesozoic mammals.
- Order Multituberculata.
- Order Triconodonta.

Subclass Eutheria. Viviparous mammals.
- Infraclass Pantotheria.
  - Order Symmetrodonta.

Infraclass Didelphia. Non-placental mammals.

Order Marsupialia, opossums, kangaroos, etc.

Of the above orders, Marsh described:

* Late Jurassic mammals, 15 genera(9) and 25 species(6).

* Late Cretaceous mammals, 19 genera(10) and 37 species(21).

Infraclass Monodelphia. Placental mammals. All of Cenozoic time. Has the following orders:

Insectivora, 12 genera(6) and 18 species(3).

Tillodontia Marsh, 1 genus and 4 species.

Taeniodonta, of uncertain systematic relationship, 2 genera and 2 species.

Cheiroptera. None of the "bats" described by Marsh belong in this order.

Xenarthra, ground sloths or Gravigrada, 1 genus and 2 species.

Rodentia, 5 genera(2) and 11 species(1).

Carnivora, 11 genera(3) and 17 species(1).

Primates, 5 genera(3) and 10 species(1). Five species are lemurs and five are tarsioids, the first of these primitive primates to be found in America.

Condylarthra, primitive ungulates, 2 genera(1) and 3 species(1).

* Amblypoda, short-footed ungulates, 3 genera and 23 species of * dinoceres.

Coryphodontia, 1 species.

Sirenia, sea cows, 1 genus and 1 species.

Perissodactyla, hoofed animals with an odd number of toes, including the * horses with 8 genera(2) and 19 species(1); the * brontotheres with 13 genera(4) and 21 species(5); the tapirs with 2 genera and 3 species; and the rhinoceroses with 5 genera and 14 species.

Ancylopoda, clawed animals with an odd number of toes, 1 genus and 3 species.

Artiodactyla, cloven-hoofed animals with an even number of toes, including oreodonts, swine-like mammals, camels, deer, antelopes, etc., 21 genera(4) and 49 species(1).

Mesozoic Mammals

From the phylogenetic viewpoint, the *Jurassic mammals* are probably the most significant of the whole class Mammalia, but unfortunately these fossils are amongst the greatest rarities, nearly all the known specimens being fragmentary jaws and isolated teeth. Even so, as G. G. Simpson said in 1928, "one is at least dealing for the most part with jaws with their included teeth and direct comparisons between the established genera are possible in most cases".

The first Mesozoic mammal jaw was found in England in 1764, but it was not recognized as such until 1824, when the great anatomist, Cuvier, saw it and pronounced it mammalian. In 1871 it was named *Amphilestes broderipii* by Owen. Professor Marsh, from his European studies, was fully aware of the desirability of obtaining more of these early mammals, and he was constantly urging his field men to be on the watch for small fossils. Due to this prodding, one of his best collectors, W. H. Reed, excavating for dinosaurs at Como Bluff, Wyoming, in 1878, found a good lower jaw of a mammal about the size of a weasel. Marsh named this find *Dryolestes priscus*, and added that it represented a marsupial "allied to the existing opossums". Late in 1879, Marsh named more of these "medieval" mammals, saying that they show "such a resemblance to known types from the Purbeck of England, that some connection between the two faunae is clearly implied." Further study convinced him that these mammals

"cannot be satisfactorily placed in any of the present orders. This appears to be equally true of the European forms. . . . With the exception of a very few aberrant forms, the known Mesozoic mammals may be placed in a single order, which may appropriately be named Pantotheria."

This order is still recognized by some systematists, and Marsh's order Allotheria is now raised to a subclass.

These finds led to a more systematic search for mammals, notably in the famous Quarry 9 at Como, from which, thanks to a year's careful and persistent search, nearly all the more than 400-500 separate specimens of American Jurassic mammals have come. The cost involved in getting these tiny fossils makes them worth more than their weight in gold, and they are among the great treasures of the museums at Yale and at Washington.

Carrying out Marsh's original intention, all the Mesozoic mammal material thus collected has now been elaborately monographed by George G. Simpson (1928), who finds 44 Jurassic species in 23 genera. However, even our present knowledge of these early mammals, garnered over more than a century of endeavor by many paleontologists, represents, according to Simpson, only "lights in the vast darkness of the Age of Reptiles—and very dim lights most of them are".

No authentic *Cretaceous mammals* appear to have been found anywhere until 1882, when isolated teeth of such were discovered by J. L. Wortman in the Laramie formation of Wyoming. It was, however, not until 1889 that they began to be found in any quantity, Hatcher writing Marsh on May 20 that he was sending to New Haven by registered mail "a package containing some 4 or 5 species of Laramie mammals. . . I hope you will be pleased and will not despise them because they are few in number. They are by no means abundant, the few I send you requiring several days careful search." Marsh was pleased indeed, so much so that on June 8 he telegraphed Hatcher to stop work on ceratopsian skeletons and go after mammals entirely, for which he then had four different localities. Within the next four years, Hatcher, assisted by C. E. Beecher and other collectors, sent to Yale about 5000 teeth and some jaws and skeletal parts. As early as July 1889 Marsh had a paper in print describing 12 genera and 18 species of these Cretaceous mammals, and announcing that he had in preparation for the United States Geological Survey a memoir on this "rich mammalian fauna". In this paper he gives credit to Hatcher for the discovery of "material for a new chapter in paleontology".

Simpson's study finds that these Cretaceous mammals are still very inadequately known, because of their usual isolated occurrence as teeth "which cannot be associated into natural genera in the majority of cases . . . the characters of two consecutive teeth of a single genus cannot be determined in many instances." Marsh was aware of the necessarily artificial nature of his classification of these Cretaceous mammals; as Simpson says, Marsh had to resort to an analytical basis, giving names "not to distinct animals but to different types of teeth. Under the circumstances there was much to be said for this procedure." Even yet the time is not at hand for a synthesis of these teeth into genera and species based on entire animals, and Simpson concludes that "a revision, in the strictest sense, is impossible".

THE CURIOUS DINOCERATA

The relatively abundant short-footed amblypods for which Marsh erected the suborder Dinocerata originated in Wyoming during the late Paleocene and died out at the close of the Eocene epoch, being the most striking and characteristic animals of middle Eocene (Bridger) time. They are also known in Mongolia, whither they migrated from America. Some of the larger forms, standing 6-7 feet high at the shoulders, were elephant-like in bodily build, but they had no trunks and their curious heads were wholly unlike those of the proboscideans in that they bore three pairs of horns; and, in the males at least, the upper canine teeth were drawn out into long recurved saber-like tusks that must have been terrible weapons, although the manner of their use is unknown. The brain was exceedingly small.

While Leidy was the first to discover bones of the Dinocerata, his material was very fragmentary. To Marsh belongs, as Wortman said in 1899, "the credit of the final determination of their structure and affinities; he classified them in a separate and distinct order, Dinocerata, a name which has been very widely adopted by naturalists."

In September 1870, Professor Marsh, with a large party of Yale students, explored the Green River basin of western Wyoming under military escort. Here they found a large "boneyard", in which mammal remains were the most abundant fossils. Among these was a partial skeleton which Marsh the following year referred doubtfully to Leidy's genus *Titanotherium*, calling the species *T. ? anceps*. He returned a number of times to this basin, and to other nearly as rich ones in the Green River country, and brought back many more specimens of this group, which he named Dinocerata in 1873, and of which he finally had more than two hundred individuals, including some twenty skulls in good condition—striking testimony to the tenacity and thoroughness so characteristic of Marsh as a collector.

Between 1872 and 1885, Marsh issued no fewer than thirty-four papers treating of the Dinocerata, the series culminating in the quarto volume entitled *Dinocerata, a Monograph of an Extinct Order of Gigantic Mammals*, which, illustrated by 200 woodcuts and 56 lithographic plates, ranks among his best studies. This volume describes 3 of Marsh's genera, *Dinoceras, Tinoceras,* and *Laoceras* (subgenus), and 1 of Leidy's, *Uinta-*

therium, the four together having 23 species named by Marsh and 6 named by other authors (Cope 3, Osborn 2, Leidy 1).

It was the naming of these mammals that led in large part to the intense rivalry between Cope and Marsh, into which the older Leidy—a man "insensible to and unaffected by the ordinary passions of ambition or rivalry"—was unfortunately drawn.

While a student in Germany, Marsh had met Cope, and previous to 1870 they had exchanged friendly letters. Shortly after Marsh's return, he called on Cope at Haddonfield, New Jersey, collected fossils with him, and purchased some of his material. Marsh's expedition to the West in 1870, however, and its great success in securing vertebrate fossils, as reflected in his papers of 1871 describing 4 new genera and 27 new species, showed the Philadelphia group, represented by Leidy, Cope, and Hayden, that here was a very real competitor.

Hayden had begun exploring on his own account in the Missouri River country as early as 1854; in 1856 he joined Lieut. G. K. Warren's survey, and in 1859 that of Capt. W. F. Raynolds. In 1867, he was called on to organize the United States Geological Survey of the Territories, which, at the time of its formation, was one of four separate national surveys in the Rocky Mountain country. All the vertebrate fossils collected by Hayden had been turned over for study to Leidy and later to Cope, and up to and including 1870 the former had described from the West slightly more than 100 new species. After the early seventies, Leidy dropped more and more out of the field of western vertebrate paleontology, but Cope in 1872 published thirty-four papers and notes, a strong indication of his intention to remain there.

When Congress abolished the four independent surveys in 1879, and called for a single new organization, the United States Geological Survey, to be headed by Clarence King—a reorganization with which Marsh had considerable to do—Cope and Hayden found themselves supplanted in their work for the federal government.

Returning to the battleground of the Dinocerata, Marsh published thirty-five papers on this group between 1871 and 1884, and Cope at least twenty-nine. Seven of Cope's papers describing new genera and species were dated 1872; Marsh doubted this date and he set to work to find out the actual dates of issue, presenting his findings in ten different papers appearing during 1873. As a result of this tangle of conflicting dates, the taxonomy of the Dinocerata is even yet not settled, nor will it be until some judicially minded vertebrate paleontologist, fully conversant with the International Rules of Nomenclature, studies all the great mass of material in the various museums.

The Great Brontotheres

On the third Yale expedition to the West, in 1872, two members of the party, H. B. Sargent and J. W. Griswold, found remains of a huge new mammal, to which Marsh in the following year gave the interesting name *Brontotherium gigas*, the "great thunder beast." Marsh showed this striking new type to be a true perissodactyl, and, according to Osborn, "was able in a very few words to throw a flood of light upon the characters of the skeleton." These animals are often called titanotheres, but since the generic name *Titanotherium* (of Leidy) no longer stands, it would seem that for the name of the group we should fall back upon Marsh's term brontotheres; this is also W. B. Scott's conclusion (1937). These creatures once roamed in great herds over what is now the Great Plains of eastern Colorado, Wyoming, Dakota, and Nebraska. Their brains were no larger than a man's fist even in the largest of the group, which attained almost the bulk of an elephant. As Scott says, these great beasts "were even more dull and stupid than are modern rhinoceroses."

Although elephantine in bulk, the brontotheres were less heavily built proportionally, and stood somewhat higher. The head was saddle-shaped, with a blunt horn on either side of the nose. The first of the group were comparatively low of stature, and their "horns" were small knobs, well back of the eyes. With the passage of geologic time, the horns grew longer and the animals larger, so that the skull became a yard long and the horns a foot high and on the very end of the nose. These animals arose early in the Eocene of North America, and died out in the Oligocene, a geologic interval of about ten million years. Recently they have been discovered in the Eocene and

Oligocene of Mongolia. Their genetic evolution took place along four main stems, but counting all the side branches, Osborn later indicated not less than eight phyletic lines, with 23 genera, 8 of which were named by Marsh.

Between 1873 and 1891, Marsh published thirteen papers on these brontotheres. In 1889, he presented a restoration of *Brontops robustus*, pointing out that it represented the largest animal of its time. Bones of this animal were first found in 1874 by H. C. Clifford, south of the Black Hills near Chadron, Nebraska, not far from the White River, but not until 1886 were most of its parts finally recovered, and the left hind leg is still missing; the mounted skeleton is one of the greatest treasures in the Peabody Museum.

In the early 1880's Marsh planned a large and well illustrated monograph on the brontotheres, and for it made sixty lithographic plates, but at the time of his death in 1899 he had not even begun to prepare the manuscript. The United States Geological Survey in 1900 transferred the task of writing this monograph to H. F. Osborn, but he was not able to finish it until 1919, and another ten years passed before the two handsome volumes appeared under the title *The Titanotheres of Ancient Wyoming, Dakota, and Nebraska*. They form the most far-reaching work on a single group of vertebrate fossils ever published, and it is pleasant to read in them that Marsh

> "made the largest and most valuable contributions to our knowledge of this family and of its evolution. He planned the monumental field work of John Bell Hatcher, by which the great collection for the United States National Museum was made [which has more than 158 skulls and jaws] and he supervised the preparation of the sixty lithographic plates, which are here reproduced."

Increase of Intelligence in Geologic Time

From 1870 on, whenever Marsh had sufficient material, it was his rule to have his preparators section the rear end of fossil skulls and clean out all the rock or crystalline material in the brain cavity. Into this cavity was then poured warm gelatine, which, because of its marked pliability, could be easily pulled out of the cavity, when cold, without tearing off any of the projecting parts. From this gelatine cast a more permanent mold would be made that permitted the taking of other replicas.

By 1874, he had brain casts of many Cenozoic mammals, and these enabled him to make a first attempt at a generalization regarding brain growth in geologic time. On the evening of June 17, he presented his conclusions before the Connecticut Academy of Arts and Sciences in New Haven. The Eocene mammals, he said,

"all appear to have had small brains, and in some of them the brain cavity was hardly more capacious than in the higher reptiles. The largest Eocene mammals are the *Dinocerata*, which were but little inferior to the elephant in bulk. In *Dinoceras* . . . the brain cavity is not more than one-eighth the average size of that in existing Rhinoceroses. . . . The gigantic mammals of the American Miocene [=Oligocene] are the *Brontotheridae*, which equalled the *Dinocerata* in size. In *Brontotherium* Marsh . . . the brain cavity is . . . about the size of the brain in the Indian *Rhinoceros*. In the Pliocene strata of the West, a species of *Mastodon* is the largest mammal, and although but little superior in absolute size to *Brontotherium*, it had a very much larger brain, but not equal to that of existing Proboscidians. The Tapiroid ungulates of the Eocene had small brain cavities, much smaller than their allies, the Miocene *Rhinocerotidae*. The Pliocene representatives of the latter group had well developed brains, but proportionally smaller than living species. A similar progression in brain capacity seems to be well marked in the equine mammals."

In 1876, Marsh briefly recapitulated his knowledge as follows:

"*First*, all Tertiary mammals had small brains; *second*, there was a gradual increase in the size of the brain during this period; *third*, this increase was mainly confined to the cerebral hemispheres, or higher portion of the brain; *fourth*, in some groups, the convolutions of the brain have gradually become more complicated; *fifth*, in some, the cerebellum and olfactory lobes have been diminished in size."

These statements he repeated in his Nashville address the following year, adding:

"In the long struggle for existence during Tertiary time, the big brains won, then as now; and the increasing power thus gained rendered useless many structures inherited from primitive ancestors, but no longer adapted to new conditions."

In his Presidential Address at Saratoga in 1879, he went still further, saying:

"More recent researches render it probable that the same general law of brain-growth holds good for birds and reptiles from the Mesozoic to the present time. The Cretaceous birds, that have been investigated with reference to this point, had brains only about one-third as large in proportion as those nearest allied among living species. The Dinosaurs from our Western Jurassic follow the same law, and had brain cavities vastly smaller than any existing reptiles."

To the five conclusions regarding brain growth stated in 1876, and later presented as an "outline of a general law of brain growth," Marsh made two additions in the Dinocerata monograph (1885), as follows:

6. "The brain of a mammal belonging to a vigorous race, fitted for a long survival, is larger than the average brain of that period in the same group."

7. "The brain of a mammal of a declining race is smaller than the average of its contemporaries of the same group."

HONORS

When one considers that in Professor Marsh's time, honors and other evidences of distinguished achievement were not as numerous as they are now, those that he received make an impressive list.

On the academic side, his record includes the class valedictory at Andover, a High Orations stand at graduation from Yale, a Berkeley Scholarship, and election to Phi Beta Kappa; he received an honorary Ph.D. from Heidelberg University at its 500th anniversary in 1886, and Harvard's doctorate of laws in the same year, at its 250th anniversary.

President of the American Association for the Advancement of Science in 1878, he was vice-president of the National Academy of Sciences from 1878 to 1883, and its president from 1883 to 1895. He was vertebrate paleontologist of the United States Geological Survey from 1882 to 1899, and honorary curator of vertebrate paleontology in the United States National Museum from 1887 until 1899.

From the Geological Society of London, of which he was elected a Fellow in 1863 and a Foreign Member in 1898, he received the Bigsby Medal in 1877; and twenty years later he received Vertebrate Paleontology's *cordon bleu*, the Cuvier Prize from the Institute de France, becoming Correspondent of the French Academy the next year.

He was a member or an honorary member of forty-one scientific societies or academies, and six of a non-scientific nature, distributed as follows: United States, 26; England, 4; Belgium, 4; Germany, 4; France, 2; and one each in Canada, Mexico, Argentina, Ireland, Denmark, Italy, and Russia.

His epitaph, written by his lifelong mentor, Professor Brush, reads: "To Yale he gave his services, his collections and his estate."

"Here are they to whom, from the depths of space, were whispered in the night watches its long hidden secrets. There, too, are those who, in the silence of the laboratory, rejoiced in the fertile marriage of the elements, or they who, like confessors, heard from dead bones or rock or flower the immeasurable history of the silent ages of earth."

S. WEIR MITCHELL,
At the Jubilee banquet of the National Academy of Sciences.

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OF

Othniel Charles Marsh

1831–1899

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