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SAMUEL WENDELL WILLISTON

1852—1918

A Biographical Memoir by

RICHARD SWANN LULL

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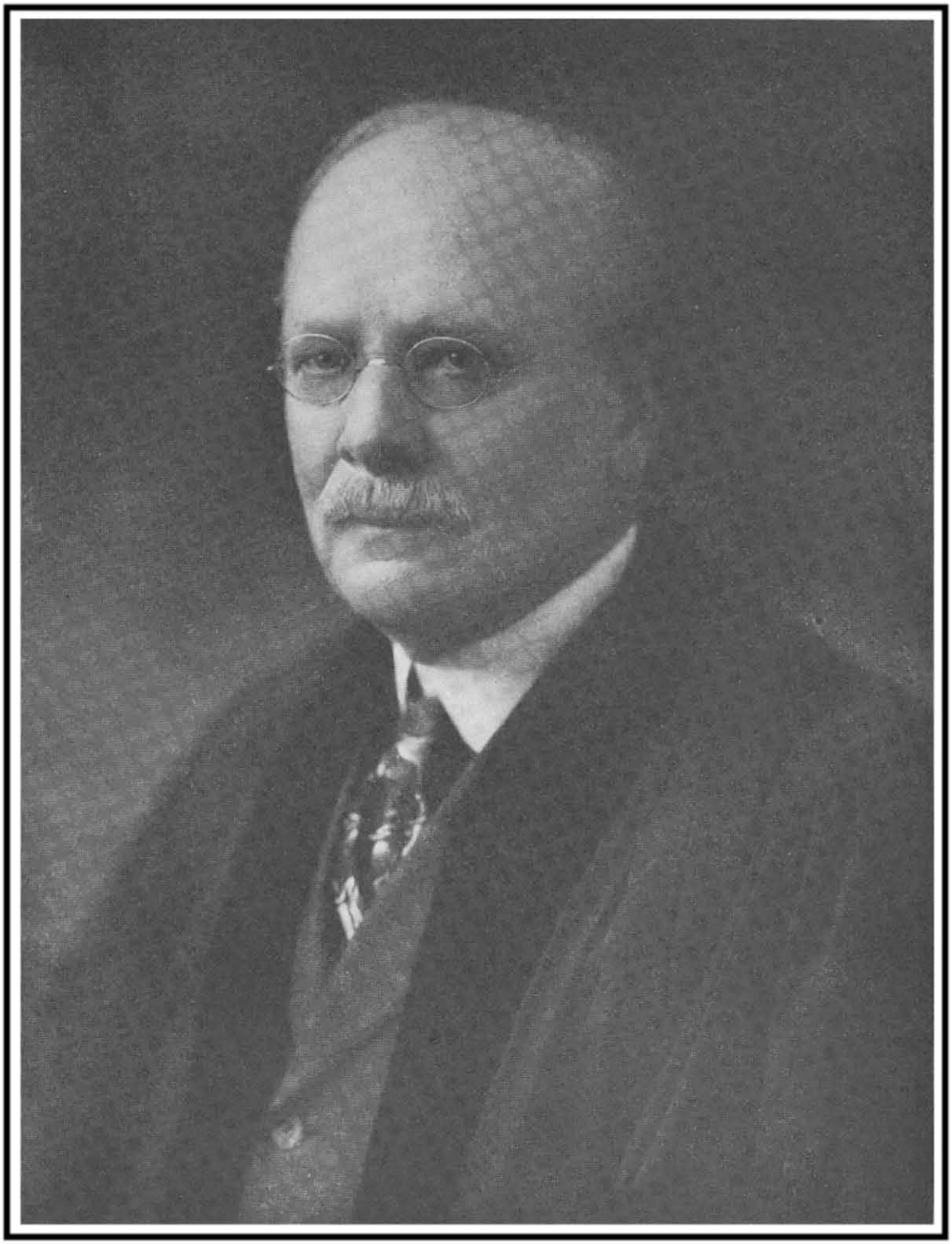

S. W. Mellon

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Part I.—Biographical Sketch.

In his immediate family, Prof. Williston stood as a conspicuous figure, as a scholar, a man of research, and one who by an innate superiority made himself what he was. For he owed little to his forebears other than the heritage of those sterling qualities which have made New Englanders in general so vital a force in the evolution of our national character and prestige; his scientific tendencies were an individual characteristic, and he stands as the only recorded Williston to follow lines of scientific research.

Williston's father, Samuel Williston, was a blacksmith, and, although a man of considerable native ability, was totally untrained in the affairs of book men. He possessed, however, that pioneer spirit which impelled so many eastern men to migrate to the developing West and seek in a new environment the elusive fortune which the East did not provide. Hence, while Williston was born in Boston, his development, in so far as environment exerted a control, was due almost exclusively to the stimulating conditions of the newly invaded West. Here he spent his boyhood. Of less robust physique than were his three older brothers, he sought companionship in whatever books came his way, reading without discrimination, largely because the volumes were so few. His was a laudable ambition, however, for he very soon announced his determination of being the most learned man in Kansas.

His schooling was necessarily erratic, but none the less progressive, beginning with the alphabet, which was learned from the lettering on the cookstove, and continuing through the elementary schools of Manhattan, Kans., coupled, as has been said, with the most omnivorous reading. It was largely due to the influence of his mother, Jane Turner, that Williston and his brothers had any opportunity for schooling, for she determined that they should not suffer the handicap of illiteracy against which her husband had to contend.

Williston's first interest in paleontology was aroused in his seventh year. The boys had often gathered clams in the Blue River near Manhattan, but he found fossil clamshells on the summit of a hill known as Blue Mont. He knew clams could not crawl on land, and accordingly sought of his father and Sunday-school teacher the solution of the mystery. Their explanation, had they but known, was like that by which the ancient Greeks sought to reconcile the presence of mollusks' shells high upon the hills around the Mediterranean, and to the boy the simple Biblical explanation of their being relics of the Deluge seemed at that time sufficient and served to awaken an interest in the Book of Genesis which he had not had before. There were also large stones filled with fossil shells of lower Permian age in the boys' favorite swimming hole, and these constituted Williston's first subjects for paleontological study.

Fishing and hunting were the father's favorite recreations, and the preparation of the fish for cooking was young Samuel's task. Catfish, shad, and river sturgeon, the last with its apparent lack of a vertebral column, in place of which there was a long fibrous rod, the notochord, gave rise to much speculation on the part of the boy, and this also served directly to stimulate his interest in natural history.

Blue Mont College had been founded in 1859, but was merged into the State Agricultural College in 1864, and two years later Williston was permitted to enter it as a student. Stimulated by his reading, he soon decided to become an author, but the nearest approach possible at this time was to aid in the printing of a semiweekly newspaper at Manhattan. It was during this service that Williston's first literary contribution appeared—a supposedly humorous

account of the capture of Jefferson Davis, by the "printer's devil," who was at that time but 13 years old.

However, the value of learning the printer's trade did not outweigh that of further schooling, so Williston was sent back to the Agricultural College to continue his work. Here he read Lyell's "Antiquity of Man," which made him a firm believer in evolution, despite its evident antagonism to the teaching of the church. His friend and preceptor, Prof. Mudge of the Agricultural College, to whom he owed so much, remained opposed to the doctrine until his death. Under Prof. Mudge, Williston studied natural philosophy, chemistry, botany, geology, zoology, veterinary science, mineralogy, surveying, spherical geometry, conic sections, calculus—a range of subjects possible only in the older days. In 1869 unrest again seized Williston, so in spite of the fact that he had not completed his collegiate education he decided to seek his fortune, and after somewhat varied and disheartening experiences received the opportunity of doing railroad construction work, first in a clerical, later in an engineering capacity, until finally his health, which was still not at all robust, compelled him to give up such work and return to college. He completed his course in 1872, taking the bachelor of science degree, for he did not feel sufficiently proficient in Plato and Herodotus to make up the back work necessary for the degree of bachelor of arts. The panic of 1872 and 1873 made it impossible for him to obtain employment as a civil engineer. This circumstance proved to be of vital importance in his career, for, an early interest in medicine reawakening, he determined to study under the supervision of the family physician, Dr. Patee, of Manhattan, a regular procedure in those days, when all that was required was that a student of medicine "read" in some physician's office for three years, taking two courses of lectures of four or six months each, the second merely a repetition of the first, before coming up for his degree. Williston was given very little advice or direction in his studies, except that he was told to study anatomy and physiology first. For material he excavated in an old Indian burial ground, and the study of the bones thus exhumed directed his attention to osteology, in which he later became so high an authority.

Trouble in the Agricultural College in 1873 led to the dismissal of Prof. Mudge, and Williston, not understanding the situation, took the former's classes for a while. The apparent injustice of the matter, however, made him so strong a partisan of Prof. Mudge that his manifestation thereof proved more than the authorities could stand and he was asked to leave. Otherwise he might have succeeded his preceptor as a teacher of comprehensive "science."

Williston's convictions concerning evolution, the result of absorbing the writings of Darwin, Huxley, Tyndall, and especially a German writer, Buecher, coupled with evidences from his own observation, led to his delivering in the Congregational Church of Manhattan what he believed to have been the first public lecture in favor of evolution ever given west of the Mississippi River. This was in February, 1874, and was, as he himself says, given with the cocksureness of youth, the address being lacking neither in positive nor dynamic statements. Such a thing was daring in those days, nevertheless Williston was shocked at the severe criticism which he received in the local press.

Meanwhile Prof. Mudge was carrying on geological explorations in western Kansas and had discovered the famous specimen of the Cretaceous toothed bird, *Ichthyornis*, which by pure accident he sent to Prof. Marsh rather than to Prof. Cope, for whom he intended it. Marsh's interest was promptly stimulated, and in his characteristic way he immediately engaged Mudge to collect fossils for Yale College. Mudge and a young assistant collected for a while in the northwestern part of the State, and then, as the hope of success seemed more promising in the Smoky Hill Valley, decided to move thither. Fear of the Indians, however, proved to be too much for the assistant, and Mudge was forced to seek other aid. He engaged one of his former students, H. A. Brous, who in turn invited Williston to accompany him, and after fulfilling an engagement to play the cornet in a band on July Fourth, Williston began what was to be his subsequent life work as a paleontologist. Thus, as he says, "It was this accidental and thoughtless decision that led to my life's devotion to Paleontology. Had I not gone with him in all probability [to-day] I would have been a practitioner of medicine somewhere in Kansas."

Upon the completion of the summer's campaign, Williston went to the University of Iowa for the first course of medical lectures, but in the meanwhile Prof. Marsh's attention had been called to him, probably because the specimens collected by each man were marked with his name. At any rate, in February Williston was invited to come to New Haven, and the offer was eagerly accepted, for, as he says—

> I had lived practically all my life remote from scientific men, and authors were almost unknown. I had always been a bookworm of the most accentuated type; I had grown to reverence, almost to worship, the writers of books and especially of scientific books. * * * Such men as Huxley, Darwin, Dana, Gray, and Marsh were my ideals of all that was great and good. I thought them impeccable and almost infallible. My greatest ambition was to follow humbly in their footsteps—to write a book sometime myself and to make discoveries.

Hence the first meeting of Prof. Marsh and the young westerner on March 19 or 20, 1876, was of great moment to the latter, and he records his impressions of the professor in no uncertain terms. The remainder of his visit was spent chiefly in the study of bird skeletons, and by May 1 he was once more in the field in Kansas with a larger party, again in charge of Mudge. A long season was followed by Williston's return to New Haven, and in 1877 he was himself for the first time placed in charge of the Kansas party, while Mudge was sent to Texas.

Williston hoped very much to do original work, and with this end in view spent much of the preceding winter in studying fish skeletons in his own time, although under Marsh's direction, but when he asked permission to do actual research on the Cretaceous fishes which he believed Prof. Marsh had no intention of studying it was denied him on the ground that it would distract his attention from his regular duties. Williston soon realized that he would probably never have the opportunity of doing independent research on fossil vertebrates so long as he was Prof. Marsh's assistant, and this realization was to have a very important influence upon his future career. The season of 1877 was very long and tiring, as he spent no fewer than 10 months in the field, and it was during this period that his interest in insects, at this time chiefly beetles, was aroused. On his return to New Haven, in January, 1878, he was determined to find some independent field of research, and after mature deliberation chose the Diptera, of which he eventually became the foremost American authority. But one more season, that of 1878, was spent in collecting for Prof. Marsh, and from this work Williston was recalled in July. The following January a new contract was made between them, whereby Williston was permitted to complete his medical studies, which he did, taking his M. D. from Yale in June, 1880.

Upon graduation, Williston was appointed assistant in osteology in Yale College, and in 1881 he was placed on the Government pay roll as assistant paleontologist. In December of that year he married Miss Annie I. Hathaway, of New Haven, who survives him, with four of their five children. He remained with Prof. Marsh until 1885, although discontented, chiefly on account of the repressive policy of the latter. Hence in 1885 their relations were finally severed, Williston receiving the degree of doctor of philosophy from Yale at commencement.

He was now somewhat at a loss as to what course to pursue. He finally, however, refused the offer made by Dr. C. V. Riley, the United States entomologist, to serve as his chief assistant, and began the practice of medicine, in addition to which he acted as assistant editor of Science, under Prof. Scudder. In September he was appointed demonstrator of anatomy in the Yale Medical School, spending his days in New York in his capacity as editor and his evenings at Yale in teaching. July of the next year brought him the title of assistant professor of anatomy, at a very small salary, which he was forced to eke out by his medical practice and by serving as town physician. It was as a health officer of New Haven in 1888 that Dr. Williston carried through single-handed an epidemic of smallpox, caring for the sick and burying the dead with a singleness of purpose and devotion to duty which in war times would have won for him a high military honor. The year 1887 saw his appointment as professor of anatomy at Yale; 1890 brought an offer from the Kansas Agricultural College which was declined, but an appointment as professor of geology in the University of Kansas was accepted in September of that year.

Much that has been said of Prof. Williston's early life and struggles has been gleaned from a manuscript autobiography prepared by him in May, 1916, and kindly placed at the writer's

disposal by Mrs. Williston. With the acceptance of the chair at Kansas, however, he thought the "recollections could with propriety end." The man had most assuredly found himself, and the upbuilding of his character and education was accomplished when he entered thus upon the final phase of his scientific career. It is nevertheless to be regretted that he ended his autobiography here, for his later career, while less romantic, was of greater importance to science, both from the standpoint of teaching and of research.

Dr. Williston's term of service in Kansas extended from 1890 to 1902, and to the title of professor of geology were added those of professor of anatomy and dean of the School of Medicine. In addition, he was appointed a member of the State board of health, of which it is said that, largely because of his enthusiasm for work in behalf of the health of the community and his ability to get things done by injecting new life into that body, it has since had the reputation of being one of the most efficient and progressive of the State boards of health. He served also as a member of the State board of medical examiners (1901–2). The year 1902 brought the call to the University of Chicago as professor of paleontology, and there his affiliation lay with the Department of Zoology until almost the close of his career, when he was made director of the Walker Museum in addition to his professorial duties.

The manysidedness of Dr. Williston's accomplishments is abundantly attested by the varied character of his employment, in which, at any rate in his earlier life, he was to a certain extent the victim of circumstances. He could not always follow his greatest inclination, but invariably recognized opportunity and made the most of conditions which might well have discouraged a lesser man, and, as the final results show, these opportunities all served to make the fruition the more abundant and valuable when he came to the fullness of his career.

Williston was a born teacher. My greatest impression of this came at the initial meeting of the Paleontological Society in Cambridge in 1909 where, under President John M. Clarke's administration, a number of us were setting forth, usually from a read manuscript, our ideas concerning the aspects of paleontology. Then rose Williston, whose paper was on "The Birthplace of Man," walked to the front of the desk, and without notes, in a simple conversational manner unfolded a marvelous exposition of his theme. Without a thought of disparagement of the other contributions, Williston's stands supreme as one of the finest and most inspiring presentations I have ever heard, and I knew at once why as a teacher he was eminent. The direct testimony of three of his students bears this out. Riggs says of him in a letter:

> His attic-study [at Chicago] and limited exhibition space became the Mecca of every paleontological pilgrim. This brought him in turn a limited but permanent fund to carry out his work; brought greater opportunity for extended publication; and brought also an honorary degree from his alma mater. These were the outward expressions of approval. There came with it a following of eager and enthusiastic students. They gathered in his little study and marveled at his lectures. They followed him regularly and often to the Field Museum for demonstrations. They marveled more at his enthusiasm and the broad scope of his conceptions than at the intrinsic interest of his subject.

I am also permitted to quote from Prof. Case, who says:

> I believe that the "Mark Hopkins and a log" idea of a university was never more nearly realized than in Dr. Williston. His knowledge of men and things was so wide and his acquaintance with many branches of science so intimate that in the heat of a barren fossil field, or under the stars at night by the side of a camp fire, some bird, or flower, or fossil, some insect—"one of mine, I named it in 1870-odd"—would start a talk that held his little band of student assistants enthralled until hunger, thirst, or sleep were forgotten.

Prof. Williston was greatly interested in the scientific society of the Sigma Xi, and in a number of educational addresses delivered under the auspices of that organization, emphasized very strongly the principles of training and practice for which it stands: a broad training in the sciences, but, above all, that productive scholarship which is manifest in a high quality of original scientific research. Williston's influence in such education and his own attainments in line with these principles were recognized by the society, which conferred upon him its vice presidency from 1899–1901, and its presidency from 1901 to 1904. He was also a member of the Sigma Xi council for the years 1895 to 1904, 1907 to 1909, and 1910 to 1918, and was instrumental in forming the Chicago chapter in 1903.

Dr. Williston's addresses, which have been mentioned, are notable, and of the several which have been printed, the most important are those before the Kansas Academy of Sciences in 1897, the Ohio State chapter of the Sigma Xi in 1903, the Kansas chapter in the same year, and the Yale chapter in 1917. His presidential address at the sixth biennial convention of the society was considered so important that part of it is incorporated into the appendix to the constitution and is often read to initiates as the best summation of the principles for which the Sigma Xi stands. Still another noteworthy address was that delivered before the National Educational Association at Denver in 1909, on the subject, "Has the American college failed to fulfill its function?"

It has perhaps been evident that Williston's inclinations would have led him at once into vertebrate paleontology as a field for research, with the probable result of more than doubling the quantity and increasing with greater knowledge the quality of his output in that department of science; but here opportunity passed him by and circumstance drove him to entomology as an outlet for the pent-up energies of his creative mind. And his work in that field was of the highest quality, as Riley's offer surely shows, for, as Williston himself says, "Had I accepted the place of chief assistant perhaps I would now be the United States entomologist." Williston's research began with the beetles, but he speedily turned his attention to the flies, the results being published first in 1877, a few papers together in 1878, then exclusively from 1880 until 1886, when his second paleontological paper appeared. From 1887 until 1896 the entomological papers were still the bulk of his output, but from this time on those in paleontology became more and more numerous until the insect research practically ceased in 1899. In 1908, however, Williston did a remarkable thing in laying aside his paleontology and taking up once more the study of the flies, his purpose being to make a final (third) revision of their taxonomy and publishing his "Manual of the North American Diptera." In this final volume, which is both compendious and minute in detail, Williston shows a breadth and accuracy of knowledge surprising in any case and doubly so when one considers that he had done no research on the flies for more than a dozen years.

Williston also wrote of recent zoology, mainly on the habits of creatures which came casually within the scope of his observation; he wrote of sanitation and river pollution, of mankind in the abstract and specifically when called upon to pay tribute to departed colleagues. But his main research, as with his teaching, lay with the vertebrates of the geologic past, and herein the volume of his work equals that on the insects and in the prejudiced eyes of a fellow vertebratist has a value which greatly exceeds it. For the vertebrate work is not solely systematic, as was the entomological, but gave opportunity for broad generalizations, anatomical, evolutional, and philosophical, of a very high order.

At the University of Kansas the local paleontology naturally attracted Williston's attention, partly because his initial work with Prof. Mudge in 1874 was in the rich Niobrara Cretaceous, and because the work was in part that of the Kansas University Geological Survey. For more than 12 years, with the material secured by Dr. F. H. Snow and Judge E. P. West as a nucleus, Williston sought to build up the university collections, embodying the scientific results in Volumes IV and VI of the State survey. This research deals largely with the creatures of the Niobrara chalk, all of which are marine or aerial, with the exception of a rare dinosaur or two.

At Chicago, Williston found that his predecessor, Dr. Baur, who had also served for a number of years under Prof. Marsh at Yale, had already made some collections of Permian material, and this fact gave the trend to his future work. As Mr. Riggs (letter) says of him:

> He made expeditions into the Trias and then into the Permian of the Southwest. Year after year his collectors were sent into this field and soon publications announced their discoveries. Despite the rigors of climate, the insufficiency of funds and the protests of his field men, he clung to this field and its problems for 12 years, ending only with his life. He unearthed a fauna which has been much sought but little known. With only a single preparator, with no illustrator but his own pen and brush, he made known this strange and primitive reptilian fauna with a celerity and acumen which astounded his co-workers.

In this exploration Williston found great difficulties in his way, for he says in "American Permian Vertebrates" (p. 2):

> The [Texas Permian] beds are the most difficult of exploitation of any known to me in a field experience of 35 years. Usually the fossils are more or less hidden in concretionary nodular masses, almost invisible or indistinguishable to the untrained eye until they have been broken up and weathered, when the inclosed fossils have lost much of their value. Rarely single bones and even whole skeletons are found in clay deposits almost or quite free from matrix, but many such are not to be expected.

Finally, however, as a result of painstaking research, bone beds, notably the Cacops bed discovered by Paul Miller in 1909, were found which yielded considerable more or less perfect material. It was also Williston's privilege to study the Marsh collection of Permian material at Yale, one result of which was the unearthing of specimens from storage, the perfection of which was totally unsuspected, notably the practically perfect Limnoscelis type. As a result, Williston, supplemented by E. C. Case, who also had access to the American Museum material, has given us a knowledge of Paleozoic air-breathing vertebrates, Amphibia and Reptilia, which was almost unhoped for. It was largely because of the quality of his research in this line that Yale University honored herself by admitting Prof. Williston to the doctorate for the third time, as the degree of doctor of science was conferred upon him in June, 1913.

Williston's life is a stirring tale of one who rose superior to heredity, environmental limitations, and the petty discouragements of life, especially those due to financial restrictions in the pursuit of a costly science. He immortalized himself not only in the amount of his published research, of over 4,000 printed pages, some of them bearing the impress of genius, but in the knowledge and inspiration which he instilled into those whose privilege it was to sit at his feet. Certain of these, such as Branson of the University of Missouri, Sellards and Beede of the University of Texas, Logan of the Mississippi Agricultural College, and Moore of the University of Kansas, have followed lines of work more strictly geological; but Case of the University of Michigan, Riggs of the Field Museum, Brown of the American Museum, Moodie of the University of Illinois, and Mehl of the University of Missouri form a group which will worthily carry on his vertebrate research. Vale magister!

PART II.—PUBLISHED RESULTS.

CONTRIBUTIONS TO ENTOMOLOGY.

The list of Dr. Williston's published writings embraces a considerable range of subjects, and in the two departments of entomology and vertebrate paleontology includes works of high authoritative value. Those in entomology being outside the narrow limits of the present writer's research, he must turn to others for a critical review. Dr. J. M. Aldrich, of the United States National Museum, has kindly sent me an estimate of this department of Williston's activities, and with his permission I extract from it the following:

> Williston never held an official entomological position. But he found time to do much valuable work as a pioneer in dipterology. * * * His interest in the flies began to be serious about 1878. At this time Osten Sacken had returned to Europe, and there was not a single American student of the order but Edward Burgess, the Boston yacht designer, who published only one small paper. So Williston was virtually alone on the continent. In the absence of guidance, he plowed his way by main strength (as he often narrated to the writer) through descriptions of species until here and there he made an identification, which served as an anchor point for a new offensive. He had few definitions of genera, so had to work backward from the species. After a year or two of this tedious and time-wasting effort, he came upon Schiner's Fauna Austriaca, in which the Austrian families, genera, and species of Diptera as known up to 1862–1864 are analytically arranged and succinctly described. To his immense relief and satisfaction, he now found that all his American flies could be traced to their families, and most of them to their genera, in this fine work. He was so impressed by the saving of time accomplished that his own publications coming later show the effect of this early experience on every page; everywhere he has the beginner in mind and is clearing the way for him.
>
> In a few years he began publishing tentative papers analyzing the American families and genera of the flies. These he extended and enlarged in a pamphlet in 1888, and again in a bound volume in 1896; and in 1908 published a third edition still more complete, with 1,000 figures, his well-known "Manual of Diptera." This third edition is his main contribution to entomology. It is a handbook unapproached by anything else dealing with a large order of insects.

From necessity he published it at his own expense; it was eight years before the receipts from sales covered the cost of printing, but happily he lived to see this consummation.

His other papers of his early period, 1881–1889, dealt with Asilidæ, Conopidæ, Tabanidæ, and smaller groups, and especially with Syrphidæ, in which his fine monograph of 1886 is still in universal use, and by the taxonomic genius of its author has created in the United States an ineradicable belief that the family is an easy one, well adapted for the beginner to publish in; a mistaken belief, but highly complimentary to the monographer.

From 1890 his more important papers were concerned with tropical Diptera (Mexico, St. Vincent, Brazil), and with bibliography. As his official duties grew more exacting, he gradually abandoned entomology, but he had as many farewell appearances as an opera singer, for he could not resist the temptation to come back again and again. Even as late as the spring of 1917, when he was visiting the writer and reveling once more in a collection of Diptera, his old enthusiasm came back so strongly that he planned describing some new genera, and in fact did publish one (Annals Ent. Soc. Amer., vol. 10, p. 23). But after 1896 he did little work on the order except in preparing the third edition of his Manual, which cost him two years of arduous work, as he drew 800 figures with his own hand. His deep interest in genera and his very wide acquaintance with them, together with his universally recognized taxonomic ability, made him, in the period 1890–1900, the peer of Osten Sacken, Brauer, and Mik as a world authority in Diptera.

PALEONTOLOGICAL RESEARCH.*

The first of Prof. Williston's paleontological papers appeared in 1878—a brief discussion of the American Jurassic dinosaurs [1]—and was followed in the next year by an expression of opinion on the dinosaurian origin of birds.[2] One or two other dinosaur papers followed at rare intervals, but it was not until 1890 that he began his more intensive study of vertebrate forms. His removal to Kansas in 1890 reawakened, as we have seen, his interest in the fauna of the Kansas Chalk, and the beginning of a series of papers upon these forms resulted, the initial one being on a plesiosaur from the Niobrara Cretaceous of Kansas (1890).[5] The same year there appeared a morphologic paper on the structure of the plesiosaurian skull,[6] of which, as Williston says, our knowledge had previously been very incomplete. In this paper he announces for the first time the presence of sclerotic bones within the orbit, the single temporal arch, and other important details of structure. The following year saw Williston's attention turned to the mosasaurs and pterosaurs of the Niobrara, his initial article in each group appearing at that time.

PTERODACTYLS.

Williston's first paper on the pterodactyls [7] is based upon a well-preserved specimen of Pteranodon in the Kansas University Museum, and from the skull he argues against the probability of the remarkable elongated occipital crest figured by Marsh and since proved to be correct, although Williston held to his opinion for a long period of years. He also described in detail the hinder extremities, and finally gives a very excellent summary of the anatomical peculiarities of the genus Pteranodon, based upon his own observations and those of Prof. Marsh.

The second paper by Williston on the pterosaurs is that entitled "Kansas Pterodactyls" (1892).[9] In this he lists the species of Pteranodon previously described by Marsh and Cope, and those of the genus Nyctosaurus described by Marsh. He then passes to a discussion of the morphology of the skull and pubis of the former genus, followed by a full description of a new specimen of *Nyctosaurus gracilis* Marsh, which was preserved in the Kansas University Museum, and which served to put the genus on a more secure basis. Finally the author summarizes his views as to the relationship of the pteranodonts, expressing a belief that instead of being confined exclusively to Kansas, as had been thought, they may also occur in Europe in the form of the genus Ornithostoma Seeley.

In 1893, Williston again wrote of the Kansas pterodactyls,[11] this time stating emphatically his belief, backed by recent publications by Prof. Seeley, of the congenerousness of the forms Ornithostoma and Pteranodon, and the precedence of the former name. He adds that Cope was able to see this while Marsh was not, notwithstanding the latter's wealth of material on which to base an opinion. It is interesting to note, however, that the latest authority, Eaton, in 1910 still holds to the opinion of Marsh, using the name Pteranodon for the American types, as

* Superior figures in this section refer to the serial numbers of the articles listed under "Paleontology" in the appended bibliography.

does O. P. Hay in his catalogue of fossil Vertebrata (1902). This paper of 1893 gives further morphologic description of the pelvis and hind limb of *Pteranodon (Ornithostoma) ingens*.

But three more papers on this interesting group appear from his pen: on the mandible of Ornithostoma (1895),[21] on the skull (1896),[22] and a restoration in 1897.[26] In his report on the Geological Survey of Kansas, 1898, there is a view (frontispiece) of the reptiles of the Kansas Cretaceous ocean, previously published in Popular Science Monthly, in which a number of pteranodons are seen, one clinging to the cliff, the others in the air, and none of them display the crest in its full development as held by Marsh and now abundantly proved to be correct.

In 1902 [56] [63] and 1903,[68] Williston described in detail a remarkable specimen of Nyctodactylus which had recently been discovered in the Kansas Chalk and which was so complete that many details of anatomy of the group were learned from it. As usual, not only does he give a very detailed description of the morphology of the animal, but his picture of its small body, not larger than one's fist, compared with the 8 feet of wing expanse, the peculiar articulation of the hind limbs, giving it a most laborious gait when on the ground, and the conjectures as to its young, which could not have been viviparously born—all have a striking interest to one who would visualize as living beings the creatures of the past. His arguments, moreover, are so complete that one feels instinctively that his conclusions are well founded

MOSASAURS.

The paper on the Kansas mosasaurs in 1891 [8] gives the first morphologic description of a complete skeleton of a member of this interesting group, although, as Williston says, Baur had already studied and figured another genus, the description of which had not been published. In his introduction, Williston discusses the nomenclature of the mosasaurs, with its very much confused synonymy, which he later was privileged partially to unravel. In his morphologic description he shows his powers of visualizing as a living form the creature under his observation, for, as he says (p. 345):

> It is doubtful whether there was ever another vertebrate animal so admirably adapted for rapid and varied movements through the water. Though the smallest of the mosasaurs, it [*Clidastes velox*] was by far the most graceful in its proportions, the most delicate and exquisitely constructed in its details.

Marsh had denied the presence of sclerotic plates. Williston, however, says:

> It is certain that none of the Kansas forms of this order were covered with bony scutes, as described by Marsh, the bones so described being, undoubtedly, sclerotic plates.

This observation was subsequently verified by the finding of impressions of the mosasaurian skin.

In 1892,[10] Williston, aided by his pupil, E. C. Case, wrote still more extensively of the mosasaurs of Kansas. This work, Part I, includes the genus Clidastes, and opens with the usual specific list and the authors' conception of the synonymy. Then follows a morphologic description of *C. velox* and a discussion of the synonymy. The new species, *C. westii*, is also described in comparison with its nearest allies.

The next year [12] Williston published his first restoration of a mosasaur, that of *C. velox* (*vide supra*), which, with certain modifications, served as a basis for his restoration of 1897 that has since become standard. No further mosasaur papers appear until 1897, when a new genus, Brachysaurus, is described,[29] the extremities of Tylosaurus, discussed,[30] and the principal genera, Clidastes, Platecarpus, and Tylosaurus, restored as full length, rather diagrammatic skeletons. These figures are also now accepted as standard and have been republished a number of times.

"The Range and Distribution of the Mosasaurs," 1897,[32] is an extremely important paper in which Williston discusses not alone the synonymy, but also the geographic and geologic range of the entire group, together with some important generalizations concerning their distribution and relationships.

Then follows Williston's monumental work on the Upper Cretaceous paleontology of Kansas, 1898,[39] in which no fewer than 138 pages and 62 plates refer to the group under discussion. This work virtually completes Williston's investigations of the mosasaurs, for but three

minor papers on additional anatomical features and a thoughtful article on the relationships and habits appear subsequently. The 1898 memoir is a work of monographic value and completeness, as a résumé of its contents will show. The opening pages are an historical summary of the work previously done on the mosasaurs. Succeeding this comes a section on the range and distribution of the group and a generic and systematic summary. This is followed by an elaborate series of comparative anatomical descriptions, in which the homologies of the cranial and other skeletal elements are discussed with that detail and degree of accuracy of which Williston's broad anatomical knowledge made him master.

Next come systematic descriptions and a discussion of the biology of the group, with restorations. He speaks of the creatures as marine lizards of moderate size, ranging from 10 to perhaps 37 or 38 feet, living in shallow waters, although some of the larger of them ventured far out to sea. Their feeding habits, as evidenced from the very peculiar lower jaw which had a joint in its mid-length, are discussed, but Williston felt that the rigidity of the breast girdle precluded any very remarkable feats in the way of swallowing bulky prey. He believed that the food consisted of the numerous small fishes which swarmed the seas with them—possibly an occasional young mosasaur such as, curiously enough, is almost unknown as a fossil. He believes, further, that the mosasaurs rarely came ashore, although they must have done so for egg laying, as there is no evidence that they were viviparous, but the body is not sufficiently serpentine, nor the limbs sufficiently strong, for terrestrial locomotion. They were very pugnacious, as numerous exostoses on the skeleton show. The body was covered with a scaly skin, the scales closely resembling those of a large monitor in size and shape. This knowledge is based upon a specimen of Tylosaurus in which the carbonized scales are present on the anterior part of the body. Not only are the skeletal restorations of the three principal genera given, but a restoration in the flesh of *Clidastes velox*, with the associated *Uintacrinus* and *Ornithostoma* (*Pteranodon*) *ingens*.

The publication of this memoir, supplemented by the researches of Dollo of Belgium, gives us a body of information concerning the mosasaurs as authoritative as it is complete, and one which has served as a basis for all subsequent research upon the group.

PLESIOSAURS.

The plesiosaurs of the Niobrara also naturally attracted Williston's attention, and he published his first paper on the group in 1890,[5] describing a new species, *Cimoliasaurus* (*Elasmosaurus*) *snowii*, in which he pays particular heed to the hitherto little known skull. Another paper, based upon the same specimen, appeared in Science about the same time.[6] In 1893,[13] Williston wrote on an interesting food habit of the plesiosaurs, but did not discuss them again until 1897,[28] when he described another new form from the Kansas Cretaceous (Comanchian). In 1902 [57] there appeared a morphological paper on the plesiosaurian cranial elements and still another [59] on the restoration of *Dolichorhynchops osborni*, a new Cretaceous plesiosaur. This latter skeleton was worked out of the matrix and mounted, and is to-day one of the very few such free mounts in the country.

The paper on certain homoplastic characters in aquatic air-breathing vertebrates,[61] published simultaneously with the one just mentioned, is the forerunner of Williston's much later work on "Water Reptiles of the Past and Present." In the former he sums up the general lines of adaptation which all secondarily adapted aquatic vertebrates must follow, and includes some interesting observations on the plesiosaurs, their rather clumsy form, lack of speed, and feeding habits, for he believed that many of them fed largely upon cephalopods and other invertebrates, as did the ichthyosaurs; the plesiosaurs, however, lived in relatively shallow water, as compared with the ichthyosaurs. He speaks here again of the stomach stones, later called gastroliths, found in abundance with the remains of plesiosaurs, and, in some instances, carried several hundred miles from their source. He held, however, that the plesiosaurs differed not a little among themselves in habits, as evidenced by their great variations in form. They exceeded in size the largest mosasaurs, but were never a match for the latter in prowess or voracity. Like the gavials, they were comparatively harmless creatures. "Were they living

to-day, [they] would find unopposable foes in the vicious and cruel crocodiles. They were relatively stupid and slow, cruel enough to the smaller creatures, but of limited prowess. But in structure and habits they are among the most remarkable of all the animals of the past or present." (Water Reptiles, p. 76.)

Williston's most extensive memoir on the plesiosaurs appeared in 1903,[67] as a publication of the Field Columbian Museum, during the time he served that institution as associate curator of the division of paleontology, in addition to his professorial duties in the University of Chicago. This paper was called Part I, and was to have been followed by another, which, however, never appeared. He speaks of the great number which have been described from the United States, 32 species and 15 genera, of which in not a single instance has there been even a considerable part of the skeleton made known, while the skull is known in but three, and only one of these has been described. And yet plesiosaurs are not at all rare in American deposits or collections. The monographic studies on the group, undertaken by Williston, were for the purpose of clearing up the confusion which then existed concerning these animals, but he deemed it wise, as there was still much to be done, to publish his detailed researches on the three species *Dolichorhynchops osborni*, *Brachauchenius lucasii* and *Cimoliasaurus snowii*, rather than wait for the completion of the entire work, and it was fortunate that he did so, in view of the fact that the second part did not appear. This was to contain the descriptions and illustrations of two or three other skulls.

The origin of the plesiosaurs Williston also proposes to discuss in a later paper. Here he contents himself with merely saying that he believes their nearest affinities among all reptiles, recent or extinct, to be with the dicynodonts (see table facing p. 133). After the introduction there is a catalogue and brief bibliography of the North American plesiosaurs, followed by the morphological description of the three species mentioned. Another new species is described, *Polycotylus ischiadicus*, a further description of *Plesiosaurus gouldii* Williston is given, propodial bones of young plesiosaurs which are abundant in the Chalk are described, and the essay closes with a discussion of the peculiar food habit of the plesiosaurs of which he also wrote in 1902. This last brought forth a discussion from Dr. C. R. Eastman which was met by Williston in a rejoinder in Science for October 22, 1904.[69]

The plesiosaurs are still further discussed in a paper entitled "North American Plesiosaurs: Elasmosaurus, Polycotylus and Cimoliasaurus," appearing in 1906.[78] In this instance, the study was based largely upon material in the Yale Museum, some of which had been collected and studied by the author himself twenty years or so before. Prof. Marsh had begun a critical study of the Yale material, hence much of it was prepared and some illustrations made, all of which, through the courtesy of the curator, Prof. Schuchert, were placed at Williston's disposal. The genus Cimoliasaurus is defined as distinct from the long-necked Elasmosaurus. Of the latter, a number of species, two of them new, are described. The genus Polycotylus is also clearly diagnosed, and Trinacromerum is believed to be distinct from Polycotylus although the reasons for this belief are not given. No generalizations are included in the paper.

Two years later,[86] Williston again published on the genus Trinacromerum, mainly a morphologic description of the type species, *T. bentonianum*, to which he adds another new species, concluding with a summation of the family Polycotylidæ, which is defined, with a list of genera and species and their bibliography. Finally there is a list of the described North American plesiosaurs, 36 in all, arranged in stratigraphical sequence.

A paper on Brachauchenius, published in 1907,[79] discusses not only the characters of this remarkable genus, but the relationships of the plesiosaurs as a whole. In discussing similarities between them and the turtles, Williston concludes that such as they show are due solely to parallel evolution, and that there is only a remote relationship between the two orders in osteological structure.

"The plesiosaurs," he says (p. 489), "could not have been derived from any ancestors that might by the widest stretch of imagination be called Chelonia, or Chelonia-like. Nor could the turtles have come from any forebears even suggesting the sauropterygian structure. I am still strongly of the opinion that the Sauropterygia were derived from a primitive therocephalian ancestry; while I am firmly of the opinion that the turtles have had a quite independent

origin from some primitive cotylosaurian, like the Chelydosauria, as Case has forcefully shown. The turtles occupy a phylum distinctly their own, no more intimately related to the plesiosaurs than they are to the ichthyosaurs or rhynchocephalians. I can not accept the contention of McGregor that the Ichthyosauria had a primitively saurocrotaphous (I need not apologize for the word) type of skull, but would rather believe that they, too, enjoyed a genealogical line all their own from the most primitive type of reptiles, and that they should no more be grouped with the dinosaurs and crocodiles than with the plesiosaurs and theriodonts."

A very excellent final summary of Williston's knowledge and beliefs concerning the Sauropterygia, both plesiosaurs and nothosaurs, is given in his book on the water reptiles (1914). It is to be regretted, however, that his more ambitious project of monographing the group in full was not carried to completion, though much that he did was of morphologic value.

DINOSAURS.

Prof. Williston wrote but little of the dinosaurs, and that mainly upon the two genera Claosaurus and Stegopelta which have been preserved in the marine Cretaceous of Kansas. His early papers are brief ones: "American Jurassic Dinosaurs" (1878),[1] "Are Birds derived from Dinosaurs" (1879),[2] and "Note on the Pelvis of Cumnoria (Camptosaurus)" (1890).[4] In 1898,[37] in the same volume of the Kansas Geological Survey which includes his great work on the mosasaurs, he discusses dinosaurs in general, and specifically the *Claosaurus agilis* from the Niobrara, with Marsh's restoration of *Trachodon* (*Claosaurus*) *annectens* by way of illustration. There is, however, no new information contained in the paper.

Another article in 1898 [45] is on the sacrum of Morosaurus, a brief morphological description of a specimen in the Kansas Museum. In 1899 Williston conducted an expedition to the Freeze Out Hills of Wyoming (Morrison formation), and it was then and there that the reviewer first met him. The party collected the more familiar Morosaurus, Diplodocus, and Stegosaurus, and a carnivore, Creosaurus, which is the subject of a brief paper published in 1901.[55] In it Williston discusses the distinctions, which are by no means clear, between Creosaurus and Allosaurus, and concludes that his specimen, of which he has the nearly complete fore limb, belongs to the former genus because of the very slender scapula. He also comments on the age of the so-called Atlantosaurus beds of Marsh, now held to be Morrison, and believes that they should bear the name Como, unhesitatingly referring them to the lower Cretaceous.

In 1905 [76] Williston published his most notable contribution to dinosaurian discovery when he described a new genus of armored dinosaurs, Stegopelta, from the Cretaceous of Wyoming. This dinosaur, which comes from what Williston has called the Hailey shales, has been further and much more minutely described by Roy L. Moodie in 1910, and proves to be one of a rather extensive group of forms sharply distinct from the aberrant Stegosaurus which has given its name to the armored dinosaurs as a whole. In 1910 [93] Williston, with Pierce Larkin, described a new sauropod dinosaur from the Trinity Cretaceous of Oklahoma, of interest as one of the two last recorded instances in time of the American Sauropoda.

That Williston had further unpublished ideas of great value on the dinosaurs was evident from his verbal discussions of the group. It is to be hoped that in his incompleted work on the reptiles many of these opinions are recorded. They are of course included in his several reptilian classifications, notably the table of 1917 (facing p. 133).

CROCODILIA AND CHELONIA.

Williston made a number of contributions to our knowledge of the crocodiles and turtles, mainly, however, in connection with other forms of the same faunal horizons. For instance, in his 1898 work on the fauna of the Niobrara Cretaceous, one finds four pages devoted to crocodiles,[38] a general statement concerning the group, and a specific description of the only Kansas form, *Hyposaurus vebbii* Cope. The turtle section of the same work, pages 351–369, is only in part the work of Williston,[40] the remainder being from the pen of Prof. Case. The former discusses the turtles of the Chalk and the appearance of the group in time, by way of introduction. He then passes to a morphological description of *Desmatochelys lowii*. There are no generalizations on either the Chelonia or the Crocodilia until the work on "Water Reptiles of the Past and Present" (1914).

BIRDS, FISHES, AND MAMMALS.

Prof. Williston concerned himself but little with the birds, largely because of their rarity in the geologic levels with which he was most familiar. He did, however, make a few observations on their derivation in 1879,[2] wrote on the dermal covering of Hesperornis in 1896,[23] and, in 10 pages of his Kansas Cretaceous report, 1898,[36] summarized the birds from the Niobrara Cretaceous. In his list of Kansas birds he follows Marsh's erroneous lead of including Hesperornis in the Ratitæ; he feels, however, that the mere possession of teeth is not enough to justify its inclusion in a separate group, and the name Odontornithes is in consequence abandoned. A restoration of Hesperornis based upon Marsh's figure of the skeleton is included.

Williston's study of fishes is comparable to that of birds—the result of his association with the Kansas Chalk. He does little with the class, and that little does not greatly advance our knowledge, as in certain of the other groups. His study of the Tertiary mammals is of like character, and in no sense ranks with his masterful researches on the aquatic reptiles of the Cretaceous and upon the Permian tetrapods.

PERMIAN VERTEBRATES.

Williston's first essay on the vertebrates of the Permian appears in 1897 [27] and is based upon a small collection obtained in the excavation of a well in Cowley County, Kans., from near the base of the Permian as defined by Prosser. Another paper in the same year[33] describes a labyrinthodont tooth from the Kansas Carboniferous which has the same curious infolded structure as in the case of Mastodonsaurus of the Old World Trias. Two years later[51] appeared a third paper on the Paleozoic Tetrapoda, this time on the genus Eryops Cope, mainly on the morphology of the coraco-scapula, with a note and illustration of the lower jaw in addition.

After another five years[72] came a valuable morphological and phylogenetic discussion entitled "The Temporal Arches of the Reptilia." This was invoked largely by the work of Prof. Osborn on the reptilian subclasses Synapsida and Diapsida, which appeared the previous year; the main dissension on Williston's part is as to the use of the term Synapsida proposed by Osborn for the group of reptiles with a single temporal arch, "since this group really does not differ in any essential respect from the Synaptosauria (in the wider sense) of Fürbringer and differs from the Synaptosauria of Cope, as most recently defined by him, chiefly in the inclusion of the Cotylosauria." Williston goes on to say (p. 175): "But I believe that Cope was right in separating the two groups, since he recognized, as does Osborn, the ancestral relations of the Cotylosauria to both the single and double-barred reptiles."

Furthermore, Williston can not accept as definitely proved or even probable the conclusion that the reptiles are really diphyletic, since the turtles seem to have had an independent origin from the cotylosaurs. Cope's scheme of relationships, published in 1896, seems to express fairly well Williston's views of reptilian phylogeny at this time.

The work on water reptiles, 1914, contains the following (p. 15):

> It may be said decisively that no classification of the reptiles into major groups, into superfamilies or subclasses that has so far been proposed is worthy of acceptance; there is no such subclass as the Diapsida or Synapsida, for instance, and we have very much more to learn about the early reptiles before any general classification of the reptiles can be securely founded. [See table facing p. 133.]

Hence, the significance of Williston's study of the Paleozoic forms which we are discussing.

In a "Notice of some new reptiles from the upper Trias of Wyoming," 1904,[71] Williston describes four new genera and species of reptiles from a horizon which he calls the Popo Agie beds. The material is meager for either generic or specific identity, and no conclusions other than suggestions of relationships are given. In 1908, he published at least three papers on the Paleozoic tetrapods, one on Lysorophus,[80] a Permian Urodele, the skull of which he discusses and figures at some length, showing the creature to have been of snakelike body, with feeble powers of vision, probably perennibranchiate, bare-skinned, and more or less mud-burrowing in habit. He does not believe that the genus stood in direct ancestral relationship with the living Necturus

and Proteus, but thinks it very probable that it was close of kin to the ancestors of these forms (see table facing p. 133). This same paper discusses salamander-like footprints from the Texas red beds and newly discovered ventral ribs in Labidosaurus.

Another article, entitled "The Cotylosauria,"[84] is very largely a redescription of *Labidosaurus incisivus* from a specimen in the University of Chicago collection originally described by Case. Williston also discusses the history of the origin and use of the term Cotylosauria and adds a protest against the later work done on the taxonomy of the reptiles, as follows (p. 148):

In a recent review of the literature of the Reptilia, I find all of the older groups usually called orders have been raised in recent years by well-known writers to superordinal or subclass rank, save the Ichthyosauria and Chelonia, the two groups of all others most entitled to high rank! And most of the suborders have been elevated to orders—thirty or more. And what has been gained?

Williston's third paper on these ancient forms, published in 1908, is on "'The Oldest Known Reptile'—*Isodectes punctulatus* Cope."[85] This species, which is from the Coal Measures of Linton, Jefferson County, Ohio, was unhesitatingly referred by Cope to the Reptilia and said by him to be "the first identification of a true reptile in the Coal Measures." However, because of recent studies connecting the Stegocephalia so intimately with the Reptilia, it is somewhat hazardous to affirm positively that the specimen, which lacks the skull with its distinctive parasphenoid bone, is a true reptile. Nevertheless, Williston does not see in the skeleton a single character which is not reptilian. M. Thévenin, of France, had recently described an air-breather from the uppermost Carboniferous of France under the name *Sauravus costei*. This the distinguished author believed to be rhynchocephalian, but Williston does not consider it either a stegocephalian or cotylosaurian type, as in the American forms the final proof would lie in the degree of reduction of the parasphenoid bone, whether or not the condyles were paired. He further states that from the evidence here shown it is clear that the primitive reptilian phalangeal formula was that now persistent in the Lacertilia and Sphenodon, 2, 3, 4, 5, 4, the number 2, 3, 3, 3, 3, so characteristic of the mammals, being a late specialization and having no genetic relationship with the similar formula of most turtles. In other words, the phalangeal formula is not of the great importance that some authors attach to it.

Finally, Williston says (p. 400):

There are those who believe that the reptiles arose from two distinct groups of the Amphibia, one from the Microsauria, the other from the Temnospondyli, and I must confess that Isodectes helps that theory materially, for its relationships with the Microsauria on the one side can not be gainsaid. But, the close relationships between such forms as Pariotichus, Procolophon, Telerpeton, the Pelycosauria, the Cotylosauria, Pareiasauria, and Temnospondyli complicate matters here exceedingly, and leave the whole subject still in great obscurity.

In the table of 1917 (facing p. 133), Williston derives the Amphibia and Reptilia as a whole from the Protopoda, known only from their footprints in Devonian and Mississippian rocks.

The year 1909[90] brought forth one of the most important of Williston's papers, "The Faunal Relations of the early Vertebrates," short but very fundamental, and a basis for much which was to come. Here he compares in some detail the successive land faunas of North America with those known elsewhere from Mississippian time through the Mesozoic, and gives a graphic table showing the distribution, both in space and in time, of the principal groups above the fishes. He summarizes his evidence as follows (p. 399):

The Pennsylvanian fauna has nothing distinctive, at least till near the close; there must have been a continuous and free interchange of land animals with the eastern continent till near the close. Before its close, it had already diverged and certain true reptiles had appeared. Before the beginning of Permian times an interruption of migration occurred, producing a complete and continuous isolation of the Permian American fauna. With the close of these times a long interval elapsed, during which physical conditions were almost uniform over a large part of the Rocky Mountain area at least, during which interval we have no records of land or fresh-water life, but which is represented in part by marine forms of remarkable character, possibly in part derived from American ancestors. With the reappearance of land forms in the Upper Triassic we find certain evidence of free migrations again, with the closest relationships between eastern and western forms, none of which could have been derived, immediately at least, from the known American Permian types. The marine vertebrates of the Upper Jurassic, the next American air-breathers of which we have any knowledge, indicate an advance in specialization over the contemporary forms from the eastern continent, but they also indicate a continued migration of the aquatic forms at least. With the land forms again

appearing at the close of the Jurassic and in the Lower Cretaceous, we find strong evidence of a community of faunas, but with a striking absence, hitherto, of some of the smaller forms known from earlier times in the eastern continent. The Upper Cretaceous again shows a belated arrival on the western continent of eastern types, after their advent or even disappearance there. With the exception of certain Triassic marine types, we have no distinctively American Mesozoic groups of air-breathing vertebrates, until we reach the Benton, Niobrara, and Pierre Cretaceous, all indicating a continued, but possibly restricted, intermigration between the eastern and western continents during the whole of Mesozoic times. * * * That the communication between the two continents in Pennsylvanian time may have been by way of the North Atlantic region is not at all improbable. Indeed, taking into consideration the close relationships known to exist between the European and American type[s] of this period, closer perhaps than existed at any subsequent time during the Mesozoic, this more direct way of communication would seem very probable.

Williston goes on to adduce evidence in favor of the belief of a southern communication between Africa and South America and, during part or all of Mesozoic time, free communication between North and South America. He feels that there may have been one trans-Atlantic bridge, the southern one, but that this was sufficient nevertheless to afford a means of intermigration between both the northern and southern continents of the old and new worlds.

The discussion of the relationships of the various amphibian, reptilian, and mammalian groups in this paper gives expression to Williston's beliefs, some of which are most decided, although his evidence is not always forthcoming.

Another paper of the same year [88] was on the skull and extremities of Diplocaulus, a very curious microsaurian from the Permian, with a head remarkably extended in its transverse diameter. The paper is largely morphologic—the brief discussion of the taxonomic rank of the group which Williston would make the family Diplocaulidæ of the Microsauria.

Two other papers, one on Pariotichus [89] and one on Trematops,[91] follow. Both forms are from the Permian of Texas, and the partial result of the expedition to these beds sent out by Chicago University during the autumn of 1908. The Pariotichus skeleton is of particular interest because for the first time the natural skeleton of a cotylosaur is known, with all of its bones in anatomical relations, scarcely a single one being disturbed by extraneous force in fossilization; so that from it a clearer and more authentic description could be given than ever before.

Seven genera of Permian reptiles are enumerated as pertaining to the Pariotichidæ, he having added one, Labidosaurus, to the original six included within the family by Cope.

Trematops is also represented by an almost complete skeleton, this time of a rachitomous amphibian curiously intermingled in situ with the remains of a cotylosaurian reptile. The amphibian forms the type of a new genus and species, and has as its nearest ally the well-known Eryops originally described by Cope, although its smaller size, greater slenderness, and head structure separate the genera widely.

Four papers on Permian vertebrates came from Williston's hand during the year 1910, one of which [98] discusses the skull of the reptile Labidosaurus, while another [97] makes known in detail the entire skeleton and armor of a remarkable new genus, Cacops, and to a lesser extent another new genus, Desmospondylus, and erects two new families: Dissorophoridæ to include Dissorophus Cope and Cacops Williston, and Trematopsidæ, based upon the previously described genus Trematops.

The material here described was sought and found in the "barren" deposits of the Permian of northern Texas, which so rarely pay for exploration, but which, when they do, pay abundantly in the degree of perfection of the material; for, as Case has observed, but one or two specimens a season can be expected from these clay beds. Mr. Paul Miller discovered in 1909 a remarkable bone bed containing, according to Williston's estimate, 50 or 60 skeletons, with not another indication of bone in adjacent exposures of several hundred acres, save a few ounces of fragments found a half mile away. The great majority of the skeletons belong to the genus Varanosaurus Broili, of about the same size—that is, 4 feet in length; there is, in addition, a femur of Desmospondylus, while all of the amphibian remains belong to Cacops. The skeleton which is figured as the type of Cacops is unusually perfect and is mounted with great skill, only certain of the phalanges being restored, together with the distal segments of the limbs from the right side; it is, moreover, almost entirely one individual.

Of it Williston says (p. 279):

The creature as mounted presents an almost absurd appearance, with its large head and pectoral region, absence of neck, and short tail. It is very certain that it possessed no other dermal ossifications than those of the median dorsal carapace, and it would seem almost as certain that the creature was aquatic or largely amphibious in its habits. * * * What the significance of the dermal carapace was I am at a loss to suggest. That it could have been of protection to the creature seems more than doubtful, whatever may have been its use in Dissorophus, where it covered the whole dorsal region. But this coincidence is remarkable; with an external turtle-like ear opening, it had also the beginning of a turtle-like carapace. And this parallelism is also seen in Diadectes [this it will be remembered is an amphibian], with dorsal dermal plates and turtle-like ears. * * * Whatever may have been the habits of the creature, it, with its nearly related Dissorophus, must be classed among the oddities of vertebrate paleontology.

In his paper on new Permian reptiles, 1910,[96] Williston describes in part the material taken from the so-called Craddock bone bed, discovered by Paul Miller in the autumn of the previous year on the Craddock ranch near Seymour, Tex. These fossils include a great variety, among which was the type of *Aræoscelis gracilis* and of a new family, the Aræoscelidæ. He also discusses the problem of the development of the holospondylous vertebræ, which has given rise to much contention among paleontologists, and of which he wrote in detail in the last year of his life.

In the next year, 1911, came the publication of an important book, "American Permian Vertebrates." [100] This, as the author says, comprises a series of monographic studies, together with briefer notes and descriptions, of new or little-known amphibians and reptiles from the Permian deposits of Texas and New Mexico. The sources of the material are mainly three—the University of Chicago collection, made in recent years by field parties under the charge of Paul Miller or the author; earlier collections of the University of Texas, made by Prof. E. C. Case; and finally, the Permian fossils in the Marsh collection at Yale, many of which were unknown to science until brought to light for study by Prof. Williston. An interesting comment upon our knowledge of reptilian classification shows that the time is not yet ripe to attempt phylogenies of the groups other than the dinosaurs, crocodiles, phytosaurs, pterosaurs, and rhynchosaurs, because we are less sure of them than we were a dozen years ago. The more recent general classifications of the reptiles by Cope, Osborn, Boulenger, and others have offered suggestions of value, but are by no means the real solutions of the reptilian and amphibian phylogenies. Certain morphological problems are discussed in the following pages and the author has given what seem to be the legitimate conclusions regarding the immediate relationships of the forms under discussion. The present work, however, is offered more as a contribution to our knowledge of ancient reptiles and amphibians, with such summaries and definitions, based chiefly upon American forms, as the evidence at hand permits. A summary of the genera from the Texas Permian follows:

Amphibia: Lysorophus, Diplocaulus, Trimerorhachis, Eryops, Cacops, Dissorophus, Aspidosaurus Cardiacephalus.

Reptilia: From the uppermost beds, Labidosaurus, Naosaurus, Dimetrodon, from lower horizons, Naosaurus, Dimetrodon, Clepsydrops, Varanosaurus, Trispondylus, Casea, Aræoscelis, Captorhinus, Diadectes, Seymouria, etc., of which perhaps the most characteristic are Labidosaurus of the upper and Cricotus of the lower zone.

Williston feels confident, however, that no definite line can be made between the two divisions, and that at present Clear Fork can be used in a general way to designate the upper, and Wichita the lower part of the Texas deposits.

In the paper on Permian reptiles, published in Science in 1911,[104] Williston proposes a classification for the therocrotaphic reptiles (excluding the Theriodontia): Order Theromera [later he uses the spelling Theromorpha]; suborders Pelycosauria, Poliosauridæ, Edaphosauridæ, Caseidæ, Aræoscelidæ(?), Therocephalia, Anomodontia, Dinocephalia, and Dromasauria, the first five American, the others African. In his restoration of the cotylosaur Seymouria in the same year,[101] he makes known to us, aided by a very accurate drawing, the complete osteology of the creature that stands lowest in rank among reptiles, approaching in many ways the contemporary amphibians, for, as he says, so far as the characters are

shown in the figure, there is not a single thing to differentiate the form from an amphibian, unless it be the apparent absence of the cleithrum. The palate is different from that of other known reptiles, though distinctly reptilian in structure. Williston continues (p. 236):

> The American cotylosaurs, more especially the Diadectidæ, Limnoscelidæ, and Seymouriidæ, show marked resemblances in many ways to the contemporary amphibians, in their short legs, broad feet, enormous humeral entocondyle, digital fossa of the femur, pronounced adductor crest, as well as girdles; but I do not believe that these resemblances were so much the result of phylogeny as of convergent evolution, the adaptation to similar environmental conditions and similar habits.

In "A new family of reptiles from the Permian," 1911,[105] Williston describes briefly the contents of a collection of Permian fossils from New Mexico in the Marsh material at Yale, made more than 30 years before. This was found in beds equivalent stratigraphically to the lower or Wichita division of Texas. Certain forms are either closely allied to or identical with those of the Texas beds, others are quite different; this Williston attributes to differing environmental conditions, since the identical or allied forms of New Mexico are from the red clays and red sandstones which are quite like those of the Texas deposits, while the unlike forms are from sandstones and clays unlike anything in the latter State. There is also a complete absence of concretions and of fish remains in New Mexico. While a full discussion of the Yale material was published in "American Permian Vertebrates," a remarkable new form, Limnoscelis, was described somewhat in extenso, as it is not only the finest thing of the collection, but is one of the most notable specimens of a reptile ever obtained from the Permian deposits of America. There is more than one individual represented, so that parts lacking in one are present in another; but one specimen is practically perfect and is in essentially complete articulation, the skeleton lying as the animal died. *Limnoscelis paludis* is a cotylosaur, representing the new family Limnoscelidæ, a large form, 7 feet over all, powerful, of carnivorous habits, but a subaquatic or marsh-dwelling reptile, with limbs strongly suggestive of the turtles. The relationship lies most closely with Diadectes and Pareiasaurus, which, together with Propappus also, may perhaps be placed in the same order of reptiles. A restoration of Limnoscelis by Williston was described in 1912.[107]

A joint paper by Williston and Case, in the same year,[106] treats of the allied skulls of Diadectes and Animasaurus. Perhaps their most remarkable feature is the differentiated dentition, with strong chisel-shaped incisors and curious transversely elongated cheek teeth. They have usually been considered as herbivorous, but the character of the incisors, the absence of any power of trituration in the unworn maxillary teeth, and the possibility of the use of the palatine processes of the maxillaries as accessory organs of mastication lead to the suspicion that the animals were not exclusively, if at all, herbivorous, and that they may have included the less well-protected invertebrates in their diet.

A very important paper entitled "Primitive Reptiles, a Review," also appeared in 1912.[108] This summarizes our knowledge of the Permocarboniferous tetrapods of the world, correlating those characteristics upon which phylogenies and classification must depend. Of the foreign forms, Williston had no autoptic knowledge, but he had studied personally nearly all of the known American material and was thus in position to speak authoritatively. The characters of these creatures are grouped under those which are constant and those which are inconstant and variable. It is conceivable that with a more complete knowledge of certain genera some of the constant characters will be transferred to the variable list, but unless error has been made the reverse will not be possible. These characters which are enumerated are the chief ones upon which we must depend, for the present at least, for the classification of the known Permocarboniferous reptiles.

Williston expresses emphatically his lack of faith in the DeVreesian "mutation theory" of the origin of species, nor does he believe that any paleontologist can defend such a theory. And he does not consider that any theory of the origin of species, or even of evolution, can get very far when *time* is left out of account. If, in any series of phylogenetic forms, we find a gradual transformation of structure. or the gradual acquisition of new characters, we do right in uniting

them all in a single group, for the sole end of all taxonomy is phylogeny. Williston here defines the two larger groups, the Cotylosauria and Theromorpha, discussing also the relationships of the Old World Protorosauria and Proganosauria, and then describing the reptiles of the Lower Permian of Europe. This is followed by a discussion of the position of the Microsauria and of Lysorophus, which he now believes to have no direct ancestral relationships with any modern vertebrates, but to owe its resemblance to certain existing types to community of habit (see, however, table facing p. 133).

The genus Aræoscelis, originally described by Williston in 1910, is further discussed in two papers in 1913.[111,114] His final conclusions as to its place in reptilian taxonomy are startling, for he believes it to be the first known lizard, and that from the Lower Permian. Aræoscelis can not be placed in any known order of reptiles, unless it be admitted to the Squamata, and he does not think that the differences from the Squamata will justify its ordinal separation if we are to classify organisms phylogenetically. He says: "I would rather modify the definition of the order Squamata to include the genus as a representative, doubtless with Kadaliosaurus also, of a distinct suborder, the Aræoscelidia." He believes that after he has published the full details of Aræoscelis his readers will agree as to its phylogenetic association with the Squamata as in the general acceptance of the genus Lysorophus as an ancestral urodele. In "The Osteology of some American Permian Vertebrates," 1914,[122] he gives this further evidence in the form of a complete discussion of the osteology of Aræoscelis, the entire skeleton of which is now known with the exception of the tail beyond the fourth vertebra. He again compares the genus with certain foreign types, notably Protorosaurus, Kadaliosaurus, Paleohatteria, the Proganosauria and Ichthyosauria, and thus concludes (p. 400):

> I have urged that the resemblances of Aræoscelis to the Squamata would justify its inclusion in that order as a suborder, under the name Aræoscelidia, coordinate with the Lacertilia and the Ophidia. And I believe that will be its final disposition under some subordinal designation. But it seems to me that the relations with Protorosaurus and Kadaliosaurus are too definite, too pronounced, to warrant their dissociation. I would therefore propose to unite these three genera, together with, provisionally, Haptodus and Callibrachion, under the order Protorosauria of Seeley, and place the order immediately before the Squamata in any serial classification of reptiles.

This he brings out graphically in the table of 1917 (facing p. 133).

A restoration of Aræoscelis is given, both skeletal and in the flesh, and the creature is described as an extremely light and slender, terrestrial and arboreal reptile, with springing powers, and possibly with a parachute development of the body membrane. Its length, when adult, was about 2 feet.

Another skull of the curious Casea adds to the information given concerning this reptile in "American Permian Vertebrates." There is also a description of Arribasaurus, a new genus based on *Dimetrodon navajoicus* Cope, and a discussion with figures of the primitive structure of the mandible in reptiles and amphibians.

A joint paper by Williston, Case, and Mehl appeared in 1913,[117] a large quarto memoir on the Permocarboniferous vertebrates of New Mexico. This is divided into several chapters, all but one of which are by Williston and Case. Chapter I is geological, a description of the vertebrate-bearing beds of north-central New Mexico, whereas the others are all concerned with vertebrate description, of which the most notable are the discussions of the skull of Aspidosaurus, of a nearly complete skeleton of Diasparactus, of Ophiacodon, and of the pelycosaur Edaphosaurus.

Prof. Williston's book on "Water Reptiles of the Past and Present," 1914,[118] has been repeatedly referred to, but its importance is such that it should be discussed in somewhat greater detail. It summarizes in a most authoritative manner our knowledge of the reptiles which have become adapted to aquatic life, and also includes an important chapter on the classification of reptiles, for, as he says, the classification of reptiles is still a matter of much doubt and uncertainty, no two authors agreeing on the number of orders or the rank of many forms. Many strange and unclassifiable types which have come to light in North America, South Africa, and Europe, have thrown doubt on all previous classification schemes, and have weakened our faith in all attempts to trace out the genealogies of the reptilian orders, and

classification is merely genealogy. It is only the paleontologist who is competent to express opinions concerning the larger principles of classification of organisms, and especially the classification of reptiles. The neozoologist, ignorant of extinct forms, can only hazard guesses and conjectures as to the relationships of the larger groups, for he has only the specialized or decadent remnants of past faunas upon which to base his opinions.

The third chapter is an illuminating discussion of the skeleton of reptiles, in which the principal elements are not only fully described, but illustrated by the author's drawings. The chapter on the Age of Reptiles contains a chart (that of 1909) showing the range in time of the various reptilian suborders, beginning with the Carboniferous. Each important horizon is taken up in turn and the character of the sedimentation and location of the chief exposures discussed. This section is illustrated by Williston's restorations of various Permocarboniferous reptiles.

The fifth chapter discusses the principal structural changes which water-living brings about, comparing the reptiles in their modifications with other important aquatic types. Then in orderly sequence the water-inhabiting groups are discussed: Sauropterygia; Lystriosaurus of the Anomodontia; the Ichthyosauria, in which the culmination of aquatic adaptation is reached; Mesosaurus, of the Protorosauria; many of the Squamata, especially the marine iguana, Amblyrhynchus; and the agialosaurs and mosasaurs.

Another chapter treats of the Thalattosauria, recently described by Merriam, and of Champsosaurus of the Rhynchocephalia. Crocodile-like forms are included under two orders, Parasuchia and Crocodilia, Geosaurus, an upper Jurassic crocodile, going to the extreme and developing an ichthyosaur-like tail for swimming. The final chapter discusses the Chelonia, the most sharply distinguished order of reptiles, and the one which has had the most uniformly continuous and uneventful history from the Triassic up to the present time.

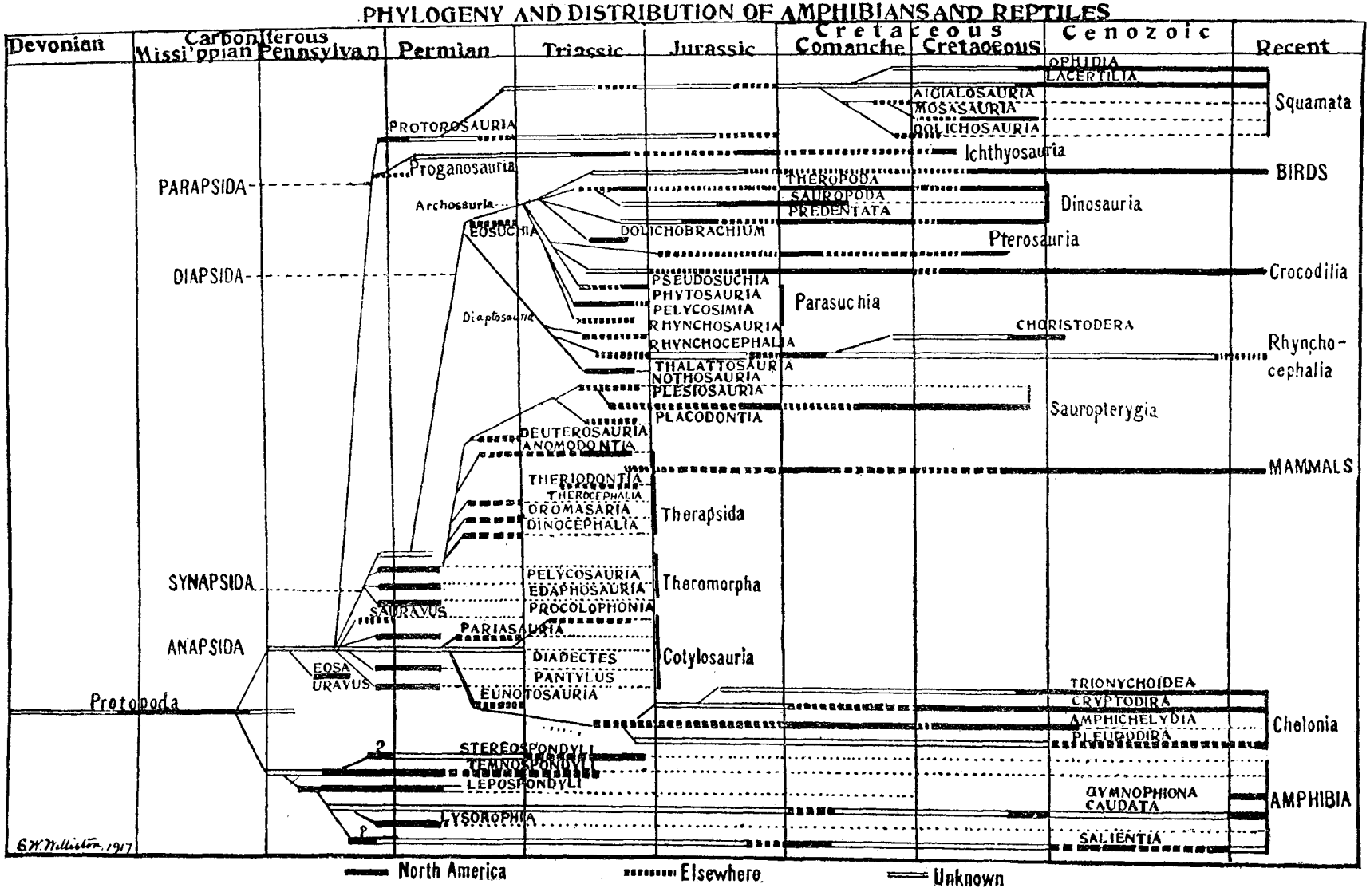
In "Restorations of some Permocarboniferous Amphibians and Reptiles," 1914,[121] Williston presents some interesting interpretations in the flesh of these ancient tetrapods, drawing them personally after a careful study of the more or less complete skeletons in the collections of the University of Chicago, the American Museum, and Yale University, the technical descriptions of which had recently been published. Of these he says (p. 57):

> I will not attempt to give any technical details of their structure here; my only desire is to place before the general student of geology something of what I see, after years of study of the fauna, in some of the animals that lived in Texas and New Mexico during the closing times of the Pennsylvanian and the early times of the Permian. The land vertebrate fauna of those times in America must have been very rich. More than 40 distinct genera of amphibians and reptiles are represented in the collections of the University of Chicago, and the remains of at least a dozen more are preserved in the American Museum and at Yale University. It is the oldest fauna of reptiles known in the world, and by far the most comprehensive of the older amphibians known. The animals of the South African Karoo system are nearly all of later age, upper Permian as distinguished from lower Permian and Carboniferous, and they were, for the most part, more highly specialized and less primitive.

Williston says, in conclusion, that whatever may be the merits of these restorations as works of art, they have been drawn with the most scrupulous accuracy so far as form and proportions are concerned, the musculature derived from the study of living reptiles, and they are all based upon practically complete skeletons; in a few only the precise length of the tail is yet unknown, or the front toes.

In 1915 Williston described *Trimerorhachis insignis*, a temnospondylous amphibian, from abundant material;[123] two genera of Permian reptiles, Glaucosaurus, with immense orbits, and Chamasaurus of the slender jaw;[125] as well as a new genus and species, *Mycterosaurus longiceps*, a pelycosaur related to Dimetrodon.[124]

Several papers of importance appeared during 1916. In Part II of the "Osteology of some Permian Vertebrates,"[130] Williston describes in detail the curious Pantylus from Texas, which as he says, is, so far as his knowledge goes, the earliest reptile in geological history having a bony dermal armor. Isodectes is also further discussed, and the species *Theropleura retroversa* Cope, which had been known from the centrum of a single vertebra, is now described practically in toto. The ventral ribs of this form are very remarkable, numbering some 200 on a


PHYLOGENY AND DISTRIBUTION OF AMPHIBIANS AND REPTILES
Devonian
Carboniferous
Missi'ppian
Pennsylvan
Permian
Triassic
Jurassic
Cretaceous
Comanche
Cretaceous
Cenozoic
Recent
OPHIDIA
LACERTILIA
AIGIALOSAURIA
MOSASAURIA
DOLICHOSAURIA
Squamata
PROTOROSAURIA
Ichthyosauria
Proganosauria
BIRDS
PARAPSIDA
THEROPODA
SAUROPODA
PREDENTATA
Dinosauria
Archosauria
EOSUCHIA
DOLICHOBRACHIUM
Pterosauria
DIAPSIDA
Crocodilia
PSEUDOSUCHIA
PHYTOSAURIA
PELYCOSIMIA
Parasuchia
Diaptosauria
RHYNCHOSAURIA
CHORISTODERA
RHYNCHOCEPHALIA
Rhyncho-
cephalia
THALATTOSAURIA
NOTHOSAURIA
PLESIOSAURIA
Sauropterygia
PLACODONTIA
DEUTEROSAURIA
ANOMODONTIA
MAMMALS
THERIODONTIA
THEROCEPHALIA
GROMASARIA
DINOCEPHALIA
Therapsida
SYNAPSIDA
PELYCOSAURIA
EDAPHOSAURIA
Theromorpha
PROCOLOPHONIA
SAURAVUS
PARIASAURIA
ANAPSIDA
DIADECTES
Cotylosauria
EOSAURAVUS
PANTYLUS
EUNOTOSAURIA
Protopoda
TRIONYCHOIDEA
CRYPTODIRA
AMPHICHELYDIA
Chelonia
PLEURODIRA
STEREOSPONDYLI
TEMNOSPONDYLI
LEPOSPONDYLI
GYMNOPHIONA
CAUDATA
AMPHIBIA
LYSORophia
SALIENTIA
G.W. Mellister 1917
North America
Elsewhere
Unknown

side. This is followed by a discussion of the origin of the sternum from the anterior ventral ribs in the Amniota, for which the evidence, according to Williston, seems complete.

The paper entitled "Synopsis of the American Permocarboniferous Tetrapoda," 1916,[131] is of the highest possible importance, for in it we have almost the last statement by Williston concerning these forms which he knew as did no other. In commenting on his paper on primitive reptiles, 1912, Williston says (p. 193):

> The lists of constant characters [see p. 016] then given have been reduced, as I felt sure they would be, by recent discoveries. * * * The final distinction between the two orders [Theromorpha and Cotylosauria] thus seems to be limited to a single character, the absence or presence of the temporal perforation, a character which, it might be urged, is not of supreme importance, though Broom considers the Cotylosauria a superorder.

The following pages present a synoptic review of the generic, family, and ordinal characters of the American Permocarboniferous Amphibia and Reptilia as Williston interprets them, in the hope that it will serve as an inventory of our present knowledge, regardless of personal views as to its taxonomic application. He does not attempt to characterize the various proposed suborders of reptiles, because he does not know how to measure them, nor how to distinguish them from families; nor is he at all sure, on the other hand, which are family and which are merely generic characters. Illustrations of the more important types are included in the summary.

The skeleton of Trimerorhachis is again discussed in 1916.[129] The animal had been described by Williston before, but now for the first time a connected skeleton has been found, through which alone, as he had predicted, the ribs, tail, and feet could be made known. The creature had the small limbs and broad neckless body of the modern Necturus, and Williston believes that the type under consideration was an aquatic animal incapable of progression on land, and in all probability, like Necturus, a perennibranchiate.

Labidosaurus is described in detail in 1917,[133] some half dozen very perfect specimens having been found by Mr. Miller near the Craddock ranch in 1916. The sclerotic plates of the eye are demonstrated and the entire skeleton shown, together with a flesh restoration. The peculiar rakelike teeth of the premaxillæ are bent backward, however, so that they effectually lock the lower jaw and would prevent its opening were that their position during life. An extremely important paper on the phylogeny and classification of reptiles was also published in 1917,[134] and represents Williston's last published views in the matter of the relationships of the four classes of terrestrial vertebrates, all expressed graphically and with great clarity in a table somewhat similar in general plan to the one published in 1909, although that was merely a table of distribution in time and space while to the present one is added a graphic view of the phylogenies. The 1917 table is here reproduced.

His most primitive group he calls the Protopoda, including therein the upper Devonian footprint, Thinopus, and subsequent forms known only from their tracks in the Mississippian. From these he derives the Amphibia on the one hand and the Reptilia on the other, representatives of each group being known from the Pennsylvanian, hence the inference that the division occurred during Mississippian time. Of the reptiles, he recognizes four great divisions, the Anapsida or Cotylosauria, Synapsida, Diapsida, and Parapsida, deriving the mammals from the second and the birds from the third. His use of Osborn's terms is of interest, for he was critical of them in earlier years (see p. 126). As he says (p. 413):

> It was Cope who, years ago, first suggested that in the temporal region of the skull the surest criteria for the classification of the Reptilia are to be found. Woodward carried the suggestion further, and showed their availability, but it was Osborn and McGregor who first applied them definitely. They assumed too much, as we have seen, but the credit is due to Osborn, more than to anyone else, for the foundation of a true reptilian phylogeny, and to him we owe especially a better knowledge of the double-arched reptiles. He has called them the Diapsida, and there is no better name for them. After the elimination of the forms which we are sure do not belong with them, we are all now, I think, in accord as to their phyletic unity.

The group or subclass of single-arched reptiles, with due modifications of the original concept, may properly bear the name Synapsida given to it by Osborn. It is the group that gave origin to the mammals and has long since been extinct. The temporal opening which, as

Williston believed, arose by the separation of the squamosal and jugal, and not by a definite perforation of any bone, is the sole character by which the group is ultimately distinguished from the Cotylosauria, its ancestral stock. What further phylogenetic work Williston did for his incomplete book on the Reptilia is not now evident to the reviewer. At present the paper under discussion forms the final published statement by one of the highest authorities.

But two papers other than reviews came from the press in Williston's final year, one on the evolution of vertebræ,[136] the other, Part III of the "Osteology of some American Permian Vertebrates." [137] The first of these discusses the homologies of the elements of vertebræ, primitive and otherwise, with their evolution, and is of great value to the student. The other describes further the genera Eryops Cope, Chenoprosopus Mehl and Naosaurus Cope, differentiating the last clearly from the closely allied Edaphosaurus.

GEOLOGY.

In his geological writings, Williston merely discussed such formations as he was concerned with paleontologically, for he was, like most vertebratists, primarily a comparative anatomist, and concerned with geological matters largely as he was with geographical ones, merely from the standpoint of distribution. He wrote of the Kansas Chalk, of semiarid Kansas, of the Kansas red beds, a summary of Kansas geology for a popular work by Angelo Heilprin, on the Laramie (Lance) Cretaceous of Wyoming, on the red beds and Morrison of Wyoming, and finally, with Case, on the Permocarboniferous deposits of the Southwest.

MAN.

A number of papers on man came from the pen of Williston, again largely, one might say, as a by-product of his other research. They discuss chiefly the occurrences of prehistoric man in Kansas, and he records one of the few authentic instances of the occurrence of human artifacts with extinct animals in America. He also wrote two papers on human evolution, of which the second, on the birthplace of man, has already been alluded to as an address delivered before the Paleontological Society in 1909 (see p. 118).

SUMMARY.

The most notable results of Prof. Williston's research lie, aside from the insects, almost entirely within the groups of Amphibia and Reptilia of the Paleozoic and Mesozoic. Compared with the volume and worth of this research, his other work on the fishes, birds, and mammals is almost negligible. He taught, however, many biologic, anatomic, and taxonomic truths of far-reaching application, so that a student of vertebrates of any class, either recent and extinct, can not afford to overlook his results. He gave us much that we know of the fauna of the Cretaceous, notably of the pterosaurs, plesiosaurs, and mosasaurs, and to him we also owe a very large part of our exact knowledge of the Paleozoic air-breathers, for his indefatigable work in the field and laboratory, aided by a few, very devoted co-laborers, has brought to light a fauna amazing in its extent and degree of perfection—entire skeletons of forms many of which were either new to science or known in very fragmentary condition. Williston not only gave a very clear understanding of the osseous morphology of the forms under consideration, throwing much light upon such vexatious problems as the homologies of the cranial elements, of the individual vertebræ, and of the amniotic sternum, but by careful comparative study of existing forms was enabled to restore his creatures in the flesh in a way that, anatomically at least, is thus far above criticism. He discussed at some length the life conditions, feeding and other habits, prowess, and evolutionary adaptations of the forms which he studied, and his knowledge was such that he could generally recognize such resemblances as were the result of convergence and such as actually implied a like heritage. His ideas concerning the phylogenies of the amphibian and reptilian groups developed somewhat slowly, due to his desire that such should be founded upon a considerable body of attested fact. In his final paper on phylogenies, in 1917, he

acknowledges, as the best that we have, those broader groupings of such men as Osborn, whose work he was inclined to criticize most emphatically when it first appeared 15 years before.

Williston laid a broad and fundamental foundation for the fabric of our knowledge concerning the cold-blooded air-breathers, building solidly and securely much of the superstructure as well. It is doubtful whether later students of the reptiles particularly will find much that is amiss, especially when the last work of the master shall have been published posthumously. On the other hand, it is the writer's belief that they can build thereon fearlessly, knowing that that which has been done is secure.

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