

SCIENCE

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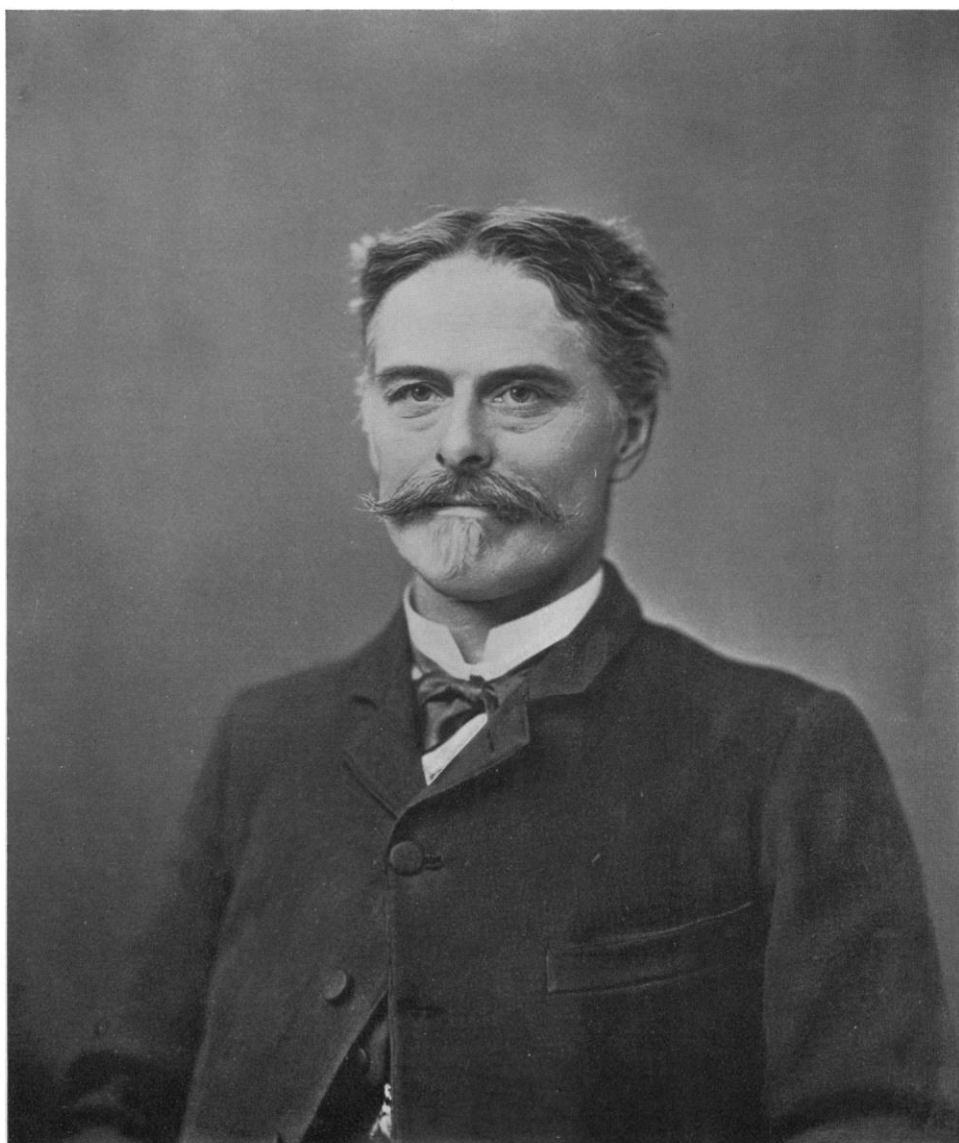
EDWARD D. COPE.

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Prof. J. McKeen Cattell, Garrison-on-Hudson, N. Y.

NATURAL science and philosophy have sustained a heavy loss in the premature death of Professor Edward D. Cope. His work began at a most favorable time, in 1859, when comparative anatomy first felt the impetus of the 'Origin of Species,' and for thirty-eight years his active mind has been hastening our progress in no less than five great lines of research. In each, his inspiring example and leadership will be sadly missed. He passed away upon April 12th, at the age of fifty-seven, in the full vigor of his intellectual powers, leaving a large part of his work incomplete. Almost at the last he contributed several reviews to the *Naturalist*, and upon the Tuesday preceding his death he sent to the press an elaborate outline of his University lectures containing his latest ideas of the classification of the Vertebrata. For two months his health had been affected by a serious disorder, which might possibly have been remedied by a surgical operation. This was unfortunately postponed until it was too late, and the end came so suddenly that his family decided not to remove him from his house, in Pine Street, which was both his study and museum. He thus passed away in the scene of his life work, surrounded by his fossils and books. A gathering of his scientific friends in his memory also took place here a few days later. His will proves to be consistent with his life, as he leaves



Very truly yours
E. W. Cope.

all his rare scientific treasures for the benefit of the Philadelphia Academy of Sciences and the University of Pennsylvania. It is hoped that the following sketch of his early life and brief review of his principal writings will give some idea of his genius and of his position in the world of science.

Edward Drinker Cope was born in Philadelphia, July 28, 1840, of distinguished American ancestry.* His great-grandfather, Caleb Cope, is said to have been the staunch Quaker of Lancaster, Pa., who protected Major Andre from mob violence. Thomas Pim Cope, his grandfather, founded the house of Cope Brothers, famous in the early mercantile annals of Philadelphia. His father was Alfred, the junior member of the firm, a man of very active intellect, who showed rare judgment in Edward's education. Together the father and son became brisk investigators, the father stimulating by questions and by travel the strong love of nature and of natural objects which the son showed at an unusually early age.

In August, 1847, they took a sea voyage to Boston, and the son's journal is full of drawings of jellyfish, grampuses and other natural objects seen by the way. When eight and a half years old he made his first visit to the Museum of the Academy of Natural Sciences, 'on the 21st day of the 10th Mo., 1848,' as entered in his journal; he brought away careful drawings, measurements and descriptions of several larger birds, but especially the figure of the entire skeleton of an Ichthyosaur, with this quaint memorandum: "Two of the sclerotic plates look at the eye—thee will see these in it." At the age of ten he was taken upon a longer voyage to the West Indies. Thus the child was in a remarkable degree the

father of the man. The principal impression he gave in boyhood was of incessant activity in mind and body, of quick and ingenious thought, reaching in every direction for knowledge, and of great independence in character and action. It is evident that he owed far more to paternal guidance in the direct study of nature and to his own impulses as a young investigator than to the five or six years of formal education which he received at school. He was especially fond of map drawing and of geographical studies. His natural talent for languages may have been cultivated in some degree by his tutor, Dr. Joseph Thomas, an excellent linguist, editor of a biographical dictionary. Many of his spare winter hours were passed at the Academy. After the age of thirteen the summer intervals of boarding school life and later of tutoring were filled among the woods, fields and streams of Chester county, Pa., where an intimate knowledge of birds was added to that of batrachians, reptiles and insects. He always showed a particular fondness for snakes. One of these excursions, taken at the age of nineteen, is described in a letter to his cousin (dated June 24, 1859); at the close of a charming description of the botany of the region appears his discovery of a new type:

"I traced the stream for a very considerable distance upon the rocky hillside, my admiration never ceasing, but I finally turned off into the woods towards some towering rocks. Here I actually got to searching for Salamanders and was rewarded by capturing two specimens of species which I never before saw alive. The first (*Spelerpes longicauda*) is a great rarity here. I am doubtful of its having been previously noted in Chester county. Its length is 6 inches, of which its tail forms nearly four. The color is deep brownish yellow, thickly spotted with black, which becomes confluent on the tail, thus forming bands. To me a very interesting animal—the type of the genus *Spelerpes*, and consequently of the subfamily Spelerpinae, which I attempted to characterize in a paper published in the Proceedings of the Academy of Natural Sciences. I send thee a copy, with

* In the preparation of this article the writer is indebted to several members of Professor Cope's family, also to Professor Bashford Dean and to Professor George Baur. The latter has contributed especially a section upon the Reptilia.

the request that thee will neither mention nor show it,* for—however trifling—I would doubtless be miserably annoyed by some if thee should. Nobody in this country (or in Europe, of *ours*) knows anything about Salamanders, but Professor Baird and thy humble coz., that is in some respects. Rusconi, the only man who has observed their method of reproduction, has written enough to excite greatly one's curiosity and not fully satisfy it. With suitable appliances of aquariums, etc., I should like to make some observations. The other Salamander I caught was *Plethodon glutinosus*—the young—remarkable for the great number of teeth that lie together in two patches on the 'basisphenoid' bone; about 300 or more."

Another passage gives an insight into his strong opinion, so often expressed afterward, as to what constitutes the real pleasures of life:

"Pleasant it is, too, to find one whose admiration of nature and detail is heightened, not chilled, by the necessary 'investigation'—which in my humble opinion is one of the most useful as well as pleasing exercises of the intellect, in the circle of human study. How many are there who are delighted with a 'fine view,' but who seldom care to think of the mighty and mysterious agency that reared the hills, of the wonderful structure and growth of the forests that crown them, or of the complicated mechanism of the myriads of higher organisms that abound everywhere; who would see but little interesting in a fungus, and who would shrink with affected horror from a defenseless toad* * * Dr. Leidy is getting up a great work on comparative anatomy which is to be the modern standard. Such a work will be very useful to those who want to go to the bottom of natural history; it is an interesting study, too, to notice the modifications in form—the degradations,† substitutions, etc., among the internal organs and bones. The structure, forms and positions of teeth, too, are interesting to notice—so invariably are they the index of the economy and the position in nature of the animal."

This is the reflection of a lad of nineteen, an age at which some modern educators would have us believe our young men are just ready for the collegiate Freshman class.

*This passage probably indicates that he was sensitive to being teased about his interest in these animals.

†A word used by French writers of the time to express lines of descent.

During the same year young Cope went to Washington to study and work in the Smithsonian Institution under Spencer F. Baird, and it is amusing to observe him in the above letter classing himself with Baird as the only Americans who knew anything of the Batrachia. Upon April 19, 1859, he contributed his first paper (alluded to above) to the Academy 'on the primary divisions of the Salamandridæ, with a description of two new species.' He followed this by a full description in the same year of reptiles brought from West Africa by Du Chaillu, naming several new forms; also by a catalogue of the venomous snakes in the museum. In the succeeding three years he made twenty-four communications upon the Reptilia and established himself at the age of twenty-two as one of the leading herpetologists of the country.

It is obvious from other portions of the letter that by this time young Cope's career was fully determined in his own mind. Here and in the papers he was now presenting he shows keen observation and powers of systematic diagnosis, a wide range of self-acquired knowledge, and familiarity with the characteristics of his distinguished seniors, Agassiz and Leidy. This period included a year's study (1858-9) of anatomy and clinical instruction at the University of Pennsylvania. In 1863 he traveled abroad for several months, visiting especially the museums of Leyden, Vienna and Berlin and extending his horizon as a comparative anatomist, for upon his return he at once showed the impulse of the philosophical spirit, complete familiarity with the history of opinion and marked power of generalization. Thus his papers, which began to crowd the pages of the 'Proceedings of the Academy,' chiefly in recent herpetology and ichthyology, display a new breadth and range as in his division of the Anura into the *Arcifera* and *Raniformes* (Firmisternia) and his demonstra-

tion of the main evolution principles in these groups.

In 1865 he married Miss Annie Pim, daughter of Richard Pim, of Chester Co., Pa. In the year 1864 Haverford College called him to a professorship of natural science. This position, however, he held for only three years. Twenty-two years later he again resumed teaching as professor of geology and paleontology in the University of Pennsylvania, all the interval having been devoted to exploration and research. In 1865 he first began to extend his studies among the mammalia, especially the Cetacea, recent and extinct, of the Coastal Tertiary. Early in 1866 a wider paleontological field opened in the vertebrata of the Cretaceous marls of New Jersey, whence he procured the remains of Dinosaurs, describing especially the carnivorous *Laelaps*, and grouping (Nov., 1866), these reptiles into three great suborders, *Orthopoda* (*Hadrosaurus* and *Iguanodon*), *Goniopoda* and *Symphopoda* (*Megalosaurus*, *Laelaps* and *Compsognathus*). In the same year appeared the continuation of his tropical American and Sonoran herpetology and his third contribution to the history of the Cetacea. Henceforward his papers become far too numerous to consider together and we must endeavor to follow merely the main outlines of his life work.

This was a bright era in the history of the Academy, Leidy, Gill and Harrison Allen being frequent contributors. In 1868 Cope gave his first complete synopsis of the extinct Amphibia of the world. Between 1868 and 1870 he made his first six contributions upon the Plesiosaurs of the Cretaceous of Kansas and in 1871 began his first western explorations in these beds. This led to his connection with the U. S. Geological Survey, under Dr. Hayden, and to further explorations in Wyoming (1872) and Colorado (1873), which resulted in the discovery of many new types of fishes, mosa-

saurs, chelonians, dinosaurs and other reptiles, notably *Portheus*, *Platecarpus*, *Clidastes*, *Compsemys* (type of the *Amphichelydia*, Lydekker), *Protostega*, and *Agathaumas*. These were described chiefly in the Bulletins of the Survey and in the Transactions of the American Philosophical Society, and culminated in his first large volume 'The Vertebrata of the Cretaceous Formations of the West,' No. II., of the Hayden quartos, published in 1875.

He spent his summers in the Bad Lands, exploring the Bridger and Washakie, Wasatch, New Mexican and Judith River (1877 formations). The latter exposures he visited in 1874, in connection with the Wheeler Survey, securing a collection which is now preserved in the National Museum, and publishing a most vivid description of the geology of this interesting region. His movements in the field are described by one who was with him as so rapid and full of energy, so regardless of food and rest, that he wore out the other members of his parties and did not allow time for thorough search; yet he himself found a number of his most important types.

The fruits of the New Mexican journey appeared in many bulletins and were finally collected in his second great volume, 'The Extinct Vertebrata obtained in New Mexico by Parties of the Expedition of 1874,' Vol. IV., of the Wheeler Survey. In 1874 appeared the first of his studies upon the comparison of American and European horizons, and of his contributions to the John Day fauna. His collections were now accumulating so rapidly as to demand more time for research and for many years he was fortunate in securing the field services of C. H. Sternberg and Dr. J. L. Wortman. He continued to make brief expeditions, among the last being his trip into the Laramie region.

As early as 1868 it may be said that he had laid the foundations for five great lines

of research, which he pursued concurrently to the end of his life; these must, however, be followed separately to be understood and appreciated. Only for comparatively brief intervals would one line be pursued exclusively in order to complete some special memoir, for his marvelous memory apparently held and resumed the details of all the others with perfect ease.

FISHES.

Cope's work in ichthyology would alone have given him high rank among zoologists. In his early papers (1864) he appears as an enthusiastic systematist, studying especially the living forms of Teleosts, making careful diagnoses of all types that came into his hands, critically considering the problems of distribution, never casting aside those types whose especial difficulties had been the stumbling block of earlier writers. Thus he studied successively the fishes of Michigan (1864-65), of Virginia (1868), of the Lesser Antilles (1870), the cyprinids of Pennsylvania (1867), again the fishes of South Carolina (1871), of Alaska (1872), of Montana, those from South America collected by Professor Orton (1872-78), those from the territories collected by the Wheeler Survey, and even not infrequently new forms from Africa and the East Indies.

Almost from the first he set aside the superficial characters which had been employed in the classification of fishes, sympathizing keenly with the morphological spirit in systematic study which Dr. Gill was then showing. A great step in his career was, therefore, his purchase, while abroad, of Professor Hyrtl's private collection of fish skeletons, which gave him nearly a thousand admirable preparations for immediate study. Owen had proposed (1866) the Teleostomi to include the old Ganoids and Teleosts. Before the American Philosophical Society, in 1870, and the American Association, in 1871, Cope dem-

onstrated the law that the primary divisions of the Teleostomi are indicated by their *fin structure*. This is now the accepted basis of sub-ordinal classification. Besides proposing the *Actinopterygii*, he established the fundamental division (Holocephali, Selachii, Dipnoi, Crossopterygii, Actinopterygii) of the living fishes into five groups, as they stand at the present day, upon cranial and fin structure. In 1876 Huxley adopted Cope's wide separation of the Holocephali from the Selachii. Fin structure as a taxonomic motive was uppermost in his mind and undoubtedly served to direct his attention later to the foot structure of land vertebrates as of diagnostic value.

The masterly part Cope continued to play in the major classification of the fishes may be gathered from a perusal of the introductions of Smith Woodward's standard volumes 'Catalogue of Fossil Fishes of the British Museum.' In 1884 he proposed a new Elasmobranch subclass, *Ichthyotomi*, from the Permian *Diplodus*. This order was subsequently enriched by his discovery of *Didymodus* and is now firmly established to include the pleuracanth and other paleozoic sharks. In 1889 he proposed another great sub-order, the *Ostracodermi*, which is also established.

His interest in the phylogeny of the group was naturally intensified by increasing knowledge of extinct forms, and here his wide studies among living types stood him in good stead, for he was first brought in contact with fishes from the Tertiary and Cretaceous, from the vertebrate remains from the New Jersey Greensand (1869) to the rich yields of the Green river shales (1871-7). The older fishes had long been in the hands of Professor Newberry, the pioneer among the fossil fishes of North America, but his studies came naturally to lead him among the more ancient types in his eager study of phylogeny. Into this difficult field he carried his work always with

suggestive results; for the most abstruse problems he had ever at hand a wide range of answers. Thus the curious fish-like *Bothriolepis* he compared to an armored ascidian, basing this surprising view upon a remarkable similarity in the arrangement of plates, arguing that it was reasonable to expect in the early horizon of *Bothriolepis* that the back-boned creature should be built on the plan of the ascidian tadpole. His final opinions and additions to the taxonomy and phylogeny of the fishes are inserted in the syllabus of his university lectures (1897).

AMPHIBIANS.

"There never has been a naturalist," writes Dr. Baur, "who has published so many papers upon the taxonomy, morphology and paleontology of the Amphibia and Reptilia as Professor Cope." The first of a series of more than forty papers upon the former group is the one 'On the Primary Divisions of the Salamandridæ, with descriptions of two new species,' alluded to in his letter above, and presented at the age of 19 (April, 1859). It exhibited the precocious taxonomic instinct which soon afterwards prompted him to attack and rearrange the major divisions of the Amphibia. Rapidly following this first essay by others upon the Anura, in 1865 and 1866 he outlined the larger Ecaudate or Anurous divisions: I. Aglossa; II. Bufoniformia; III. Arcifera; IV. Raniformia. At the age of 25 he described his first extinct Amphibian, *Amphibamus*, from the Carboniferous of Ohio, and at 28 he published his first large quarto memoir, 'Synopsis of the Extinct Batrachia, Reptilia and Aves of North America.*' This contained, in addition to the above, the recent urodelous divisions, Trachystomata, Gymnophidia, Proteida, but of chief importance, to include the Permian and Triassic forms of the world, he proposed the great extinct order *Stegocephali*, which

* Trans. Amer. Phil. Soc., read 1868, pub. 1869. See also Proc. Phil. Acad. Nat. Sci., 1868, p. 211.

has since been universally adopted. As a supplement to this memoir appeared in 1874 his 'Catalogue of the Air-Breathing Vertebrata from the Coal Measures of Ohio,' including results also published in the paleontology of the Geological Survey of Ohio of the same year. His researches and collections in the typical coal measures and Permian extended to Iowa and Illinois, leading to the determination of *Cricotus*, which in 1880* he made the type of the suborder *Embolomeri*, or *Stegocephalia* with double vertebral rings. In 1877 he received the first remains of *Eryops* and *Trimerorachis*, from the supposed Triassic, but actually Permian beds of Texas, animals which in 1882 he made the type of the *Rachitomi*, a second suborder of *Stegocephalia*. This accession of material, as we have seen, ranks with that of the Puerco among the chief events of Cope's scientific career, for the Permian of Texas yielded to him not only these remarkable Batrachians with complex vertebræ, but also the great primitive representatives of the Reptilia. The suborders *Rachitomi* and *Embolomeri* have been grouped as *Temnospondyli* in contrast with the specialized *Labyrinthodontia* and simpler *Microsauria* of Europe, chiefly made known through the labors of Fritsch, Credner, Gaudry and Miall. Cope's brief memoir of 1884 upon the 'Batrachia of the Permian Period of North America' summed up his previous contributions, but he anticipated that the more exhaustive monographic treatment of the rich amphibian and reptilian fauna of this period, exclusively collected and described by him, would constitute a volume of the Hayden Survey memoirs and give him an opportunity of rounding up his prolonged studies.

In the meantime his investigations upon the living Batrachia extended to Central and South American species, as well as to very original observations upon the laws of

* *American Naturalist*, p. 610.

geographical distribution of the Amphibia, which were published by the Smithsonian Institution. In 1875 he prepared a 'Check List of the North American Batrachia and Reptilia' for the U. S. National Museum; this was followed by an essay 'On the Zoological Position of Texas' (1880). Soon afterwards, at the request of Spencer F. Baird, he began the preparation of a general work upon the Batrachia; this was facilitated by a manuscript prepared for a work of the same character both by Baird and Girard, but was not completed until 1889. As a volume of 523 pages and numerous plates this work,* while showing many signs of haste and subject to considerable changes in the larger systematic divisions, fortunately remains as a monument of the immense range of knowledge and observation of its author upon the structure and habits of the living representatives of this group. It must always be a matter of regret that he could not have published his final views upon the extinct forms. One of his most important generalizations from the latter, contained in a short memoir, 'The Intercentrum of the Terrestrial Vertebrata' (1881), is that the vertebræ of living amphibia are composed of intercentra and are, therefore, not homologous with the true centra (pleurocentra) of reptiles, birds and mammals.

REPTILES.

We have already traced Cope's initial work upon the Reptilia. As in other groups, his researches rapidly branched out in many directions, first his treatment of the reptiles of the Bridger and other freshwater Tertiary lakes in connection with the mammalian fauna; second, the continuation of his systematic description of the Kansas Cretaceous fauna; third, the brief papers upon the herbivorous Dinosaurs of the Dakota (1877 and 1878) and the horned

* 'The Batrachia of North America.' Bull. No. 34, U. S. Nat. Museum.

Dinosaurs (*Monoclonius*) of the Laramie formations; fourth, the numerous papers upon the Reptilia of the Triassic and especially of the Permian. The latter must be considered the most important and unique in their influence upon paleontology. In 1875 he first announced the discovery of reptiles in the Permian, and in 1877 he reported the first primitive Crocodilia (*Belodon*) and Dinosauria (*Clepsysaurus* and *Zatomus* in the Triassic of North Carolina.

The detailed sequence of this reptilian work is clearly stated by Professor Baur: "Already in 1864 he published a paper on the characters of the higher groups of the Squamata.* Two years later he made his first remarks about the Dinosaur *Laelaps*,† and in 1867 he compared the carnivorous Dinosaurs with the birds;‡ this he did before Huxley's paper upon the same subject appeared.§

In 1870 he read an important paper before the American Association 'On the homologies of some of the Cranial Bones of the Reptilia and the systematic arrangement of the class.'|| He discussed the following topics.: 1. Homologies and Composition of the cranial arches. 2. The cranium of the Ichthyosauria. 3. The cranium of the Anomodontia. 4. The homologies of the opisthotic. 5. The squamosal bone. 6. The columella (epipterygoid.) 7. The systematic arrangement of the Reptilia. 8. Critical remarks on the system. 9. The Rhynchocephalia and supposed Lacertilia of the Trias and Permian. 10. Stratigraphic relation of the orders of Reptilia.

His classification is this:

A. Extremities beyond proximal segment not differentiated as to form.

I. *Ichthyopterygia*: Order *Ichthyopterygia*.

* Proc. Acad. Phila., 1864, p. 224.

† *Laelaps aquilunguis*, Cope. Proc. Acad. Nat. Sci., Phila., July, 1886, p. 275-279.

‡ Ibid., 1867, p. 234-235.

§ *Popular Science Review*, 1868, p. 237-247.

|| Proc. Assoc. Adv. Sci., XIX., p. 194-247.

B. Extremities differentiated.

II. *Streptostylia*: Orders *Lacertilia*, *Pythonomorpha*, *Ophidia*.

III. *Synaptosauria*: Orders *Rhynchocephalia*, *Testudinata*, *Sauropterygia*.

IV. *Archosauria*: Orders *Anomodontia*, *Dinosauria*, *Crocodylia*, *Ornithosauria*.

In 1875 the large volume 'The Vertebrata of the Cretaceous Formations of the West' appeared, as Vol. II., of the Rep. U. S. Geol. Surv. Territ. (302 pp., Pl. LVII.). This work contains extensive descriptions, especially of the Mosasaurs, also of Testudines, Crocodylia, Plesiosaurs and Dinosaurs (Iguanodontia): *Agathaumus*, Cope (*Triceratops*, Marsh; *Hadrosaurus*, Leidy (*Trachodon*, Leidy; *Diclonius*, Cope, *Claosaurus*, Marsh).

Cope's most epoch-making contributions, however, are his researches on the Permian Reptiles of Texas, which commenced in 1878. In the Proceedings of the American Philosophical Society of this year he established the sub-order *Pelycosauria* of the *Rhynchocephalia* to contain *Clepsydrops*, *Dimetrodon*, *Diadectes*, *Bolosaurus*, *Pariotichus*, *Empedias*. In the December *Naturalist* of the same year the order *Theromorpha* was created, with the sub-orders *Anomodontia*, Owen, and *Pelycosauria*, Cope. The *Pelycosauria* were considered as the ancestors of the *Mammalia*. In 1880* a new division of the *Theromorpha* was established, with the name of *Cotylosauria*, to contain the family *Diadectidae*. In a skull of *Empedias* he described two occipital condyles, being misled by the missing basioccipital. In 1883† he placed his genera *Pariotichus* and *Pantylus* in a new family *Pariotichidae*; characterized by the over-roofing of the temporal fossæ and the presence of the supra-occipital and par-occipital plates (intercalare, Cope). He now found the basi-occipital in position and the *Cotylosauria* were given up. In 1890 (March 12th) Cope placed again the *Cotylosauria* as a sub-

order with the *Theromorpha* distinguishing three families: *Pareiasauridae*, *Pariotichidae*, *Diadectidae*. In 1882* Seeley had established the order *Pareiasauria*; Lydekker (1889) and Zittel considering it a sub-order of the *Theromorpha*. In 1892† the *Cotylosauria* were made an order by Cope. The two last papers published by Cope in the Proceedings of the American Philosophical Society give much new evidence about this very interesting group. The titles of these papers are: 'The Reptilian Order *Cotylosauria*'‡ and 'Second Contribution to the History of the *Cotylosauria*.'§ In this paper a new family, *Otocelidae*, was described with the following characters: Posterior border of temporal roof excavated laterally by the meatus auditorius externus. Teeth present in a single row, not transversely expanded. Ribs immediately overlaid by parallel transverse derm-ossifications which form a carapace. This family he considered, or at least suggested was, ancestral to the Chelonians.

Cope had in preparation for many years an extensive work on the *Lacertilia* and *Ophidia* of the United States, to be published, like his *Batrachia*, in a bulletin of the United States National Museum.|| The

* Proc. Roy. Soc., Vol. 44, p. 383.

† Trans. Am. Phil. Soc., Vol. XVII.

‡ Proc. Am. Philos. Soc., Vol. XXXIV., 1896 (Feb. 2d), p. 436-457, Pl. VII.-IX.

§ Ibid., Vol. XXXV., p. 112-139, Pl. VII.-X. Aug. 15, 1896.

|| Many preliminary papers have appeared for this publication, of which the following are named below:

'An Analytical Table of the Genera of Snakes.' Proc. Am. Philos. Soc., 1886, p. 479-499.

'The Osteology of the *Lacertilia*.' Proc. Am. Philos. Soc., Vol. XXX., 1892, p. 185-221. Pl. II.-VI.

'On Degenerate Types of Scapular and Pelvic Arches in the *Lacertilia*.' Journ. Morphol. Vol. VII., 1892, p. 233-244, Pl. XIII.

'The Classification of the *Ophidia*.' Trans. Amer. Philos. Soc., Vol. XVIII., April 15, 1895, p. 186-219, Pl. XIV.-XXXIII.

'On the Hemipenes of the *Sauria*.' Proc. Acad. Nat. Sci. Phila., August, 1896, p. 461-467.

* *American Naturalist*, p. 304.

† Proc. Amer. Philos. Soc., p. 631.

MSS. for this work cost him much labor, especially during the past two years, and for a while interrupted all his other work. It was characteristic of him to turn aside for a laborious detailed investigation of the soft anatomy of the snakes in the hopes of finding some satisfactory means of classifying this puzzling group. This investigation constituted his latest original work and was barely completed before his death.

MAMMALIA.

Up to 1868 Leidy held the Western paleontological field exclusively. In this year Marsh and Cope also entered the Western territory and began the simultaneous exploration and description of a limited fauna in a somewhat limited region, with the inevitable result of a struggle for priority and a permanent rupture of friendly intercourse. It is necessary to allude to the fact, because it greatly affected the subsequent history of American paleontology. Fortunately, the western fossil area proved to be a vast one, and the remarkable discoveries by Wortman in the Big Horn and Wasatch, beginning in 1878, also by Baldwin in the Puerco of New Mexico, beginning in 1880, and the explorations already described of Cummins in the Permian of Texas, afforded Cope a noble field of research quite free from the haste of rivalry. From the Wasatch ungulates Cope established the stem forms of three lines of Perissodactyla and of far wider import than these, the foundations of the classification of the great group of Ungulata. The generalized *Phenacodus*, which he at first regarded as a perissodactyl, furnished the key to the evolution of the carpus and tarsus, from the serial (Taxeopod) to the displaced (Amblypod and Diplarthrous) types with the interlocking joints. Kowalevsky, in 1873, had pointed out the significant articulations of the metapodials; Cope now showed the still greater importance of the

mutual articulations of the podials, firmly establishing thereupon the orders *Condylarthra* and *Amblypoda*, uniting Owen's Perissodactyla and Artiodactyla into the *Diplarthra*, and by hypothetical phyla connecting the Proboscidea and Hyracoidea with a still-to-be-discovered plantigrade, unguiculate, bunodont stem, the 'protungulate' of Huxley and Kowalevsky. These generalizations, despite errors of excess and of detail which Rüttimeyer and Osborn have pointed out, constituted the first distinct advance in mammalian classification since Owen demolished Cuvier's 'pachydermata;' they rank with Huxley's best work among similar problems, and afford a basis for the phylogenetic arrangement of the hoofed orders which has been adopted by all American and foreign paleontologists.

At the same time it became apparent that the hoofed mammals had sprung from clawed ancestors, but the Wasatch period was too remote from the parting to furnish conclusive evidence. This evidence came in a flood from the underlying Puerco fauna, the systematic treatment of which constitutes the most unique section of Cope's work among the extinct mammalia. From this material originated his second great generalization—namely, that the primitive pattern of the molar tooth consists of three tubercles. Around this *trituberculy* centers the whole modern morphology of the teeth of the mammalia and the establishment of a series of homologies in the teeth of most diverse types, wholly unsuspected in the 'Odontologies' of Cuvier and Owen, connecting the most ancient Mesozoic mammals with the most modern and specialized types, including the teeth of man. The force and application of the tritubercular law Cope clearly perceived, but left to others to fully work out and demonstrate. It promises ultimately to give us the key to the entire phylogeny of the mammalia, extending to every division of the Marsupialia

and Placentalia, and will probably be found among the Monotremata.

These are the mountain peaks, the points where exploration and discovery were followed by happy inspiration, in a chain of contributions, which includes his exposition of the faunal succession from the base to the summit of the tertiary. In the Bridger, Cope himself found the lower jaw of *Anatomorphus*, with its typically human dentition, which, owing to its extreme antiquity, occasioned him a greater surprise than any discovery he ever made; he also found the last of the great race of Uintatheres at the top of Washakie Mountain. We owe to him alone our knowledge of the scanty Wind River fauna. From the White River Oligocene his materials were poor and his work less satisfactory. From the rich Upper Oligocene, with the assistance of Wortman, he secured fine collections and has especially enriched our knowledge of the *Anchitheriidae*, *Felidae* and *Canidae*. From the Upper Miocene Deep River and Loup Fork beds he has practically contributed all that we know, especially of the Rhinoceroses, Horses, Mastodons, Camels and other ruminants and carnivora. Of the latter fauna his most complete papers were upon the evolution of the *Oreodontidae*. His latest contributions to our knowledge of the fossil mammalia were upon the fauna of the Blanco and Palo-Duro, or Goodnight beds of Texas and the rich cave fauna from Port Kennedy, Pa., brought together by Dr. H. C. Mercer. It was his intention to cover the entire later Tertiary in a second part of the 'Tertiary Vertebrata;' many of the plates and much of the MSS. of this volume are ready.

The 'Tertiary Vertebrata,' Vol. III., of the Hayden quartos published in 1883, is his most imposing contribution to paleontology, including his studies of all the vertebrate fauna of the Tertiary lakes west of the

Rockies. This work of over a thousand pages and eighty plates is said to have been the despair of the public printer owing to the constant additions made while in press. It extends from the Puerco to a portion of the Lower Miocene fauna. Besides the full description and illustration of the great hoofed orders above alluded to, it contains the full exposition of the characteristic forms of *Creodonta*, an order of primitive carnivora which he separated from the Marsupialia in 1875, and in which he placed six families of mammals from different parts of the world.

Before leaving the mammals it is fitting to speak of his work upon 'kinetogenesis,' or the mechanical origin of the hard parts of the body, especially of the teeth, vertebræ and limbs. An invaluable paper by his friend and later colleague, Ryder, put him upon this line of investigation, the results of which he published in a long series of papers culminating in his memoir upon the 'Origin of the Hard Parts of the Mammalia' and in his collections of essays in the 'Origin of the Fittest' and 'Primary Factors of Organic Evolution.' One of his chief motives in these researches was the demonstration, he believed they afforded, of the hereditary transmission of the effects of individual efforts, use and disuse, but even if this motive is subsequently shown to be an illusive one, by our future knowledge of the real nature of evolution, these investigations lose little, if any, of their intrinsic value. First, as in all his work, he brings together an immense array of valuable facts and observations; second, he extends the principle of the independent origin of similar structures; third, he in most cases successfully establishes the actual mechanical adaptive or teleological relations of the parts described; fourth, he traces the course of phylogenetic modification in a number of important organs and thus establishes certain obscure homologies, notably

those in the teeth of the Amblypoda, Coryphodon and Uintatherium.

PHILOSOPHY.

Cope's contributions to philosophy began in 1868, with the remarkable essay upon the "Origin of Genera," and, continuing steadily in a series of papers which in collected form fill three octavo volumes, they cover both the data and the factors of evolution, psychology, ethics and metaphysics. Unpublished manuscripts, prepared in connection with his last work, 'The Primary Factors of Organic Evolution,' contain also his views upon many sociological and theological problems. It is singular that at the age of 28 he adopted the Lamarckian theory under cover of a misconception of a part of Darwin's theory, for he states the *latter* in part as follows: "This is, in brief, that the will of the animal, applied to its body, in the search for the means of subsistence and protection from injuries, gradually produces those features which are evidently adaptive in their nature." He soon detected this error; but a year later, in a paper upon 'The Laws of Organic Development,' before the American Association, he again connected rudimentary will or consciousness with use and effort, and struck the keynote of all his later evolution philosophy in the sentence: "Thus intelligent choice may be regarded as the originator of the fittest, while natural selection is the tribunal to which all the results of accelerated growth are submitted." (1869.)

His chief contention in the 'Origin of Genera' is that, while a large proportion of specific characters are adaptive, few generic characters are so, and the latter evolve separately by the force of 'acceleration or retardation' of one of several plans or types of development preordained by the Creator. To sustain this proposition he applied the principles of arrested, hastened or abbreviated development with extra-

ordinary knowledge both of the osteology and soft anatomy of the entire vertebrata to hundreds of examples of *exact* and *inexact parallelism*,* and with such force that he completely establishes his law. Incidentally the principle of *heterology*, or what Lankester has since termed homoplasy, is abundantly illustrated. Darwin, in one of his letters, states that he never could understand this Cope-Hyatt† law of 'acceleration and retardation.' It is undeniable that its exposition might have been clearer; of its truth, not as a theoretical factor, but as a grand principle of evolution, there can, however, be no question, and it has received far less attention than it deserves.

Cope subsequently altered some of the main standpoints of this thesis, but his systematic definition of genera and families, horizontally or transversely to phyletic descent according to the heterologous assumption of similar structures, persisted as a conspicuous and confusing feature of all his later phylogenetic tables and writings. It is throughout evident that in 1868 he was still *en route* to his later broader conception of the sweeping extent and natural causation of evolution. He entered vigorously into the evolution campaign,‡ always showing great consideration and courtesy for his orthodox opponents and desiring rather to convert than to offend. As above noted, in 1870, he drew a sharp distinction between the 'preservation of the fittest' and 'the causes of the origin of the fittest,' which he ascribed to the increase and location of 'growth force.' In 1871 appeared 'The Method of Creation of Organic

* Parallelism is here used in the sense of recapitulation (von Baer), not of homoplasy or convergence.

† Professor Hyatt, Cope's fellow laborer in Lamarckism, worked out this law independently at the same time.

‡ 'On the Hypothesis of Evolution,' *Lippincott's Magazine*, 1870; 'Evolution and its Consequences,' *The Penn Monthly*, 1872.

Forms,* in which he set forth in a most interesting way a complete system of the modes and causes of evolution under the five laws of: (1) Acceleration and Retardation; (2) Repetitive Addition; (3) Use and Effort; (4) Bathism or Growth Force; (5) Intelligent Selection. This system was largely original with him, because he had not as yet studied Lamarck's writings, knowing them only through abstracts; it cannot be said, however, that he ever either advanced beyond or substantially modified the theoretical position he reached at the age of 31. Later, as he carefully studied the writings of the great French naturalist, he fully recognized Lamarck's priority and accepted the Neo-Lamarckian title when it was applied to him during the Weismann controversy. Cope, Hyatt, Ryder and Packard became the pioneers of the school in America. It is not necessary here to detail his widely known arguments as champion of this philosophy, which he gathered from his rich stores of comparative anatomy and paleontology and put forth in numerous essays and public discussions, concluding with his final argument before the recent meeting of the American Society of Naturalists, in Boston.† Suffice it to say that he showed much of the same kind of confident strength and of the same logical weakness which characterized Lamarck. The latter, in fact, among all naturalist philosophers is Cope's nearest prototype. The papers upon the 'Origin of Intelligence' (1872), 'Consciousness in Evolution' (1874), 'The Origin of the Will' (1877), 'On Archæsthetism' (1882), follow a line of thought largely foreshadowed by Lamarck, but none the less striking. Cope was nothing daunted by Weismann's challenge and vigorous attack upon the transmission theory, and maintained to the end

that the paleontological evidence was too strong to be refuted. His first collected essays, 'The Origin of the Fittest,'* antedated this discussion, but his second collection, 'The Primary Factors of Organic Evolution,'† enters into it very fully and with as much force of reason as the facts afford at present. This volume goes over some familiar territory, yet is striking because of the very wide range of fresh reading and research it gives evidence of. The concluding chapter contains (p. 508) his final statement of what may be called his fundamental causal principle—namely, the formative or creative rôle of consciousness from the dawn of life.

Side by side with these studies of the factors of evolution are numerous essays upon the history of man,‡ beginning in 1875, and upon the evolution of the vertebrata, progressive and retrogressive, which are full of speculative phylogeny. In formulating descent trees Cope has been second only to Haeckel. He let no opportunity slip by of at least throwing out an hypothesis as to the phyletic relations of every great type he studied, and many of these random guesses have been confirmed.

More remote from the main trend of his profession were his collateral intellectual pursuits, each of which seemed to issue from a clearly defined alcove of his brain upon consecutive occasions and express his ever widening and deepening philosophy. His progressive thought upon metaphysical problems can be followed in 'The Origin of the Will' (1877), 'Theology of Evolution' (1877), 'The Relation of Mind to Matter' (1877), 'Ethical Evolution' (1889), 'An Outline of the Philosophy of Evolution' (1889), 'The Evolution of Mind' (1890), 'The Foundations of Theism' (1893).

* D. Appleton & Co., 1897, 8vo., 467 pp.

† Open Court Publishing Co., 1896, 547 pp.

‡ Among others see 'The Genealogy of Man,' *American Naturalist*, 1893; 'Lenurine Reversion in Human Dentition,' *Journal of Morphology*.

* American Philosophical Society, December 15, 1871.

† Reported in *SCIENCE*, April 23, 1897.

In this review no mention has been made of Cope's several papers upon fossil birds or of his extremely valuable contributions to historical geology.

We have at present few data for the history of his later life apart from that furnished by his writings. His editorial connection with the *American Naturalist*, begun in 1878, in association with Professor A. S. Packard, who retired a few years later, was continued for twenty years, with a great sacrifice of time. It afforded an outlet for his continuous stream of shorter publications and for the free expression of his very independent opinions upon current scientific movements and topics. This constant occupation kept him from foreign travel; at the time of the first Paris Exposition he made his second and final journey abroad. He was a close student but never a recluse. Extremely fond of the society of thinking people, he was also a very regular attendant upon the learned societies of his city and country. It is a cause for regret, and an instance of the non-recognition of genius, that only at a very late day the Society of Naturalists and the American Association for the Advancement of Science elected him to their chief offices. His retiring presidential address was to have been made at the coming meeting of the Association.

The most conspicuous feature of Cope's personal character from boyhood upwards was his independence; this was partly the secret of his venturesome and successful assaults upon all traditional but defective systems of classification. He was no respecter of authority *per se*. Even if sometimes mistaken his fearless criticism of men and of institutions was chiefly animated by high ideals, not by personal feeling, nor for personal advantage. His open and aggressive statements made him many opponents and attracted to him many friends, because whether right or wrong they always sprang from conviction. Another marked charac-

teristic was his fortitude. He bore material reverses with stoical resignation, regretting chiefly the limitations they placed upon his explorations. He was full of cheer and determination when things looked most unpromising, allowing nothing to disturb the composure which is so essential to research. His life in fact became a fine illustration of the happiness attendant upon plain living and high investigation which he foresaw at nineteen in his letter to his cousin quoted above.

Cope is not to be thought of merely as a specialist in paleontology. After Huxley he was the last representative of the old broad-gauge school of anatomists and he is only to be compared with members of that school. His life-work bears the marks of great genius, of solid and accurate observation and at times of inaccuracy due to bad logic or haste and overpressure of work. The greater number of his Natural Orders and Natural Laws will remain as permanent landmarks in our science. As a comparative anatomist he ranks both in the range and effectiveness of his knowledge and his ideas with Cuvier and Owen. When we consider the short life of some of the favorite generalizations of these great men he may well prove to be their superior as a philosophical anatomist. His work, while inferior in style of presentation, has another quality which distinguished that of Huxley—namely, its clear and immediate perception of the most essential or distinctive feature in a group of animals. As a natural philosopher, while far less logical than Huxley, he was more creative and constructive, his metaphysics ending in theism rather than agnosticism. In mere mass of production Cope's work was extraordinary. He leaves twenty octavo and three great quarto volumes of collected researches. By his untimely death a wide gap is left which can never be filled by one man.

HENRY F. OSBORN.

COLUMBIA UNIVERSITY, May 3, 1897.