then if our astronomers see a great institution for promoting their science supported by Congress on a scale of unprecedented liberality, while, owing to defects of organization, the results do not come out on a corresponding scale, what is their duty as patriots and citizens in the premises?

The other and concluding question is this: What possible object can men enjoying the high and well-earned reputation which so justly accrues to the professional abilities of the officers of our Navy have in going outside the line of their profession to enter a field in which their best efforts can have no result but to lessen public confidence in their ability and good judgment? We can assure these officers that none of our citizens admire their professional skill and achievements more heartily than do the astronomers. We do not believe there is a director of an observatory in the land who would not welcome the advent of a naval officer to relieve him of the onerous duties of administration, were such a thing compatible with efficiency. But the director knows well that no such result would be possible unless the officer would consent to be subordinate to him, just as he would be the subordinate of the officer, if he performed scientific duty on a naval vessel.

THE RECENT PROGRESS OF VERTEBRATE PALEONTOLOGY IN AMERICA. *

THE three sciences especially favored by nature in this country are astronomy, paleontology and geology. American progress in astronomy is largely due to our relatively clear and dry atmosphere, as compared with that of northern Europe, to our inventive genius in the matter of instruments and to the private and public liberality which has founded great observatories and telescopes. Paleontology is also notably an American science, not because of the superior ability of its American votaries, but because of the vast extent of the arid region of the West exposing thousands of miles of fossil-bearing strata which in a moist climate would be covered by vegetation. This branch has especially enjoyed the liberality of the national government, and two men of large wealth, Professors Marsh and Cope, have devoted their entire fortunes to it. Except by institutions west of the Mississippi it cannot be pursued with limited means because of the great distances involved, the expense of fitting out explorations, and the equally great expense of preparing the fossils when they arrive in the East.

The development of paleontology in this country has followed the forest clearing of the East and the winning of the West by stage coaches and railroads. Mastodons, great sloths, horses and cetaceans were the principal animals found in the East. Among other early observers of this Eastern fauna was President Jefferson. David Owen, as U. S. Geologist between 1847 and 1852, explored the Mississippi Valley as far west as Wisconsin, Ohio and Minnesota. Joseph Leidy, the distinguished comparative anatomist of the old school, astonished the world in the fifties by describing the ancient fauna of Dakota and Nebraska. In 1870 the line extended west into Wyoming; Leidy, Marsh and Cope were all exploring and describing the types of this Eocene region with feverish haste, so that upon the average each animal was baptized with at least three names. It is our hard lot at present to find order out of this chaos of species. 'Après moi le déluge,' apparently was the motto

* Introduction and conclusion of a popular lecture illustrated by field and museum photographs., delivered at Trinity College, Hartford, Conn., on the occasion of the opening of the Hall of Natural History.

of each of these authors. As widely apart in their personal characteristics and methods of work, as it was possible to be, they were nevertheless the founders of American paleontology: Leidy, a pre-evolutionist and an exact descriptive writer, with little power of generalization; Marsh, a genius for the appreciation of the most important problems in evolution, with clearness as a writer, unrivaled talent as a collector and great powers of exact description, without marked originality in the invention of hypotheses; Cope on the other hand a philosopher, fertile in hypotheses, a road-breaker in classification, hasty in description and with indomitable capacity for work. The comparatively recent death of these three great men has totally changed the conditions of paleontology in this country, it now attracts a large number of students and has spread through our institutions. Whereas twenty-three years ago paleontology was exclusively in the hands of Marsh and Cope, we now find workers in the National Museum, the Yale Museum, at Princeton, the American Museum of Natural History, the Carnegie Museum of Pittsburg, and the Field Columbian Museum of Chicago, also in the Universities of Chicago, Kansas, Nebraska, Minnesota and Colorado. Explorations are now conducted on a most extensive scale, the peculiar American methods of work having been carried by two parties as far as Patagonia with remarkable results.

Before describing the work of the American Museum which is quite characteristic of the field at large, I want to speak of the philosophical development of this science.

The wise and oft-quoted remark of Huxley's, that the only difference between a fossil and a recent animal is that one has been dead longer than the other, is the epitome of the present attitude of our science. Huxley himself slowly reached this conclusion. After devoting the earlier years of his life to marine zoology, he shrank from accepting a post in the School of Mines, because it necessitated his centering his research upon extinct animals. Yet he became the Nestor of modern vertebrate paleontology, the first to thoroughly apply the principles of evolution as a means of interpretation of extinct forms. A fossil is still a synonym for dryness, and Huxley's preconceived prejudice, which was transformed into a passionate devotion for fossils, represents a popular error, which I trust I shall succeed in fully dissipating this afternoon; in fact, the chief burden of my song is that paleontology is a part of zoology or the study of animal life; that zoology is a part of biology; and that biology is the common-sense, the rationale, the philosophy of living nature as a whole.

The true modern spirit in which to study a fossil vertebrate is to imagine it as living, moving, walking, swimming or flying, begetting its kind. The size of the brain, which is really ascertained by studying its cavity in the skull, has been the subject of special researches by Leuret, Marsh, Cope and Bruce; the size and position of the organs of sight and smell are among the data of fossil psychology. Therefore we can study a fossil as thinking, that is, fearing its enemies, devising means of escape either by adhering to its friends in herds or by swift solitary flight. But such knowledge is not obtained from a few fragments, we need a very large part of the skeleton of an animal and information concerning its contemporaries before we can begin to draw such inferences, and one of the greatest advances of recent work consists in the fact that we have secured complete skeletons in the place of fragmentary parts.

If the remains of an animal are found with many others of its kind as in the case of five skeletons of Merycochoerus recently found by one of the American Museum expeditions, you infer that it was gregarious; if always found isolated you infer that it

led a solitary life. The construction of both teeth and feet teaches you whether it lived in the water, along the shores and swamps, in the meadows or on the dry grasses of the uplands and mountains. If an animal is found with short crowned teeth and spreading feet and its remains are always imbedded in coarse sandstones and gravels, you have an absolute demonstration that it lived and died near the river bank, if on the other hand the teeth are long crowned, adapted to the grasses, and the limbs are stilted like those of the antelope, you infer that it avoided water courses and that its remains were deposited in the fine dust like that now seen upon our western plains. This law has been recently used for a geological generalization by Dr. W. D. Matthew, which, if confirmed, will entirely overturn the lake-bottom theory long held for certain great formations of the Oligocene and Miocene east of the Rocky Mountains, as shown in this map.* It will bring in its train a whole series of consequences, because a new idea disturbs the relations of old ones just as the introduction of a new animal into a country may alter the whole balance of life. It will change our views, not only as to these eastern deposits, but as to the climate of this period; this which we have always supposed to have been extremely moist, will now prove to have been dry, not so dry as upon the western plains of the present day, but certainly as dry as in great districts in Africa. These fine dry subaërial or eolian deposits of drifting soil, containing animals of one type, are traversed by sandstone deposits due to intersecting rivers and containing animals of quite another type. This result has not been reached haphazard, but it is largely due to the exact study of extremely exact field records which are now made as to the level at which every specimen is found. The kind of rock in which a skeleton is found and even its position often forms a clue to its mode of deposition. Thus paleontology works hand in hand with geology and throws a clear light upon the climatic conditions of the past.

In line with zoology is the adaptation of extinct types. The very first advice I give to my students is to ponder over the function, purpose, fitness or adaptation of parts. Comparative anatomy and paleontology are alike dry where they ignore physiology, they become fascinating in the measure that they reveal design. Consider for a moment the story told by these vertebræ, part of the backbone of a great dinosaur of 50 to 70 feet in length; they are marvels of construction, with all the beauties of the flying buttress of a cathedral and rigidity of the T truss of a modern bridge; evidently the mechanical problem which this animal solved was to combine the maximum of size and strength with the minimum of weight.

This spirit of looking for 'purpose' and ignoring the conventional distinctions between a petrified animal and a living one has been more or less characteristic of the work of the master minds of paleontology from the time of its great founder Cuvier, of Cuvier's successor, Owen, and of our own Cope. Did not Cuvier propose the law of correlation, whereby he maintained that a single claw would enable us to give the habits and restore an entire animal? A generalization, not altogether supported by more recent evidence, which in his day excited great admiration and called forth the famous remark of Balzac that 'Cuvier like Cadmus builds cities from a single tooth.' The masters of every science are always in advance of the lesser men, many of whom are seeking a bubble reputation, not at the cannon's mouth, but by the laborious description of new species. Systematic description is at once the staff of our progress and the bane of our existence. Rightly

* Oligocene Lake.

done, it is a record of all the steps which nature has taken in the passage from lower to higher types but, alas, egotism, personal rivalry, in short every form of human frailty is here exhibited; there are the 'species makers,' who devise species which nature knows not of; the 'species lumpers' who ignore actual distinctions, putting together that which nature has put asunder, forgetting that it is a great convenience to have a name or symbol for every distinct stage of evolution; finally, there are the 'resurrectionists' who, seldom or never examining original specimens, pore over old literature and revive obsolete and best-to-be-forgotten names.

Paleontology has yet to gain universal recognition as a zoological science not only on the part of other workers, but of its own disciples. Its disciplinary value as a train in *exact thinking in evolution* is undoubtedly superior to that afforded either by embryology or comparative anatomy.

Modern morphology or the science of form stands on a tripod of evidence. He who tries to balance a theory of vertebrate structure upon embryology or comparative anatomy alone is like a man trying to keep a permanent and comfortable sitting on a two-legged stool. It may be inconvenient to go from the laboratory so far afield as the rocks for one's evidence, but the stability of every theory which affects the hard parts of the vertebrates depends upon the tripod, namely, upon the comparison with other living types, upon the order of development from the embryo, and upon the direct history or order of evolution in past time. We are even now sympathetically witnessing the wreck of certain favorite doctrines of the greatest comparative anatomist of our day, Carl Gegenbaur, because his work rests upon comparative anatomy and embryology alone. In this regard Huxley was an unrivaled model; he not only, so far as was in his power, rested his theories upon three kinds of evidence, but let those who are hurrying through a superficial education for brief glory as investigators ponder upon the following passage, written at the age of 31: "1856–7–8 must still be 'Lehrjahre' to complete training in principles of Histology, Morphology, Physiology, Zoology, and Geology by *Monographic Work* in each Department. 1860 will then see me well grounded and ready for any special pursuits in either of these branches." This passage, in fact all of the 'Life and Letters,' constitutes at once a brilliant argument against premature specialization (Huxley little dreamt of the modern fad of extending the elective system to the kindergarten) and a solemn injunction that he who would build high must be patient to lay his foundations broad and deep.

Is there then no distinction in the methods of thinking of the paleontologist, embryologist or comparative anatomist? I would answer a distinction not of kind but of degree. Of course none of the soft parts are preserved in a fossil, the skeleton and teeth alone remain; by direct study and comparison with living types these have to be clothed with muscles, nerves and blood vessels. We are forced to study the bones and teeth with intensified keenness and exactitude in our search for evidence as to how an extinct animal moved and fed, and I consider that *precision in methods of exact description and terminology* constitutes one of the chief advances in the work of the present day.

In the geological and biological spirit this becomes a fascinating field for the constructive imagination. To do the best work you must live in the period of your research, however, remote it may be; marshal the extinct animals before you, as the brilliant young dramatist, Rostand, marshals Wagram before the eyes of L'Aiglon; revive the physical geography, the temperature, moisture, vegetation, insect life and see before

your minds eye the keen struggle for existence. * * *

* * * Here you have before you the methods and present aims of paleontology; it is the history of the world in the period which is mistakenly called prehistoric; it is your history and mine when our ancestors were struggling upwards in the long ascent of man. Every broad, serious, honest contribution to paleontology will constitute a word, a line, a chapter in the final history which our descendants will complete.

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*BIOLOGY AS AN ELEMENT IN COLLEGE TRAINING.**

COURSES in natural science under the head of biology are a comparatively recent feature in our college programs. They may be described in general terms as consisting of a comparative study of certain types of animal and vegetable life with reference to their functions as well as their structures. Strictly speaking biology is in no essential respect a new subject. Nevertheless the term is a useful one, and courses in general biology differ in several important, if not essential respects, from those usually given under the title of zoology or botany or natural history. In the first place, these courses, as given in our colleges, endeavor to present the salient facts with regard to the properties of living things from a common or general standpoint. They attempt to bring into the foreground the resemblances as well as the differences in structure and function among varied forms of life belonging to both the plant and the animal kingdom. The intention is to give a bird's-eye view in which the general plan shall be made evident, and fundamental relationships shall be emphasized. A student who has acquired this point of view is prepared to appreciate discussions of the great general laws of biology, or, if need be, to enter more carefully upon a closer study of details.

But, in addition to this feature, courses in general biology are characterized by the emphasis laid upon the functional manifestations of living matter, by a presentation and discussion of the great questions of nutrition, heredity and reaction to environment.

In other words, the physiological point of view is brought out more prominently, if I mistake not, than is the case in the customary courses in botany or zoology. For these reasons a course in elementary biology has a special value, which has been recognized and has led to its very general introduction into our colleges. In a proper sequence of biological studies its place falls naturally in the college period. It should be preceded, preferably in the secondary schools, by an out-door study of the forms and life-histories of familiar plants and animals, and, on the other hand, should itself precede courses in botany or zoology or special professional training.

It is in this last respect that the importance of collegiate training in biology has been most widely recognized, that is, as a preparation for a future professional career, particularly the profession of medicine. Medicine on its scientific side falls into the group of biological studies, but as taught in the professional schools it concerns itself almost exclusively with a single, and that the most highly developed, form of life. The intelligent members of the medical profession have recognized freely that a general survey of the whole series of living types forms an excellent basis for the more special work of medical schools and medical practice, in that it gives a wholesome breadth of view and an educational training that may save its possessor from many

* Address delivered at Trinity College, Hartford, Connecticut, on the occasion of the opening of the Hall of Natural History.