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SOME APPLICATIONS OF PALEONTOLOGY[1]

PERHAPS the most remarkable feature in Dr. Joseph Leidy's mental make-up was the immense variety of his scientific interests and achievements. I would use the word *versatility* to describe him, were it not that that term usually implies a certain degree of superficiality, which was utterly foreign to Leidy's mind, for thoroughness and minute accuracy were characteristic of him.

Last year, the centenary of Dr. Leidy's birth was celebrated in the Academy of Natural Sciences in Philadelphia, at which each one of a number of speakers dealt with his own specialty and with Leidy's activity in that particular branch of science. I think that every one who attended that celebration was astonished to hear that fields which they had never associated with Leidy's name had been successfully cultivated by him. For instance, I imagine that very few people knew anything of Leidy's work in botany, or in geology, matters which lie outside of the range of work with which his name is usually associated, even by those to whom he was more than a name in America's honor-roll. Among all those strikingly varied fields which he cultivated so successfully, there is none, I think, which has so contributed to his fame throughout the world as that of paleontology, especially of the vertebrates. In this work Leidy was a pioneer. There had been some work done by such men as Wistar and Harlan in Philadelphia, Mitchill and DeKay in New York; but these men had dealt with such fossil remains as are found in the Eastern States, occurring near the surface of the ground and of very late geological date, including mastodons, horses and ground sloths. It was once thought, both in this country and in Europe, that North America contained no fossil vertebrates of any particular interest or importance, and that, in this respect, we should have to admit inferiority to South America and to the Old World. The first breach in this tradition was made by Leidy, when he began to receive through Dr. Hiram Prout, of St. Louis, fragmentary fossils brought in by the fur-traders from that marvellous and inexhaustible field of discovery, the White River Bad Lands of what was then Nebraska Territory.

[1] No. IV of the Leidy Memorial Lecture Series. Delivered at the University of Pennsylvania.

The White Earth River, to give its full title, is a muddy stream which flows into the Missouri, its course nearly parallel with that of the Cheyenne. Between these two rivers, and on both sides of them, especially south of White River, is the vast area of bad lands, 150,000 square miles or more in extent; and it was with the fossils collected from this region that Leidy's most important contributions to paleontology were made. This is not to overlook the value of his investigations among Eocene mammals and reptiles and Cretaceous reptiles of the Far West, but merely to emphasize the greater importance of his work on the White River fauna. Aside from the great number of short papers published in the *Proceedings* of the Philadelphia Academy of Natural Sciences, the two great monographs of 1853 and 1869 are his monuments, and they form the foundation upon which the great edifice of subsequent work has been erected.

Leidy himself did not collect from the Western fossil grounds; unless I am mistaken, his first visit to those regions was made in 1877, when I met him at Fort Bridger at the house of his friend Dr. Carter, who had sent many Eocene mammals to him. It must be emphasizeed that the art of collecting vertebrate fossils was quite undeveloped in the United States, and that the material sent to Leidy was nearly always made up of such bones as had been weathered out of the soft bad land rocks and were picked up, in a more or less fragmentary condition, so that only skulls and jaws and a few occasional limb bones were included. He had no skeletons to deal with, nor even a single well-preserved foot, only a few good skulls and a great quantity of fragments. Another reason why collections from the White River beds were so hastily and unskilfully made was that till quite late in the century the region was unsafe for white men. My first expedition to the White River bad lands was in 1882, and the U. S. Indian agent at the Pine Ridge Agency warned me that my enterprise was a dangerous one, and advised that my camps should be guarded day and night. So late as the winter of 1890-91, there were fierce battles with great loss of life between the Sioux tribe and the U. S. Army; since that time the region has been entirely safe for the collector.

One of Leidy's most serviceable friends was Dr. F. V. Hayden, long the director of the U. S. Geographical and Geological Survey of the Territories, who from 1856 till 1880 was constantly engaged in surveying and collecting in what were then the "Territories," and was thus able to send much valuable material to Leidy. Even such fossils as were assigned to the collections of the Smithsonian (there was no U. S. National Museum in those days) were first determined and described by Leidy. Hayden's collections were, in large degree, the basis of Leidy's splendid quarto monographs of 1853 and 1869. Hayden enjoyed among the Sioux the enviable reputation of being mad, and therefore his person was under divine protection and inviolable; this enabled him to go about freely, breaking rocks and picking up old bones, where other white men would not have dared to show themselves.

Before proceeding farther, it will be useful to stop for a moment and explain the oft-used phrase "bad lands." The term is a partial translation of the expression used by the French Canadian *voyageurs*, "mauvaises terres à traverser," bad lands to cross. Our abbreviated form of the term gives a false impression of utterly barren and useless grounds, whereas, in many regions, the flats and bottoms are covered with grass and form an excellent winter range for cattle. The term "bad lands" applies to the gullied and cut-up shapes of the valleys and hillsides, which are worn and gashed by the rain and melting snows. Wherever soft and easily weathered rocks are widely exposed in an arid or semi-arid climate, then bad land topography is developed, and many hundreds of thousands of square miles of these peculiar regions, often presenting views of the wildest and most unearthly scenery, extend through the Far West from Alberta to Mexico, and ranging in geological time from the Cretaceous to the Miocene. Very often, but not always, the bad lands are a paradise for the collector of fossils, because of the immense areas which are exposed to view, and if the beds, so worn and gashed, are richly fossiliferous, then great numbers of fine specimens are weathered out of the enclosing rock. Of course, if the beds were originally barren, weathering will not supply them with fossils.

What I especially wish to talk about this evening, the main subject to this lecture, is a consideration of the reasons why Dr. Leidy should have been interested in these things. Why should any one care about a lot of old bones, and why do the universities and museums spend vast sums to obtain them and prepare them for exhibition? Could anything seem more absurd than for the American Museum, in New York, to equip and maintain costly expeditions to India, to the Gobi Desert of Mongolia, to South America, merely to gather more or less petrified bones? Not only bones, but shells and tests, insects, corals and plant-impressions, are all fish for the paleontologist's net and to the uninitiated it must seem a singularly futile type of child's play. It was Darwin's great book, published in 1859, that gave a new impetus to the study of these things; before that time it was believed among geologists that the earth's history consisted of a succession of periods of calm and quiet rock-formation, interrupted at intervals by great cataclysms, which destroyed all the life of the earth.

When tranquillity was restored, a new creation was made to replace the old. This was the catastrophic theory of Cuvier, which, so far as the rocks were concerned, was gradually replaced by Sir Charles Lyell's theory of uniformity, according to which the earth's history was an uninterrupted sequence, but Lyell did not venture to suggest the evolutionary conception of plants and animals and their gradual development by natural agents.

From the beginning of the Nineteenth Century, geologists had made most careful studies of the fossil invertebrates, which were (and are still) an indispensable means in arranging the rocks of the earth's crust in chronological order. Fossil vertebrates, on the other hand, were of much less use for such purposes, because of their comparative scarcity, and therefore but few men took any interest in them. When new ones were found, they received names, were catalogued in their proper systematic order, put into glass cases, and ignored. According to the dominant theory of special creation, which taught that every species of animal and plant was unchangeable, save within very narrow limits, and owed its existence to a creative fiat, vertebrate paleontology could be little more than a descriptive catalogue of the animals which had successively appeared on the earth. Darwin's book, which immediately divided civilized mankind into two opposite and warring camps, completely changed the status of paleontology. Every one recognized that the fossils offered one of the best means of putting this newfangled theory of evolution to a crucial test. Since the fossils were the actual remains of the animals that once had lived on the earth, and since the rocks gave us their order of succession in time, then the fossils ought to make manifest whether they formed genetic series, connected by a real blood-relationship of ancestor and descendant, or whether they were due to separate acts of creation, related only ideally in a common creative plan. None of the biological sciences was so completely transformed and rejuvenated by Darwin's work as was the paleontology of the vertebrates, which thus received an entirely new content and significance, causing it to thrive and flourish mightily. I may remark here, incidentally, that some of the strongest and most convincing proofs of Darwin's views have been supplied by paleontology.

It is time for us to have done with this preliminary discussion and turn to a consideration of the topics announced in the title of this lecture, *viz.*, some of the applications of paleontology. Nature is one and indivisible, and the important discoveries made in one branch of science are sure to effect more or less radical changes in other branches. When M. and Mme. Curie announced the discovery of radium and the amazing phenomena of radio-activity, no one could have foreseen that these newly discovered phenomena were to affect profoundly the sciences of astronomy and geology. Such has been their effect, nevertheless. The discoveries of paleontology have modified biology, geology, geography, and even, strange to say, the seemingly remote science of astronomy.

The first and most obvious application of the modern paleontology, which was so fertilized and stimulated by Darwin's writings, was to explain the facts of zoology and botany; but another, and very much older, application was as a means of arranging the earth's history chronologically and correlating the histories of the various continents and seas into a single consistent and harmonious earth-history. This use of fossils does not depend upon any theory of the origin and succession of living forms. Familiarly and universally employed for sixty years under the prevailing belief in special creation, it still continues to be employed as widely now that all the world has accepted a belief in evolution. I refer to the use of fossils as a means of arranging the rocks in chronological order. This great and fundamental discovery was due to William Smith, an English engineer, though Cuvier and Brongniart made the same discovery in France almost at the same time.

Last summer I had the good fortune to be in Bath, and was invited to take part in the ceremony of unveiling a tablet to the memory of William Smith. This tablet was placed on the outer wall of a house in which Smith, in 1799, had dictated to a friend "the order of the strata." That was the beginning of historical geology. Smith had observed that the strata, or beds of water-laid rock, were arranged in a certain order, one over the other; further, he noted that each group of beds was characterized by a particular assemblage of fossils, such as occurred in no other beds, and that, from the succession of beds the succession of fossils might be made out. Having determined the succession of fossils, it was possible to apply it in new regions, and it was found to apply in other parts of England, in France and in Germany, and gradually its application became world-wide. It can be employed in America, Africa, Australia, or any other part of the earth's surface.

The principle is extremely simple, and is widely made use of in historical and archeological inquiries of all sorts. For example, the student of handwriting has learned from a careful study of *dated* manuscripts that the handwriting of the mediaeval copyists underwent changes in a certain definite order; having learned the order of change, it is possible to use that order to place *undated* documents from their handwriting alone. One needs but little experience to distinguish writing of the eighteenth century from that of the nineteenth or the seventeenth, and expert paleographers can determine the date of a document within a decade of its writing. Though simple and obvious, this principle has been persistently misunderstood, and from time to time it has been attacked. Even so great a man as Herbert Spencer could not see that it did not involve reasoning in a circle, and declared that it was unscientific. But such an inference is due to a failure to grasp the significance of the method.

The progress of life from the lower and simpler to the higher and more complex upon which Smith's system is founded is substantially the same everywhere. This is because the fossils which are employed for chronological purposes are chiefly those of marine animals; and as all parts of the sea are in communication with one another, the only barriers which prevent the universal spread of marine organisms are those due to temperature, so that the inhabitants of warm seas are very different from those of cold waters. In former ages of the earth, however, when a more uniform temperature prevailed and climatic zones were but faintly indicated, the inhabitants of the different oceans were much more nearly alike than they are now.

The paleontology which was rejuvenated, almost re-created, by Darwin proved to be an indispensable means of explaining the anomalous distribution of land animals and plants in the various continents. Before Darwin's day, much interest was taken in the geographical distribution of animals, but merely as so many statistical facts, for which no explanation could be found. As Darwin tells us in his autobiographical sketch, it was the facts of paleontology and of the geographical distribution of animals, which he observed in South America, that first led him to question the truth of the then almost universally accepted dogma of special creation. He felt assured that if the theory of evolution were to be accepted as true, it must be able to explain distribution. The present order of things on the earth, geographical, climatic, and biological, is, according to the evolutionary theory, the necessary outcome of an unimaginable series of changes throughout hundreds of millions of years; and, if that theory is to be accepted as true, it must be able to offer a reasonable explanation of this present order. If the geographical arrangement of animals in existing lands is not due to special creative fiat, but to natural causes, and is the inevitable result of the long sequence of past changes, then paleontology should be able to offer an explanation of the anomalies and paradoxes in that arrangement.

For example, the camel family is divided into two sub-families, the true camels of the Old World, native to Asia, and the llamas, guanacos, etc., of South America. This seems to be a very anomalous kind of distribution, to have the two parts of the same family separated as far as the size of the globe will permit; yet the history of the family, as recorded by the fossils, offers a simple explanation. The group originated in North America and for long ages was confined to that continent; at first, there was but a single series without distinction of sub-families, and this series shows in each successive division of geological time a continuous advance and development. Finally, the series gives off two branches; the true camels, which passed into Asia by way of the raised bottom of Bering Sea; the other, the llamas, into South America. For a time both sub-families were present together in North America, and were completely wiped out by the great Pleistocene extinctions. It is their extinction in North America which has brought about the wide separation of the surviving species.

This explanation is typical of a great many cases of what is called "discontinuous distribution;" whenever the history is known, it is found that the group in question once occupied the intervening area and then became extinct in that area. Not that all cases can be explained, by any means; in such cases the history of the animal group has not yet been recovered and deciphered, perhaps never can be. But it may be stated as a rule, without known exception, that whenever the history and development of a group has been made clear, its modern distribution is thereby explained. This could not be true were each species an immutable entity, separately created.

The present distribution of the tapirs exactly parallels that of the camels and llamas; they are found only in southern Asia and in Central and South America. Throughout nearly the whole of the Tertiary period, these curious creatures were distributed all around the northern hemisphere; in this country fossils of them have been collected from Los Angeles to Port Kennedy on the Schuylkill and southeast to Florida. Then, for some unknown reason, they disappeared from all lands save those in which they still occur. Like the camels, the tapirs probably originated in North America; at all events, they have been found here in rocks more ancient than in any other known region.

As a last illustration of the manner in which paleontology explains distribution, we may take the case of the Proboscidea (elephants and their close relatives, the mastodons). The mastodons are extinct, and the present occurrence of elephants would seem to require no particular explanation, for they are found only in the warmer parts of Asia and Africa, between which there is land connection now. In the epoch immediately preceding the present, Proboscidea were found in all the continents, perhaps even including

Australia; only elephants in the Old World, from Great Britain to South Africa and eastward to China and Siberia. In North America elephants and mastodons ranged together, but only the mastodons extended into South America. In the late Tertiary (Pliocene epoch) the facts were the same, except that the mastodons were also present in all lands of the Old World. In the middle Tertiary (Miocene) only mastodons were in existence, the true elephants having been subsequently derived from them. The mastodons appeared in North America and Europe almost simultaneously (in the geological sense of that word); but for a long time we were ignorant of their place of origin, for their appearance in the northern regions was entirely unheralded, and nothing was known in the earlier epochs which, by any stretch of the imagination, could be regarded as ancestral to these Miocene mastodons. By a process of elimination that region of origin could be narrowed to the warmer parts of Asia and Africa; and there the desired ancestors were at last found, first in the Oligocene and Eocene of Egypt, carrying the genealogy back to a much earlier time and more remote antecedents than in the northern lands.

Last year, I presented a paper before the American Philosophical Society on "The Isthmus of Panama as the Strategic Point in the Distribution of North and South American Life." In this paper I brought forward evidence to show that in the Cretaceous period the two western continents were joined by continuous land, while in the earlier half of the Tertiary period, they had been divided by a sea which occupied the site of Central America and the Isthmus. This separation brought about complete difference in the North and South American faunas; and the final re-elevation of the land accounted for the many animal groups which are now common to the two continents.

I do not mean to leave with you the impression that all the problems of animal distribution have been solved, for this is far from being the case. Many such problems still await the solution which may never be found. On the other hand, it is a highly significant fact that whenever the fossils enable us to reconstruct the history of a group of plants or animals its distribution, present and past, is thereby explained; and the cases of distribution which we cannot explain are those of which we do not know the history.

A third application of this science, to which Leidy devoted the most fertile years of his life, is that which enables us to follow the past climatic changes which have succeeded one another upon the earth. The climatic history of the earth is one of the most wonderful parts of its marvelous story and has wide astronomical bearings, as well as geological and geographical. That life has existed on the earth without interruption for a billion years or so is now a familiar fact and when it is remembered within what narrow limits of temperature terrestrial life is possible, the constancy of solar radiation throughout that unimaginable lapse of time is all but incredible. Thirty years ago Lord Kelvin's calculations of the age of the sun were very generally accepted and, according to these, the sun could not be more than 20,000,000 years old. The discoveries in the field of radio-activity have indefinitely extended the time involved in the history of the solar system.

While the climatic changes through which the earth has passed have never been so extreme as to exterminate all living things, they have, nevertheless, sufficed to bring about very remarkable results. Throughout much the greater part of the earth's recorded history, its climate has been so mild and nearly uniform that the temperature-zones, so familiar to-day, are scarcely or not at all indicated; and this fact led to the widespread belief among geologists that the glacial ages of the Pleistocene had been altogether exceptional, and due to some transitory cause from which the present amelioration was a slow recovery. Subsequently it was learned that there had been several glacial times recorded in the rocks, the oldest of which antedated the fossiliferous rocks; and there is now reason to believe that these times of refrigeration were rhythmically recurrent, at intervals of approximately 250,000,000 years. The evidence of former glaciations is mostly to be found in the rocks themselves; the fossils, which sometimes give corroborative testimony, are often unavailable, but for the less extreme fluctuations of climate paleontology gives the only evidence which can be trusted. All classes of organisms may give proofs of climatic changes, but the most useful are fossil plants.

The Mesozoic era and the earlier part of the succeeding Tertiary period had climates, not only free from other than local glaciation, but even much milder and more uniform than those of the present day. Greenland, for example, which now can support only dwarf willows and birches, 2 or 3 inches high, then had abundant forests of temperate zone type. Great palms were growing as far north as Idaho and Montana, and large crocodiles accompanied them. In the Jurassic period, the Antarctic continent, the most lifeless and desolate of all existing lands, had plants like those of England. The enormous reptiles which throughout the Mesozoic era inhabited all the continents and oceans, even in the far North, could not have endured the Arctic climate of the present. The gradual refrigeration of the climate, leading to the Glacial epoch, is likewise clearly recorded by the fossils, also the very curious fact that interglacial climates were milder than those of the present time. The term "interglacial" requires a word of explanation. After Agassiz's conception of a glacial time, when the northern parts of Europe and North America were, like modern Greenland, buried under great sheets of moving ice, had been almost universally accepted, evidence began to appear that the Glacial age had not been single, but multiple; and the proof which has accumulated in many lands has convinced nearly all students of the problem that Pleistocene glaciation consisted of at least four Glacial stages, separated by three Interglacial stages when the climate was warmer than at the present time. On the north shore of Lake Ontario, near Toronto, there is a series of bends, laid down in water, the interglacial nature of which is shown by the two glacier-made boulder beds, between which the sediments deposited in water are contained. The water-laid beds are in two series, of which the lower one has preserved many leaf-impressions, and these plainly indicate a climate considerably warmer than that of present-day Ontario. Other interglacial deposits on the shore of Hudson's Bay and in the Great Plains region contain fossils of plants and animals indicative of a relatively warm climate, milder than the climate of the same localities in recent times.

Similar facts have been observed in Europe, and in few places are the climatic indications more beautifully clear than at Mauer, where the famous jaw of the Heidelberg Man (*Homo heidelbergensis*) was discovered. This lower jaw was found in a sand-pit some forty feet below the surface of the ground; and in the same bed as the human remains, and evidently contemporary with them, were found the bones of many mammals, such as the southern elephant, hippopotamus, etc., which plainly suggest a climate warmer than that which now prevails in Central Europe. Not far above this bed are numerous bones which show the renewed refrigeration which was to lead to another glacial stage, as must be inferred from the bones of the boreal mammals which are there found. The southern animals have all disappeared from the region, and their place is taken by cold-country creatures, such as the mammoth, or woolly Siberian elephant, reindeer, and the like. The climatic inferences to be drawn from these two sets of animals are quite unmistakable, and it is interesting to note how closely the facts in Europe and North America correspond.

The whole process of reconstructing the earth's past history, the arrangement and changing connections of the great land-masses of the various seas, is dependent upon the study of fossils, which give a record of changes in their order of chronological succession. That is where geology has a great advantage over so exact a science as astronomy, for the exactitude of astronomy is confined to the present order of things; and in dealing with historical problems concerning the origin of stars and planetary systems, there is great vagueness and little certainty. For over a hundred years, the Nebular Hypothesis of the great French astronomer, La Place, was accepted by astronomers and geologists with practical unanimity, as explaining the origin and history of the solar system. Now that hypothesis has no standing with astronomers and among the geologists of England and America, the ancient hypothesis is completely abandoned, for it has been conclusively shown that La Place's conceptions are mechanically impossible. Nevertheless, many if not most of the German geologists still adhere to the scheme of La Place, chiefly because they are not convinced of the truth of the hypotheses which have been propounded to take the place of the discredited nebular theory. Astronomers have no such record of the past as the fossils offer to geologists and, in the lack of that record, they can not solve historical problems with confidence.

Needless to say, I hope, this statement is not meant to belittle the astounding achievements of astronomy, which include the highest attainments of the human intellect. Nor would any prudent man be so foolish as to attempt fixing any limit to the progress of astronomical discovery. What methods of investigating and determining the origin and development of the celestial bodies may hereafter be devised, no man can predict. At present, however, astronomy can not deal with these historical problems in an assured way.

To many minds the most interesting and important of the applications of paleontology is the testimony which the fossils give to the theory of Evolution. As we have seen, it was Darwin's book that rejuvenated the study of fossils and gave it an unheard of extension. It was immediately and generally recognized that the most crucial test of Darwin's theories would be, whether it was in harmony with the facts of the geological record, or in hopeless conflict with those facts. Even more exacting and severe was the test of future discovery. It has often happened in the history of science that a theory which satisfactorily explains and coordinates the facts known at the time it is first enunciated, is gradually undermined by the discovery of new facts, which do not harmonize with it, until the exceptions outweigh the rule and the theory collapses.

When Darwin published his great book, he showed in a famous chapter that the facts of paleontology agreed with his theory as well as could be expected in view of the admitted incompleteness and imperfection of the geological record. Since that date, the geologist has extended his exploring and collecting work to all lands that can be reached and studied. Wonderful series of fossils have been found in western North America, a work of collecting which had just begun in Darwin's day, when no one had any conception of the astonishing museum of long-vanished animal life which is entombed in the rocks of arid and semi-arid America. As we have already learned, one of Dr. Leidy's securest titles to fame is the great work which he did in revealing and reconstructing this record. Likewise, Africa, Asia, and even parts of Europe, have all yielded up treasures of fossils, of which Darwin had no inkling. He himself was one of the first to discover the richly fossiliferous beds of Patagonia, but he had not the smallest conception of what was to be found there sixty years and more after his explorations in South America.

There has thus been a veritable flood of new discoveries which put the evolutionary conception to the severest possible test. The result has been that that conception has been supported and strengthened in a wonderful way, and is far stronger and more universally accepted than it was sixty years ago. No competent person would maintain that all problems have been solved and all difficulties removed; far from it, but those difficulties are plainly due to lack of information. The record of the development of living things which is contained in the rocks is like a book from which many pages, even whole chapters, have been torn out. On the other hand, many chapters have been preserved, of which the fullness and precision make a perfectly unambiguous and most eloquent support of the theory. More than ever is it true, that by far the best, most probable and most convincing interpretation of the facts of paleontology is that offered by the theory of evolution.

This result is all the more striking when the state of the other sciences in 1859 is taken into consideration. Physics, chemistry, astronomy, and even mathematics, have been more or less completely reconstructed since that time. The principal theories which then dominated physics and chemistry have nearly all been abandoned in favor of newer interpretations. The advance of discovery has been fatal to the older conceptions. This is not true of the theory of evolution which, as stated above, is more thoroughly established and more universally accepted than ever before.

In 1876-7 Huxley delivered a series of lectures on evolution in New York; and the lecture entitled (I quote from memory) "The Demonstrative Evidence of Evolution" was devoted to the discoveries of American paleontology, and more particularly to the genealogy of the modern horses, as that had been worked out by Professor Marsh. Huxley himself had been the first to attempt a scheme of equine evolution; but, as he had access only to European material, he could make but an approximation to the later conceptions. When he saw Marsh's finely preserved fossils, arranged in chronological order, he was convinced that he had before him an actual and positive demonstration of the evolutionary theory. It wasn't that, perhaps, but it was evidence of so high a degree of probability as to be convincing. That Leidy, though a thorough-going evolutionist, has little to say concerning the interpretation of the fossils, which he discovered and described, seems at first sight surprising. But he was, in fact, laying the foundations of the theoretical structure. It was he who first showed the chronological stages and modifications in the history of many families, horses, camels, rhinoceroses, wolves, cats, etc.; and that he did not categorically draw the obvious conclusions was due to his belief that theoretical discussions should wait upon the acquisition of more complete material.

These are the more important of the applications of paleontology. Can it be a matter of surprise that Leidy, with his remarkably clear and broad outlook over the world of nature, should have felt that paleontology was the main work of his life?

WILLIAM BERRYMAN SCOTT
PRINCETON UNIVERSITY

THE CONTRIBUTION OF BIOLOGY, CHEMISTRY AND PHYSICS TO THE NEWER KNOWLEDGE OF RICKETS[1]

THE investigation of rickets is an outstanding example of the value of interweaving the basic sciences with clinical medicine and may well serve as a text to illustrate "the contributions of other sciences to medicine." It is an axiom that many disorders have been elucidated only with the aid of chemistry and animal experimentation, but the instances are few in which biology, inorganic and organic chemistry and various forms of physics have been resorted to so frequently and to such a degree. Although decreasing in incidence and severity, rickets still undoubtedly is the most common nutritional disorder of early childhood in the temperate zones. It has been the object of intermittent study ever since Glisson first described signs and symptoms of the "Englische Krankheit" in 1650. Our acquisition of knowledge concerning its various aspects may

[1] Presented as part of a symposium on "The contributions of other sciences to medicine" at the annual meeting of the American Association for the Advancement of Science, Nashville, Dec. 28, 1927.