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## *A DECADE OF NORTH AMERICAN PALEOBOTANY. 1890–1900.**

THE history of paleobotany constitutes a record of the most persistent and painstaking efforts to unravel a series of great facts which have been left by the wayside of time through an untold period of the earth's history, and to interpret them with reference to their true significance in the life of this planet.

Although attention had been directed to the phenomena of plants preserved in the crust of the earth essentially with the first discovery of coal, their occurrence did not excite very marked interest until the latter part of the seventeenth century—the observations of that time being made from the standpoint of the curious in nature, rather than from an appreciation or even suggestion of their scientific value, and it was not until 1709 that the first meritorious attempt to describe them in a scientific spirit was made. From then on through the remainder of the eighteenth century, a very considerable literature accumulated, and the infant science passed through what Ward has so very aptly called the 'twilight of its development,' while very nearly a full century passed before Schlotheim published the results of those studies which must be taken

* Address of the President of the Society of Plant Morphology and Physiology, given before the Baltimore Meeting, December, 1900.

as the real commencement of paleobotanical investigation. His work gains special prominence by reason of his having been the first to definitely and authoritatively deny the deluge theory and to assert that fossil plants represent the remains of an earlier vegetation, the originals of which are no longer to be found. But it was not until the time of Sternberg and Brongniart, of Lindley and Hutton, of Witham and of Göppert from two to three decades later, that interest in this line of research gained sufficient impetus to make its continuity assured. From that time on, progress has advanced at an accelerating rate, but the one fact which we need to keep clearly before us is that such progress as has been made in this branch of botanical science has been accomplished within the last seventy years. The activity thus referred to was chiefly confined to Europe, at least during the first half of the century, but it is of value to note that the great interest in such work, which centered there, in all probability had a well-defined influence upon the same line of studies in America—indeed, we may almost say a determining influence in promoting that spirit of enthusiasm for a subject then surrounded with the greatest difficulties, which has led to such noteworthy results. It is at least a fact of more than passing interest that the two earliest among the great paleobotanists of this continent—Dawson and Lesquereux—entered upon their work here just before the completion of the first half-century, and it seems not unlikely that while the one had imbibed a strong predilection for such studies from those eminent geologists with whom he had been associated while a student at Edinburgh, the other had gained inspiration not only from his scientific associates at Neuchatel, but also from the success of his earlier efforts as a botanist and his special studies of peat bogs for which he received the government medal, and through which also, he gained wide celebrity. It was, therefore, but natural that in returning to his native land to follow out the ideas so well established in Europe, Dr. Dawson should at once apply himself to the solution of the many problems which the rich deposits of fossil plants in the neighborhood of his own home at once suggested; and that Lesquereux, seeking in the United States an asylum from the political troubles which drove him and his colleagues from Switzerland, should at once continue there those studies which had already brought renown, and, in the rich deposits of Pennsylvania, Ohio and other States, endeavor to read the story of the ages as inscribed in the rocks of the Carboniferous formation. These facts are of significance in considering the progress of paleobotanical work on this side of the Atlantic, since Dawson and Lesquereux, the one in Canada and the other in the United States, were its most powerful exponents. Newberry was born and educated in the States, so that his activity in this direction was the result of purely local conditions. He, nevertheless, contributed most important results, chiefly in connection with public surveys, and his name stands with those of Dawson and Lesquereux as foremost among the paleobotanists of this continent. It is impossible to consider any progress in this subject, either now or in the immediate past, without reference to their work, since it stands as the foundation of that from which some of our most important deductions may be derived.

Lesquereux died on the 25th of October, 1889; Newberry died on the 7th of December, 1892, while Dawson died on the 19th of November, 1899, and thus within the short space of a decade there passed from our midst three of the most notable of the scientific men of this continent. I have felt it to be of special importance to give prominence to these names, since they stand as the great link which binds the old to the new. As they commenced their work under conditions which are unknown to-day, they completed it with a full recognition of the different point of view which had been introduced by the wonderful progress of botanical science in recent years, and their final publications fell within the closing decade of the century. With the disappearance of these three men whose great activity accomplished so much, we now turn to the Smithsonian Institution and the United States Geological Survey, with their superb resources in material, appliances, and a well-trained staff of scientific men, as the real center of our future progress.

The somewhat peculiar conditions surrounding the study of fossil plants in the earlier days of the subject somewhat naturally led to its exploitation by geologists into whose hands it fell, and where it has very largely remained until the present day. There has thus arisen a somewhat prevalent idea that the study of fossil plants constitutes a science altogether apart from that of botany, and for this state of affairs the botanists are themselves chiefly to blame for not promptly claiming and cultivating a field peculiarly their own, for, as Ward well observes, "Botanists have, as a rule, ignored paleontology, while the paleontologists have gone on with their classifications in total disregard of the former." And he very appropriately adds that "The mutual dependence of these two branches of botanical science upon each other is so apparent that it is certainly a matter of surprise that it has received so little recognition by scientific men."

In whatever conditions this state of affairs may have had its origin, it is certainly gratifying to observe that botanists generally are more keenly appreciative of the valuable nature of the evidence which fossil plants may afford in solving questions of descent. It is also encouraging to discover that history does not fully sustain the extreme charge which has been brought against the botanical profession. Accepting Ward's list of twenty-two men from Scheuchzer to Carruthers, who may be considered to constitute the world's great leaders in paleobotanical research, it is to be noted that fifty per cent. were especially trained and exercised their profession as botanists—there being among the number those who have produced a strong impress upon the general history of the science, and it will well repay us to briefly glance at some of their achievements.

In 1820 Sternberg commenced the issue of his well-known *Flora der Vorwelt*, the publication of which extended over a period of eighteen years. This important work, together with the succeeding works of Brongniart, Göppert and Corda, opened the way for the final reception of the idea of evolution in plants.

To Adolph T. Brongniart, a contemporary of Sternberg's, must be ascribed the greatest measure of influence exerted upon the development of paleobotany during the first three decades of the century,—a fact so eminently true that he is commonly spoken of as the real founder of the science. His observations upon the formation of pollen grains in the mother cells of *Cobœa*, and the frequency of occurrence of the pollen tube, were the first to direct attention to this new line of inquiry. In 1843 he devised and published a system of classification which not only maintained a strong hold in France for many years, but it gained many adherents throughout Europe. In his work on fossil plants we gain, for the first time, a definite indication of that succession in the development of plant life through the various geological formations, which constitutes so important a feature of modern botanical science.

Göppert was the first to draw attention

to a rise in temperature during the process of germination, and his works on fossil plants are too extensive and well known to require special consideration at this time; but in the prosecution of his studies, he strongly emphasized the necessity of treating all such remains from a strictly botanical point of view, and he was especially prominent in giving great weight to characters derived from a study of the internal structure, thus recognizing the school already founded by Witham in England.

Corda was already well known for his valuable work on the fungi and mosses, before entering upon those paleobotanical studies through which his name more commonly appears.

The great number and value of Unger's contributions to botanical science lent special weight to his conclusions respecting fossil plants. In 1837 he described the spermatoids in various mosses and declared them to be the male elements of fertilization. In 1855 he first directed attention to the great resemblance between the protoplasm of the plant cell and the sarcode of the more simple animals,—a discovery which was later brought into great prominence and finally led to the conclusion that protoplasm is the foundation of all organic development. He was the first to successfully oppose Schleiden's theory of free cell formation as applied to the growing apex of stems, and to show that such cells arise by division—having their origin in a meristem. His work, in conjunction with that of von Mohl, Nägeli, Braun and Hofmeister, laid the foundation for a true conception of cell formation. In his 'Anatomie und Physiologie der Pflanzen' he introduced many new and valuable ideas respecting the character of the protoplasm, and gave a concise idea of the cell in its various complexes as families, tissues and fusions. With von Mohl's text-book, this work accomplished more than any other in disseminating a knowledge of the subject up to 1860. In 1850 he issued the first complete manual of fossil plants, giving a systematic account of 2,421 species.

C. F. Schimper founded the theory of phyllotaxis. He first contributed to the study of fossil plants in 1840, and his 'Traité de paléontologie végétale' constitutes the most important of all the works on fossil botany as presenting a complete manual of the subject in accordance with the then current ideas of botanical science.

Williamson has contributed to the advance of paleobotanical knowledge in so many important ways, especially during his later years in conjunction with Carruthers, that a preliminary statement of progress would be wholly incomplete without reference to his work. His earliest experiences were gained in making the illustrations for 'Lindley and Hutton's Fossil Flora of Great Britain in 1837.' Since then his time was largely devoted to independent research in the same field, with a success which is well known, and his studies of the carboniferous flora of Great Britain have resulted in most important contributions to our knowledge of those early types of vegetation. This is especially true with respect to the Calamarieae, Lepidodendreae, Sphenophylleae, the ferns and Lyginodendron. In the case of the first two, more particularly, he laid the foundation for all our subsequent knowledge respecting them. He furthermore showed that in Lyginodendron the fructification places this group of plants beyond question among the archegoniates, but that like recent Gymnosperms, they possess a secondary wood growth from a cambium layer. In establishing this fact he came into direct contact with the views of Brongniart, who held the formation of the wood from a cambium layer to be an absolute criterion of the phanerogams. From Heterangium and Lyginodendron he reconstructed a type of plant which he described as having characters intermediate between those of the ferns and the Gymnosperms, and he thus opened the way for the final recognition of the Cycadofilices by Potonié, to which also such hitherto doubtful types as Medullosa and Myelopteris undoubtedly belong—a group of plants the recognition of which has gone far toward clearing up most important questions relating to the phylogeny of the Gymnosperms, and of the Cycads in particular.

It will thus be seen that to a large extent at least the study of fossil plants has proceeded on lines parallel with those in other branches of botanical science, and that the growth of the subject has substantially been directed by men eminent as botanists. Originally employed as a distinctive term for a subject supposedly outside of botanical science, paleobotany has more recently come to have equal rank with other divisions of the science such as histology, physiology, ecology, etc. Such artificial distinctions as formerly existed are fast disappearing, and we are now rapidly approaching, if we have not already entered upon, the first stages in the realization of that harmony between the botany of recent and extinct forms, the accomplishment of which Ward in 1885 recognized as so eminently desirable, but considered so difficult of attainment.

One of the earliest views attaching to the relations of paleobotany and geology was that of the supposed value of fossil plants in determining the age of deposits, and this found expression in the idea that the sequence with which plants were known to occur must be correlated with the succession of geological formations in such a way that the age of the latter could be ascertained by an examination of the flora. Although fundamentally correct, the precise application of the principle was found to lead to such erroneous conclusions that geologists soon came to look upon the evidence of fossil plants as untrustworthy, and it is only within recent years that there has been any material alteration in this point of view. So long ago as 1871, however, we find Sir William Dawson, who possessed a deeper insight into the bearings of evidence derived from fossil plants than was the case with the majority of geologists, expressing the opinion that "fossil plants have hitherto been regarded as of much less importance than fossil animals in determining the age of rocks, and in some portions of the geological series, where formations are strictly marine, their value is, no doubt, quite subordinate. But there are portions of the geological formations * * * in which their value becomes much greater"; and in 1892 we find him giving a more pronounced expression of opinion when he says that "The history of geological discovery in the Canadian Northwest affords a convincing proof of the value of fossil plants when carefully collected, * * * in determining the geological ages of the formations in which they occur, while there can be no question of their paramount value in indicating geographical and climatal conditions."

In 1882, Ward laid down in a definite and authoritative manner, the principles of geological correlation by means of fossil plants. He clearly showed that the old idea of contemporaneous deposits with identical fossils, as originally stated with so much prominence by Schimper and others, is entirely erroneous, and that it is relative contemporaneity or correspondence of succession which must be considered, an idea which the late Sir William Dawson often laid great stress upon in the course of his discussions with the writer. In order to give proper expression to the idea of correspondence of succession, Ward has proposed and for several years has employed the appropriate term 'homotaxis.' He lays down the general principles that

1. Great types of vegetation are characteristic of the great epochs in geology, and it is impossible for types of one epoch to occur in another.

2. Given a sufficient body of facts—*i. e.*, a suitable series of specimens—it is possible to determine as conclusively for nearly related deposits as for those more widely separated.

3. It is of the highest importance that plants should be correctly determined.

At the same time White, who deplores the 'surprising and painful inadequacy of materials relating to stratigraphic paleobotany,' shows that the present temporary obstacles to accuracy in correlation are to be found in

1. The wide vertical range of identical species.

2. The lack of standard paleobotanic sections, *i. e.*, a knowledge of plants strictly limited to various beds.

These principles form the basis of methods which have been used for the last eight years, and are employed with great success by members of the United States Geological Survey in determining the ages of deposits. This practise finds one of its latest and best expressions in a paper by Mr. David White on the 'Relative Ages of the Kanawha and Allegheny Series.' On account of similarity in the material composing it, the similar position of the series as a whole in the general lithological sequence, and the fact that the Allegheny series has been traced stratigraphically with great detail as far as central West Virginia, the Kanawha series has long been regarded as *in toto* the exact, though greatly expanded, equivalent of the Allegheny series. Following out the methods formulated by Ward, White has conclusively shown that this view is not a tenable one, but that as indicated by the testimony of the fossil plants, only the upper half of the Kanawha series can be correlated with the lower portion of the Allegheny series, in each of which identical forms of plants occur; whence it appears that the two series overlap in such a manner that the Allegheny is in direct chronological succession in the lower Kanawha.

The occurrence of plant remains in the coal measures, which were in their general features comparable with existing types in the tropics, led Schlotheim to regard fossil plants as having a direct value in determining the nature of the climatic conditions under which they flourished. This idea was later taken up by Brongniart, who amplified it, and from the various types of vegetation known by their fossil remains, determined what he conceived to be the climatic conditions of the great geological periods, corresponding to the great changes in plant types. The views thus adopted have been accepted in principle by all succeeding authorities and constitute our guide post to-day. Writing in 1879, the late Asa Gray felt no hesitation in laying down the general rule that "Plants are the thermometers of the ages, by which climatic extremes and climates in general through long periods are best measured," and in this connection he also pointed out that "Even very moderate changes either one way or the other, in temperature, would have excluded either the vine or the date palm which for at least five or six thousand years, have grown in proximity and furnished food to the inhabitants of the warmer shores of the Mediterranean." Three years later, in the course of extending his important studies relative to the Erian and Upper Silurian formations, Sir William Dawson laid down the general rule that "When we can obtain definite information as to the successive floras of any region, we thereby learn much as to climate and vicissitudes in regard to the extent of land and water," and that with reference to such points, "The evidence of fossil plants, when properly studied, is, from the close relation of plants to their stations and climates, even more valuable than that of animals." But he very appropriately adds the caution that "In pursuing such inquiries, we should have some definite views as to the nature and permanence of specific forms, whether with reference to a single geological period or to successive periods."

Balfour had already pointed out the necessity for a wide acquaintance with plant distribution in order to apply fossil plants with any success as tests of climate, and Renault in 1881, expressed views similar to those held by Dawson, when he pointed out that plants were superior to animals as a test of climate because of their relative fixity, and therefore more permanent relations to their environing conditions—the ability to migrate rendering animals an uncertain guide.

While their relative fixity is an element which imparts a special value to plants in this respect, it must nevertheless be recognized that influences such as long rivers with a northerly and southerly course, are likely to introduce a disturbing element by reason of their causing a mingling of the floras of dissimilar climates, and for this and other reasons it is generally conceded that drift material must be carefully excluded from all considerations which involve questions of climate.

Variations in the soil, exposure to light, humidity of the atmosphere and many other conditions which tend to promote structural and functional modifications, and eventually also type alterations, must be carefully weighed and that these elements have been as important factors in the past, as they are at the present day, cannot be doubted when we recall the profound modifications exhibited by the various floras of Paleozoic time, and the fact, to which Lesquereux has directed attention, that "A single modification of the character of the vegetation generally follows great geological disturbances which produce permanent changes in the atmospheric condition of a country."

In 1872 Saporta pointed to the determining influence of atmospheric conditions, and showed that the relative preponderance of the monocotyledons and dicotyledons could be referred to conditions of humidity in such a way that the former increase while the latter decrease when the humidity becomes general, or with a diminution of temperature ; and that, in consequence, a dry and warm climate favors a larger proportion of dicotyledons than a warm and moist, or a cold and moist climate. With these considerations in mind, we cannot avoid the conviction that the modern science of ecology as expounded by Warming and Schimper, and as exploited on this side of the Atlantic by Ganong and others, must throw much light upon questions of this kind by giving accurate data upon which to base comparative studies.

The peculiar conditions under which plants pass into the fossil state render it an altogether exceptional circumstance to find all parts present. This is more particularly true of those more delicate tissues and organs which constitute the structure of the gametophyte, but it also applies with considerable force to all the soft parts of the sporophyte. Important exceptions to this rule nevertheless appear. Renault has already shown that in Cordaianthus, the microspores are to be seen in position within the canal of the archegonium, as also in the pollen chamber, and they exhibit very clearly the development of the prothallus. He has also observed similar conditions of preservation in various Calamarieae. More recent investigations have also given another important example of this kind in *Parka decipiens*, the remains of which show prothalli and both kinds of spores, and, coming as it does from the Devonian, it probably stands as the most ancient representative of the heterosporous filicineæ we know. Other less conspicuous cases might also be cited, but the general fact that it is only the more resisting structures, such as those of the stem and leaves, which are recognizable, has led to attaching great importance to the anatomy of the wood. This was first pointed out by Witham, who has since been followed by many of the leading paleobotanists of Europe, and to some extent by those of America. On this side of the Atlantic, the idea was first taken up by the late Sir William Dawson in 1845, and since that time its application has been made more prominent through the work of Knowlton and others.

As a special indication of climate, the presence of growth rings—from the time of Witham who considered the absence of such structural features to be evidence of a tropical climate—has been regarded as one of the important factors in this respect. The history of the subject shows a great divergence of opinion as to the origin of these structures, but the general position may no doubt be correctly taken, that growth rings are largely dependent upon, and are therefore expressive of alternating periods of growth and rest. Such periodicity in functional activity bears a more or less close relation, among other things, to seasonal change in such a way that, other things being equal, the more definite the changes from summer to winter, the more pronounced will the growth rings become, and the more definite will be their correspondence with age. That this holds true only within certain limits is well known. Thus many Chenopodiaceous plants make several growth rings within one season independently of latitude, and the red maple, within the latitude of New York State, has been known to make twelve growth rings within a period of eight years. Fernow has recently drawn attention to the fallacy of many of the opinions respecting the value of growth rings as an index of age, and the correctness of the views which hold them to be of importance in this respect, and he points out that under ordinary circumstances in temperate latitudes the ages of trees may be correctly ascertained within a limit of one-half to one year of error. Tropical trees generally exhibit an absence of growth rings, but exceptions to this rule are not unknown. It would therefore appear that while much caution must be exercised in applying such a test to the case of fossil plants, when used with a due recognition of its limitations, the test of growth rings as evidence of climate becomes a valuable aid.

One of the most common methods of identifying fossil plants has been through their leaves. This has of necessity resulted from the fact that these organs are much better adapted to preservation than most other parts of the plant, and that they therefore constitute the most accessible of all plant remains. The work of Lesquereux and Newberry rests very largely, indeed almost exclusively, upon evidence of this sort, and the venation has been made the basis of both generic and specific distinctions. Leaves, however, offer an unreliable basis when taken alone, and this results from the fact that the venation is not of specific rank, and often fails also in generic significance, while the form of the leaf may present so many changes within the limits of the species that no great dependence can be placed upon it. This is notably the case in such genera as *Liriodendron*, *Sassafras* and *Platanus*, and it is only necessary to refer to the comparative studies by Ward, on the 'Paleontologic History of the Genus *Platanus*,' and to the observations of Holm on Liriodendron, to give emphasis to facts long known to botanists, and show what erroneous and extremely misleading results may readily follow from the study of fossil leaves, even when they are presented in a complete condition—a difficulty which is enormously increased when the fossil happens to be fragmentary, as is generally the case. The errors arising from a disregard of such facts, have led to no end of confusion, and have been among the most prolific causes of extensive revisions. It is therefore clear that for botanical purposes such fragments have a very limited value, but as Ward very correctly observes, for geological purposes it is not so much a question of correct botanical determination as the correct recognition of a plant once named and associated with a given deposit. With these limitations before us, we can form a more correct estimate of some of the recent conclusions bearing upon the climatology of former geological times.

The great analogy of climatic conditions recognized as existing between those which influenced the flora of the Dakota Group and those which now govern the vegetation of the North American continent, led Lesquereux to the conclusion that the flora of North America is not at the present epoch, and has not been in past geological times, composed of foreign elements brought to this continent by migration, but that it is indigenous. Its types are native, and the diversity of their representatives has been produced by physical influences. All the plants of the American Cenomanian, except those of *Ficus* and the *Cycads*, might find a congenial climate in the United States between latitudes 30° and 40°.

An examination of the Tertiary flora of the Yellowstone has shown that the present flora of the Park has comparatively little relation to it and cannot be regarded as a descendant of it. Knowlton concludes that the former had its origin to the south, while the latter had its origin to the north, and that the climate prevailing in Tertiary times was, therefore, quite different from that now known, and in all probability not unlike that of Virginia of to-day.

A study of the Lower Carboniferous Measures of Missouri has led Mr. David White to draw attention to the uniformity of climate which prevailed over Europe, within the Arctic Circle, in North America, Asia and, to some extent at least, in the southern hemisphere during Carboniferous times, and the probability that the extremely close relationship between the floras of the Culm, Millstone Grit and basal portions of the Lower Coal Measures in Europe and America point to wonderful facilities for plant distribution during Culm and early Mesocarboniferous time, facilities which, with the aid of an even climate, made possible the comparatively regular distribution and sequential order of probably nineteen-twentieths of the genera, and an unknown proportion of the identical species ; and he is disposed to consider that the conditions favorable to plant distribution, and consequent comparatively homogeneous dispersion of the successive floras of the Northern Hemisphere during the period extending from the later Culm to near the middle of the Mesocarboniferous, have never been equalled since. That there was plant migration cannot for a moment be doubted. Yet the evidence of distribution, of vertical range, of characteristic associations, and of the succession of the floras, indicate such geographical uniformity of climate and such facility of intermigration over a minimum distance, as to justify us in regarding the astonishingly similar associations of identical or closely related genera and species which characterize each stage, zone or group of the Culm and Mesocarboniferous, as essentially contemporaneous in all the basins of the Northern Hemisphere. From this evidence he draws the final inference that many of the species or genera of the Mesocarboniferous were, under local conditions, evolved in different portions of the land surface, whence they spread with a rapidity difficult to conceive at the present day, over the greater portion of the northern continents.

An extended study of the Pottsville series of West Virginia offers an important illustration of the rapid differentiation of, and change in, floras during this period. White shows that "The period of change in conditions of environment attending transition from Lower Carboniferous marine to true Coal Measures formation, was marked by an extraordinarily rapid development and modification of plant species. Within a relatively short period the meager flora of the Devonian and Pocono is multiplied to the inexhaustively fecund and highly diversified flora of the Carboniferous, a development scarcely possible except in this division of organic life (plants), which is the most sensitive to climatic change or environment, excepting, perhaps, the higher vertebrates. In the lower part of the Pottsville series many species show a relation to the floras of the Vespertine or Calciferous Sandstone series; in the middle portion many of the forms are unique, while in thickly developed sections it is only near the top of the series that we see occasional Coal Measures forms creeping in."

Recent investigations, by the Committee of the British Association charged with an investigation of the Pleistocene deposits in the vicinity of Toronto, have brought out in a very convincing manner the fact that three distinct climatic periods may be recognized. During the first the vegetation and the climate were comparable with those now found in Labrador and the more northern portions of the Province of Quebec. This was followed by a period during which more southern types of vegetation were introduced, and the climate was probably comparable with that now common to the Middle United States. A third wave drove these plants southward again, and once more northern types of vegetation were introduced, but not quite so boreal in their character as the first, and these conditions have remained unchanged in the present day.

From the considerations which have thus been passed rapidly in review, it would appear that the advantage which such studies offer to the botanist is not very large, and that while the value of paleobotany to the geologist may, upon these grounds, be conceded to be great, the solution of questions bearing upon climate and geological succession can only be regarded as of a secondary importance from a botanist's point of view. The great problems which confront the botanist of to-day relate to the filling in of those gaps in plant descent which become apparent from a study of existing species. He is, therefore, called upon to complete, as fully as possible, our knowledge of that sequence in development which is at present justified, not only on theoretical grounds, but also on the basis of observed facts. To this end all other branches of the subject are subordinate, and since paleobotany has already contributed in so many important ways to enlarge our knowledge in this direction, it is my purpose to ascertain how far the progress of the subject in America, during the last decade, has proved of real assistance, the directions in which aid may be looked for, and the limitations within which useful results may be expected.

Our conception of the four great primary divisions of the plant world and of their subordinate branches is based upon the theory of succession in development, but our knowledge in this respect is far from complete, and here and there gaps occur in places where, on theoretical grounds, there should be perfect continuity in development. This defect arises from several causes.

The recognized law that the history of the individual more or less fully repeats the history of the species, at once points to the superior importance of embryological data as the real link through which primitive forms may be united ; but as we approach these primitive forms it is to be observed that the differentiation of types becomes less and less clearly defined until they merge in the ancestral form, and this must hold true of extinct types as well as of those now existing. While on the one hand such approximations may greatly aid in the solution of given problems, on the other they serve to defeat this end by reason of the difficulty experienced in their recognition and in a demarcation of their precise limitations.

In the progress of development many of the more primitive types of life have disappeared, while those of advanced organization have survived, and thus many of the gaps revealed by the study of existing species are of a more or less permanent character, and can only be bridged hypothetically. It is in emergencies of this kind that we instinctively turn to geological records, and in paleobotany seek the only available means of solving the difficulty. But here again, the complete obliteration of perishable material in the process of petrifaction, the breaking-up of the original body into widely separated fragments which can be correlated, if at all, only after the most prolonged and arduous labor, and the difficulty of recovering plant remains, even though they may be present in the rocks, constitute obstacles to the progress of knowledge in this direction, of the most formidable character. Hence from a botanical point of view, our knowledge is extremely imperfect ; but when we take into consideration the serious nature of the difficulties involved, the substantial progress which has been made during the last seventy years, and more particularly during the last two decades, affords ground for much satisfaction.

In this connection we may note the somewhat suggestive observations of White to the effect that "The rapid development and series of changes or modifications, presented by the plants of the Pottsville Series of both Pennsylvania and West Virginia, point to the possibility that in this series we may eventually discover facts of the deepest significance relative to descent, but the present fragmentary nature of the material recovered, which consists altogether of portions of foliage, will not warrant final conclusions in this direction."

The relative sequence of the Pteridophytes and Spermatophytes, as also of the Gymnosperms and Angiosperms, the Monocotyledons and Dicotyledons as exhibited in geological succession, is substantially the same as that derived from the study of living forms. But with reference to their points of contact and the relations of the more subordinate divisions of these groups, especially with reference to the Thallophytes and Bryophytes, the evidence of geological records often proves altogether inadequate and conveys no very exact idea of the real phylogeny. As living plants constantly approximate to the ancestral type as we descend in the scale, so likewise a similar approximation must be exhibited in earlier geological time, and this slight differentiation of primitive forms, which are very imperfectly known to us through mere fragments of the original plants, is one of the most prolific sources of error in paleobotany, and has resulted in the constant shifting of plants from one position to another.

On theoretical grounds the Thallophytes must have flourished in the very earliest periods of the earth's history, and their remains should occur in rocks of the Laurentian age, but if we leave out of consideration those very problematical forms which have sometimes been held to represent plants from the early paleozoic, nothing recognizable appears until the Silurian, in the later portions of which we are abruptly confronted with algæ of gigantic dimensions and a high degree of organization, thereby implying the existence of a long line of ancestors in the earlier geological periods, of which all traces seem to have disappeared. Passing into the Devonian, such types gain greater prominence in point of numbers, and thence on to the present the successive formations give evidence of the continuous development of this type of plant life; and while in Nematophycus, Chondrites, Lagynophora and Bacillus we find well-developed representatives of types known at the present time, their ancestral forms are to be sought in the Laurentian and portions of the early Paleozoic, where the only evidence of their former existence is to be found in the abundance of graphite and other forms of carbon. The most perishable of all plants, the Thallophytes, readily yield to that decay which is the invariable antecedent of petrifaction, and the slight residue of structure which might remain is commonly obliterated in the further metamorphosis of the rocks in which they are held. It is therefore altogether exceptional that such plants should be preserved in recognizable form, and their value for phylogenetic purposes, although very limited, acquires an unusual interest and importance. This is eminently true of the very plants through which the line of direct descent passes, since the green algæ are, of all the group, among the most perishable. For these reasons it is in no way surprising that additional representatives of the Thallophytes among fossil plants are rare, that such plants as are found add but little to our knowledge of descent, and that they fail completely to illumine the line directly ancestral to the Bryophytes—the evidence so far accumulated bearing altogether upon side lines represented by relatively durable remains.

Among the higher Thallophytes, a few additions have been made to the Charophyceae by the recognition of the characteristic fruits in the Lower Tertiary of Wales, Ohio, where two species—*C. Stantoni* and *C. compressa* of Knowlton are found. Fruit-like bodies having the external characteristics of *Chara* have also been observed in the Devonian at the falls of the Ohio, thus giving to this group of plants the possibility of a very ancient lineage which is justified on theoretical grounds. The very fragmentary remains so far known, the preservation of which depends upon their calcareous investment, nevertheless serve to throw no additional light upon previous knowledge. Migula has suggested that these plants occupy a position superior to the Thallophytes as a whole and coordinate with the other great divisions of the plant world. This view has been adopted by Seward in his most recent contribution to paleobotany, and Campbell also regards it as deserving recognition. To the solution of this question, however, the fossil representatives contribute no information not derivable from existing species.

Among the Phaeophyceae considerable interest has attached for a number of years, to a remarkable fossil originally described by Dawson as Prototaxites under the impression that it represented a primitive Gymnosperm allied to the Taxaceae. This view was disputed by Carruthers, who was the first to determine the algoid nature of the organism, and he assigned to it the name *Nematophycus*. Subsequent investigations of North American material amply justified this view, and Dawson was led to so far modify his original opinion as to employ the name *Nematophyton*. Several provisional species from the Silurian and Devonian of America have been recorded, and to these there have been added three species from the same formations in Europe. Carruthers has been led to suggest a possible relationship to the modern Siphoneae, but an extended study of American forms leads to hesitation in giving this opinion unqualified acceptance. Several years since, the belief was expressed that there were grounds for supposing a relationship with Laminarieae, and the genus *Lessonia* was cited as likely to afford the best means of comparison, but the impossibility of securing suitable material caused such studies to be deferred. Recent studies by MacMillan have given us a detailed account of the morphology of this extremely interesting but not readily accessible plant, and from material which he has kindly supplied the writer, it is to be noted that very striking points of resemblance to *Nematophycus* appear. Without entering into details on the present occasion, it may suffice to indicate that similar growth layers, the presence of a distinct cortical structure, the general disposition of the elements as seen in transverse section, and the presence of radial spaces, occupied by elements of the medulla which there assume a horizontal position and develop special relations to one another, are all features which point with considerable force to possible relationship. Beyond these facts, however, our present knowledge respecting the phylogeny of this group of plants will not permit us to go.

The Bryophytes constitute another group which, from their delicate organization, are not likely to be found either in very considerable numbers or in a very perfect state of preservation as fossils. They nevertheless occupy a most important position in plant evolution, since they are considered to constitute the connecting link between the green algæ and the higher vascular plants, their derivation from the former being through the thalloid liverworts, while their algoid ancestry also appears in the filamentous protonema of the true mosses and in the motile spermatozoids of the entire group. From the phylogenetic position of these plants as determined by a study of existing forms, we are led to infer that they must have had their origin in very early geological times—antedating the more fully organized terrestrial forms of which they are to be considered the ancestors. There is thus good reason for supposing them to have flourished as early as Devonian or even Silurian time, but the evidence derivable from the rocks shows no recognizable remains of these plants until we reach the later Mesozoic, while it is not until Tertiary time that they become clearly defined. It is, therefore, reasonably certain that the solution of questions relating to the origin of this group must rest altogether upon evidence derived from a study of existing species—to such, fossil botany has as yet contributed nothing.

From their more durable structure, which offers a higher degree of resistance to the operation of decay, the vascular plants have always been found in the best state (sometimes remarkably perfect) of preservation, and they have therefore always presented the best of opportunities for phylogenetic studies, more especially in consequence of the great abundance of their remains and the increased probability of deriving data of permanent value from them. In considering the distribution of these plants in geological time, one is impressed not so much with their often extensive vertical range, as with the abruptness with which special types appear through representatives of a high degree of organization. This has already been noted in the case of the Thallophytes, and among the vascular plants it is no less remarkable. The ferns which first appear in the Devonian are represented not only by foliage and fruit, but also by stems of large dimensions; the *Cycads* abruptly appear in the Jurassic and Cretaceous while the Angiosperms as suddenly appear in the Mesozoic, where they gain great prominence in the Cretaceous formation.

From these and other similar examples we are justified in the inference that such highly organized types represent the culmination of lines of ancestors which must have extended far back into the earlier geological periods, a view which gains weight from recent researches.

Among the ferns the Eusporangiateae are recognized as representing the primitive forms, and they constitute the starting point for two parallel lines of descent, one of which leads to the Leptosporangiateae and finally culminates in the Heterosporeae. Recent studies of *Parka decipiens* have shown that this hitherto problematical organism from the Devonian is unquestionably to be regarded as one of the heterosporous felicineæ, possibly allied to Marsilia. The occurrence of this plant in the same horizon as that in which the Eusporangiateae first appear, somewhat abundantly and in a high state of development, is of great significance, since it points without question to the origin of the ferns at a very much earlier date, probably not later than Silurian time.

In studying a new Taeniopterid fern from the Lower Coal Measures of the Carboniferous of Henry county, Missouri, Mr. D. White notes certain resemblances on the one hand to *Alethopteris*, and on the other to *Taeniopteris*, to which he assigns his plant under the name of *T. missouriensis*. Discussing this plant in relation to other known forms of the Marattiaceae, he endeavors to construct a hypothetical relationship which shows a *Megalopteris* stock of the Lower Devonian, to give rise in the Middle Devonian to *Neuropteris*, *Alethopteris* and *Megalopteris* proper. Thence through successive formations these three lines of descent lead to *Dictyopteris* and *Odontopteris*, which culminate in the Permo-Carboniferous, and to *Danaeopteris*, *Lomatopteris*, *Oleandridium*, *Taeniopteris*, etc., which either culminate or have their origin in the Trias, while *Angiopteris* originates at this latter horizon and *Danaea* makes its first appearance in the Jurassic. The hypothesis is a suggestive one, but as the fructification of these plants is wholly unknown, and as we have no data derived from the internal structure, while the relations exhibited are based entirely upon leaf characters, it is impossible to attach very great weight to it except as a possible starting point for further observations.

Recent studies of modern Equisetaceae and the various species of Calamites by Jeffrey, offer some very suggestive conclusions respecting the phylogeny of this most interesting group of plants now in the later stages of decline. Embryological studies show that similar structures in the prothalli, the absence of a basal cell from the archegonia and the epibasal origin of both root and shoot, serve to establish a definite connection between the Equisetaceae and the Homosporous Lycopods, a relation which is further justified by a comparison of the stem structure. He also shows that the close agreement between the Equisetaceae and the Sphenophyllaceae makes the latter the protostelic ancestors of the former. An acceptance of these conclusions would carry our knowledge of the phylum back to Lower Devonian time, and show that while the direct line of descent passes through the Sphenophyllaceae and Equisetaceae, the Calamites arose as a side line.

The phylogeny of the Gymnosperms has for many years constituted a subject of the foremost importance and interest, and it has received the most careful consideration at the hands of both paleontologists and botanists. The deep interest which centered so largely in the Cycadaceae, has within the last few years received additional strength not only through the discovery of those remarkable collections of *Cycads* from the Mesozoic, which Ward has already described on the basis of their external characters, and which Wieland is now engaged in studying from the standpoint of their internal structure; but also from the very noteworthy observations of Weber and Hirase respecting the occurrence of motile spermatozoids in Zamia and Ginkgo. Our knowledge of the North American *Cycads* adds nothing as yet to the phylogeny of these plants as determined by European investigators, but the progress of the studies of the Yale material will be watched with the greatest interest, in the hope that they may yield facts of importance in this connection. In the meantime, however, the deep significance of conclusions derived from the study of European material justifies a brief reference to the position of our present knowledge of this group of plants, which may be said to have commenced with a recognition of the similar characteristics possessed by a small group represented by Noeggerathia, Medullosa, etc., characters which pointed both to a filicinean and cycadean connection, but which were too poorly defined to permit the assignment of the representatives to any specific position. A recognition of the identity of Medullosa and Myeloxylon as suggested by Solms-Laubach and later confirmed by Schenck and Weber, served to prepare the way for a clearer conception of the relations existing between the individual members as also with other groups, and this gained final expression in Potonié's determination that Noeggerathia, Medullosa, Lyginodendron, Heterangium, Cladoxylon and Protopitys represent a distinct group of plants having an affinity with the ferns on the one hand, and with the cycads on the other, thereby becoming of ordinal value. He therefore established the name Cycadofilices as a proper recognition of the important position occupied by them. An additional contribution to our knowledge of this exceptionally interesting group of plants has been given by D. H. Scott in a study of Medullosa anglica, which he shows to have a probable filicinean connection through the Heterangium type. He further concludes that while the Medulloseae are to be considered as having affinities with the Cycadaceae in a broad sense, they really constitute a short, divergent branch of the phylogenetic tree.

The ancestry of the Coniferæ has excited an interest almost as profound as that centering in the *Cycads*, and although we are enabled to trace these plants more or less fully back to Silurian time, we are as yet unable to establish their relation to an inferior group, as in the case of the *Cycads*. Our present knowledge of the descent of the Coniferæ rests chiefly upon a recognition of that line of ancestry which passes through Cordaites and culminates in the Araucarian type. This has been gained by a careful study of the structure of the wood, as also of the foliage, inflorescence and fruit, as obtained from numerous European localities, notably those in France. Extensive collections of North American Cordaitæ are represented by the wood and foliage only, and though their value for phylogenetic purposes is thereby relatively limited, they have nevertheless contributed important data derived from a study of the stem structure, and afford a striking illustration of the superior importance of those histological methods first employed in such connection by Witham, the value of which was so strongly insisted upon by Brongniart. Apart from the general evidence derived from this material, which points with great force to the development of the Araucarian type, the structure of the stem is frequently preserved with such perfection as to permit recognition of important phases in the evolution of structural features. As long ago as 1840, Don pointed out that in the tracheids of *Cycas revoluta*, scalariform structure may occur at one end and bordered pits at the other. In 1869 Williamson was able to point to similar structural modifications in *Dadoxylon*, and to show that regularly transitional forms gave proof of the derivation of the bordered pits from scalariform structure. Recent studies of North American Cordaitæ have given conspicuous examples of the same kind, and show that a continuous series of radial sections will display regularly transitional forms—often combined in the same tracheid—passing from the spiral vessels of the protoxylem through scalariform vessels, thence into tracheids with transversely elongated bordered pits, which successively become shortened up until there is developed the typical, multiseriate, hexagonal and compactly crowded bordered pit so well defined not only in the Cordaitæ, but also in the modern Araucarieæ. These facts possess the deepest significance from a phylogenetic point of view, since they afford an additional and reliable indication of derivation, and in the present connection, they serve to point with considerable force to the idea that among modern Conifera, the widely-separated bordered pit which in many instances wholly disappears is for that line of descent the culminating form of this type of structure; while in the Angiosperms the modification has been carried to a greater extreme and involves the reduction of the pit to the form of a simple slit or pore, and ultimately to its complete obliteration as a final expression of the secondary growth of the cell wall. Structural alterations of this nature involve also a more or less profound influence upon functional activity as expressed in the distribution of nutrient material.

I have thus endeavored, within the limits of the time at my disposal, to briefly indicate some of the more prominent directions in which paleobotanical activities have developed in North America within the last decade. While this review shows that some substantial progress has been made, that much has been accomplished in the direction of laying the foundation for future studies, and that the study of fossil plants is gaining greater prominence as a necessary aid to our knowledge of plant descent, it also brings into relief the fact that progress in this latter direction must of necessity be slow, and the result of laborious methods of investigation extending over such long periods of time as will permit the accumulation of great stores of material, and the careful piecing together of fragments which separately have little or no significance. Nevertheless the rapid progress which has marked our knowledge of fossil plants during the last twenty years, and the acceleration of this progress within the last two decades, together with a greater appreciation of the fundamental importance of such studies in questions of relationship, afford much ground for regarding the future of paleobotany on this side of the Atlantic as one of promise.

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## *DETERMINATION OF THE SUN'S DISTANCE FROM OBSERVATIONS OF EROS.*

The tendency of the time toward thorough organization and cooperation in large enterprises is well illustrated in modern astronomy. Twenty-five years ago, a dozen leading observatories, by mutual agreement, divided the northern sky into zones in such a way that their meridian circle observations would combine to form the excellent Astronomische Gesellschaft star catalogues; and this great work is now nearing completion. The work of charting the sky by means of photography was similarly organized by the Astrographic Conference in Paris some ten years ago.

About fifty of the principal observatories of the world are now cooperating in a great program of observation for improving our