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TRANSACTIONS OF THE SOCIETY.

II.—*The President's Address: Life and Work of Bernard Renault.*

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(Read January 17, 1906.)

PLATES IV. AND V.

I have chosen this subject for my address this year for two reasons. First, because Bernard Renault did more than any other man—with the possible exception of my late friend Professor W. C. Williamson, for whom we may perhaps claim an equal place—to make known the structure of fossil plants by microscopic investigation; and secondly because he was an Honorary Member of our own Society. It is a source of great satisfaction to me that we were able to do him this honour, conferred within six months of his death, for in his own country his merits, though realised by his scientific colleagues, by no means received the public recognition they deserved. On several occasions the subject of the structure and relationships of extinct plants has been brought before you, by others as well as by myself, and it is not, I trust, inappropriate that we should give our thoughts this evening to the career of one who, in his own field of research, acted so consistently in the spirit of our motto: "*Minimis partibus, per totum Naturæ campum, certitudo omnis innititur.*"

Bernard Renault was born at Autun on March 4, 1836, of respectable middle-class parentage. After a creditable career as schoolboy and student, he became Bachelor of Science at the Autun College in 1854, and Bachelor of Letters the next year. He then

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entered the Institut Brenot at Dijon, where he was soon afterwards appointed Professor of Chemistry and Physics. For some time he was known to the scientific world as a chemist, and his publications for the first few years of his career were all on chemical subjects. An important Thesis on Electrolysis obtained for him in 1867 the degree of Doctor of Physical Science at Paris, and a post at the Normal School of Cluny.

But in the mean time Renault had begun the work to which his mature life was to be devoted. The neighbourhood of his native place, Autun, was formerly extraordinarily rich in silicified remains of plants, which in certain fields lay on or near the surface of the ground, so as to be turned up by the plough in such quantities as to be compared to the débris of a forest. Seventy years ago these precious fragments were even used for mending roads. It seems that when Renault began to interest himself in these specimens they had already become comparatively scarce, but enough remained to repay industrious search, and besides, there were important collections previously made, notably those of M. Faivre and the Abbé Landriot. It appears to have been the former, an ardent local collector, who introduced Renault to the laborious work of preparing the fossil specimens for examination. Throughout his life Renault was in the habit of making his own preparations—an extraordinarily slow and difficult task, especially when the petrifying material is hard silica, as is the case with these French specimens. Unfortunately, he had little or no assistance, and his work, in spite of his incomparable industry, was restricted by this mechanical difficulty.

Renault made a practice of communicating his discoveries and preparations to Adolphe Brongniart, the great founder of scientific Palæobotany, who at that time was Chief Inspector of Mines at Paris. It was sometimes part of the great savant's official duty to inspect the Normal School at Cluny, where Renault was then in charge of the chemical teaching, and was thus only able to give his leisure moments to Fossil Botany. Brongniart is said to have found some consolation in these meetings with his enthusiastic disciple for the dulness of an official visitation.

The late M. Roche, the friend and collaborator of Renault, who unhappily has not long survived his distinguished colleague, and to whose biography of his friend I am deeply indebted, gives a vivid account of fossil-collecting in the stony fields of the Autun country. During the holidays, Renault was to be found almost every day "beating the fields for specimens, an exercise in which he found rest from his indoor work. With his geologist's satchel on his back, and his big hammer in his belt, he knew how to lead us in his train; he always returned with loads beyond our strength. Next day we witnessed his delight, when, after a thorough washing of the blocks, he found some parts preserved. The bad pieces,

which he did not want, were remorselessly thrown into the gutter." (Roche, 1905, p. 17.)

One day, when Renault was accompanied by his friend Grand'Eury, another illustrious palæobotanist, who happily is still with us in full vigour, a curious incident occurred. Grand'Eury, as they approached a good locality, asked his friend, "What do you want me to find?" "A *Sigillaria* with its bark on," replied Renault. In a minute or two Grand'Eury picked up a block, and without examining it said, "There's the *Sigillaria* you asked for." Chance had favoured him. Renault cleaned the specimen according to custom; it revealed itself as a magnificent *Sigillaria spinulosa*, which formed the subject of one of his best known memoirs, written in collaboration with Grand'Eury. (Renault, 1874.) It was ten years before another piece was found, and no more has been met with since then. Those who have worked at such subjects may be able to recall coincidences almost as surprising.

It was from the permocarboniferous deposits, both at Autun and at Grand Croix near St. Etienne, that Renault drew most of the material for his detailed studies. But he was able to add to the resources of palæobotanical science by the discovery of a fossiliferous bed at a much lower horizon. At Esnost, twelve kilometres from Autun, there had been some prospecting for coal as long ago as 1812. Renault examined the débris from the abandoned pits, and was able to show that they contained fossils of Lower Carboniferous age, of the stage unfortunately called Culm on the Continent, though the original Culm of Devonshire, from which the name is taken, is now known to have been of much later date, as Mr. Arber has shown. In the Lower Carboniferous of Esnost, Renault made important discoveries of petrified plants, including specimens of *Archæocalamites*, the most ancient type of Equisetales, *Lepidodendron* and its cones, with other Lycopodiaceous remains, the fern-like *Diplolabis* with its fructifications, and other fructifications of the groups, now so problematic, allied to Ferns.

Renault had scarcely started on his palæobotanical career, when he was called away on duty of a very different and sterner character. One of his earliest and most important discoveries, that of the anatomical structure of the remarkable genus *Sphenophyllum*, was communicated to the French Academy on May 30, 1870. As no one of my generation is likely to forget, war was declared by France against Prussia on July 15 of that year. During the succeeding siege of Paris, the illustrations to the *Sphenophyllum* memoir were lost, and its publication long delayed (till 1873). Renault himself, however, had no leisure for scientific regrets. "When the terrible year arrived," says M. Roche, "Renault, esteemed by all, and well known for his honourable

character, was designated by the Committee of National Defence, sitting at Lyons, to organise the defence at various points of the Saône-et-Loire. This mission was full of difficulties, in the midst of the orders and counter-orders coming from every quarter, and representing the unhappy disorder resulting from an improvised defence. Though constantly called from one point to another, searching for cartridges which were abundant just where they were not wanted, he succeeded in giving satisfaction to administrators overwhelmed by the critical position ; he received the greatest eulogies." Though Renault does not appear to have been exposed to the dangers of actual war, he none the less had to suffer severely for his country. On his way to Autun, then threatened by the Prussians, he was seized with smallpox, so prevalent under the evil conditions of war-time, and for some days was given up by the doctors. His friend, M. Penjon, Professor of Philosophy at Lille, came to his assistance during his illness ; Renault did not forget his timely aid, and commemorated him in the name of the now famous fossil fructification, *Cordaianthus Penjoni* (Roche, 1905, p. 7). During his convalescence, Renault once more found recreation in collecting and preparing the fossil plants of his native district.

With the return of more peaceful times an important change took place in Renault's position. In 1872 he was summoned by Brongniart to the Museum of Natural History at Paris—the field of all his future labours. He co-operated with his great chief in the classical work on silicified seeds, published posthumously under Brongniart's name in 1881 (Brongniart, 1881).

For the first four years Renault had no other title than that of "Préparateur," but in January 1876 he was officially nominated "Assistant Naturalist at the Museum, attached to the Chair of Botany, Organography, and Physiology." This modest post was all he obtained to the day of his death. Few men so distinguished have received such miserably inadequate recognition from their official chiefs, an injustice which his learned countrymen cannot speak of without indignation.

Renault had no laboratory at first ; after a time, however, he induced the architect of the museum to put up for him, under the head of "repairs," two little glazed wooden boxes, one on each side of the portico of the botanical and geological department. Chevreul, the venerable director of the museum, was indignant when he first saw this inartistic excrescence on the architecture of his building. The little boxes are shown in the accompanying photograph, taken by my friend, Professor F. W. Oliver, last April. The one to the left was the workshop where Renault cut his fossil sections, that to the right was the laboratory proper, where his microscopic work went on, and where he received his scientific visitors. "Renault's cage," as the laboratory was jocosely called,

Renault's Workshop and Laboratory, in the portico of the Musée d'Histoire Naturelle.

constituted to the end of his life his only official quarters. It looks exactly like a porter's lodge, and the savant whom it sheltered was often addressed by strangers as the concierge, a comic situation which he thoroughly enjoyed. Visitors to the laboratory, as I know to my cost, were sometimes the victims of the same mistake, and were not always equally capable of dealing with the position.

In this tiny laboratory the material result of Renault's labours is now deposited, in the form of no less than 7000 preparations showing the structure of fossil plants, almost all of them, as I understand, the work of his own hands. He utilised, of course, at the same time the great collections of the museum. "The fossil impressions," as M. Roche says, "were his herbarium, the silicified wood his anatomical material."

The eminent physiologist, Paul Bert, interested himself in Renault's work, and it was through his efforts that the latter was authorised to give a course on Vegetable Palæontology, undoubtedly the most important course of lectures ever given on this subject. It extended over five years, from 1879-83, and was almost wholly based on his own researches. After every lecture there was a demonstration of the actual specimens and preparations, and each hearer received a copy of the illustrations prepared for the course. The lectures of the first four years were published at Renault's own expense, and form his famous "*Cours de Botanique Fossile*," a classical work, which will always be indispensable to the student of fossil plants. The groups dealt with are exclusively the fossil Vascular Cryptogams and Gymnosperms. Then, as now, there was much difficulty and dispute as to the true boundary between these two divisions, though the position of the contested frontier has somewhat shifted since those days. The limits of the "*Cours*" are still those within which the real triumphs of fossil botany have been won. A smaller and more popular manual was published in 1888, "*Les Plantes Fossiles*." It was a great misfortune that the course was never resumed. Paul Bert wished to have a Chair of Vegetable Palæontology founded for Renault, which was obviously the right thing to do; but this, and all other efforts on his behalf, were unhappily frustrated. Simultaneously with the commencement of this course, in 1879, Renault brought out his important work, "*Sur la Structure Comparée de quelques Tiges de la Flore Carbonifère*." Besides other investigations of much value, this memoir contains his wonderful account of the complete structure of the fossil Gymnospermous family, Cordaiteæ, in all their organs reproductive as well as vegetative, perhaps the most remarkable reintegration of a wholly extinct group of plants which has yet been accomplished. The "*Tiges Comparées*" was his main thesis for the degree of Doctor of Natural Science.

Renault's work went on amid depressing conditions of neglect and even hostility. I am neither able nor willing to dwell on the

nature of these discouragements, but it is right that they should be referred to in order that we may do justice to the indomitable pluck and perseverance which enabled him to work on, in spite of all depressing influences, with undiminished energy and zeal. It is, however, deeply to be regretted that owing to the want of proper assistance his work was seriously hampered, and much valuable material remained unutilised at the time of his death.

Apart from the scientific papers—200 or more in number—to some of which I shall refer in the second part of this address, we may mention the great “*Étude sur le Terrain houiller de Com-mentry*,” published in 1888–90, in which M. Zeiller co-operated, a complete account of a rich flora of Upper Coal-Measure age. A work of even greater importance from a general point of view was the “*Bassin houiller et permien d’Autun et d’Épinac: Flore Fossile*.” The first volume, limited to Ferns, was by M. Zeiller, and appeared in 1890. The second, accompanied by a magnificent atlas of over 60 plates, is the sole work of Renault; it appeared in 1893–6, and deals with all groups of palæozoic plants, and more especially with their internal structure. In this great book his work may be said to have culminated, though the stream of his publications flowed vigorously to the last.

Renault appears to have been as successful in the character of a public lecturer, especially at his native town of Autun, as he was in the field of original investigation. M. Roche speaks of him as “a great populariser of Science.” Owing chiefly to his influence, Autun became a scientific centre of an importance almost unparalleled in the case of a provincial town.

Renault’s health began to be seriously affected in the year 1902, when he was much troubled by retinal hemorrhage, which for some time compelled him to forego the use of Microscope or lens—a painful deprivation to so zealous an investigator. This affection of the eyes was but a symptom of severe internal mischief, and the end soon approached. It is a comfort to learn that the patient suffered little and never realised his danger, his friends, who were well aware of his critical condition, studiously keeping the knowledge from him. He preserved his consciousness to the last, without any anticipation of death, and passed away on October 16, 1904.

The French Academy had always recognised the value of Renault’s work, as shown by various prizes awarded him, at dates ranging from 1873 to 1902. Since his death I hear that it has been proposed to name one of the streets of Paris after him, an honour often conferred on deceased men of science in that capital. I have had the privilege of seeing a large number of letters from Members of the Academy vigorously supporting this proposal.

For the photograph of Renault reproduced in this address I am indebted to his cousin, Madame Bocquet Renault, who, I under-

stand, was accustomed to help him in his work as secretary. The photograph was taken in 1888, when he was 52 and in full vigour. The only time I met Renault myself was five years later; he then already looked appreciably older. On that visit I found him just emerging from his workshop, where he was evidently in the act of preparing some of his fossil sections. He was exceedingly kind in showing me the most interesting things in his collection, and I remember he at once convinced me of the truth of one of his conclusions, as to which we in England had been somewhat sceptical up to that time, namely that the fossil named *Astromyelon* by Williamson was really the root of *Calamites* (Renault, 1885 and 1896). The generous and candid treatment which I experienced on that occasion at Renault's hands was the more admirable, as he evidently regarded me as an emissary from the enemy's camp, for I was then working in conjunction, as a junior colleague, with Williamson, his old rival and often his opponent. The position might have been difficult, but Renault happily possessed a sense of humour, and any divergence there may have been on scientific questions only added a certain piquancy to our personal relations.

Renault's work as a palæobotanist was far too extensive to be dealt with as a whole within the limits of a Presidential address. The most that can be attempted is to give a few illustrative examples.

As M. Zeiller points out, the work of Renault falls naturally into two divisions (Zeiller, 1904); the first embracing his investigations of the higher fossil plants, more especially the structural specimens from Palæozoic strata, while the second was concerned with fossil micro-organisms, Bacteria, Fungi, and the lower Algæ, and their action, especially in relation to the production of coal in its various forms.

The second period coincides approximately with the last ten years of his life; but the two lines of work overlapped, his researches on the higher plants continuing to the last, concurrently with the investigation of micro-organisms.

I shall here limit my remarks almost wholly to the former, which is more familiar to me, and is also, without question, of more assured value.

1. BOTRYOPTERIDÆ.

Renault's first palæobotanical paper (dated 1868, but published in 1869) is on a Fern-like petiole (*Anachoropteris pulchra*), from the Upper Coal-Measures of Autun (Renault 1868). He noted, among other points, the presence of pitted elements in the wood—a rare character among true Ferns. Though of no great importance in itself, this early work stands in close relation to one of his most fertile lines of research.

A little later, in a memoir dated 1869, but not published till after the war, in 1871 (Renault, 1869), the structure of stem and petiole is described, and their relations determined, in the two genera *Zygopteris* and *Anachoropteris* (*Z. Brongniartii* and *A. Decaisnei*). The genera are well distinguished by their petiolar structure, though the stem with its single vascular cylinder, recalling that of some of the Filmy Ferns, is of similar organisation in both. At the same time the petioles of other species of *Zygopteris* were described. This was an excellent piece of work, and we shall see to what it led.

A few years afterwards, in 1875, Renault announced the discovery of a new genus, *Botryopteris* (Renault, 1875), giving an accurate account of the anatomy of the stem, although he had only a single fragment to work with. This is, perhaps, the simplest type of stem known, the vascular cylinder consisting merely of a solid strand of tracheides, and affords the rare case of a Palæozoic plant differing in the direction of greater simplicity of structure from its probable nearest allies in the recent flora. This, however, even in the case of *Botryopteris*, only applies to the stem. Renault further described the characteristic petiole, and, what was more important, was able to identify the fructifications, dense masses of large, pyriform sporangia, each with a broad, band-shaped "annulus." He found that they were grouped in tufts on the branches of a naked rachis, indicating dimorphism of the fertile and sterile fronds. As regards the affinities of the new genus, Renault pointed out, with remarkable acumen, analogies with the Hymenophyllaceæ, Osmundaceæ, and Ophioglossaceæ, inferring that there was a relation to all three groups, and coming to the conclusion that *Botryopteris* was intermediate between the true Ferns and the Ophioglossaceæ. His views appear fully justified in the light of later research.

The next year (Renault, 1876) the fructifications of *Zygopteris* were discovered, and proved to present a clear affinity with those of *Botryopteris*, though differing in well-marked generic characters.

In the Cours de Botanique Fossile (Renault, 1883), the two genera are treated as the representatives of a distinct family, the Botryopterideæ, which from that time onwards has played a more and more important part in the taxonomy of the Palæozoic flora (Renault, 1891 and 1896). Although some of Renault's conclusions, especially as to the heterospory of the family, may not have been substantiated, one of his greatest services to science was the recognition of this group—far more extensive, probably, even than he imagined. At the present time they are regarded by many authorities as the most important representatives of the primitive Filicineæ, which long preceded the advent of Ferns, in the narrower sense, as we know them at the present day.

2. PECOPTERIDEÆ.

At the present moment much of the interest of Palæozoic botany centres in the Pecopterideæ. The discoveries of the last three years have transferred so many of the so-called Ferns to the ranks of seed-bearing plants, that doubts have even been expressed whether, at least in the older Carboniferous strata, there were any true Ferns at all. Apart from the Botryopterideæ, a group which some would separate from the Ferns proper, the last refuge of the true Ferns has hitherto been found in the genus *Pecopteris*. This stronghold, it is true, was rudely shaken when, in April of last year, M. Grand'Eury discovered fronds of *Pecopteris Pluckenetii* laden with seeds! The species, however, is an aberrant one, and cannot decide the fate of the genus as a whole. A large number of the species of the form-genus *Pecopteris* are known to have borne fructifications of the type commonly recognised as Marattia-ceous. The sporangia are somewhat massive, without a definite annulus, and, in the more characteristic cases, are united together, like the carpels of a multilocular ovary, to form compound fructifications known as synangia. While our knowledge of the external characters of such fructifications is chiefly due to Stur, Zeiller and Grand'Eury, it is to Renault, more than anyone else, that we owe an acquaintance with their internal organisation, which he described in *Scolecopteris polymorpha*, *Ptychocarpus unitus*, *Pecopteris geriensis*, *P. oreopteridia*, *P. exigua*, *Sturiella intermedia*, and others (Renault, 1883 and 1896). The case last mentioned is particularly interesting, as here the sporangia, though grouped in definite synangia, possess a kind of annulus, thus showing a remarkable combination of characters. Renault's observations undoubtedly tended strongly to confirm the idea of the Marattia-ceous affinities of the fossils in question. Whether this view, once, as it seemed, so unassailable, can hold its ground, or whether we shall have to admit that all these fructifications, like *Crossotheca Höninghausi*, were but the pollen-bearing organs of Pteridosperms, cannot yet be decided. In either event, the ultimate decision will rest, in no small degree, on the accurate data afforded by Renault's researches.

3. NEUROPTERIDEÆ.

The building-up of our knowledge of this family, now recognised as one of the main divisions of the Pteridosperms, has been the work of many investigators, among whom Renault claims an important place. It was he who first demonstrated the anatomical structure of the leaves of *Neuropteris* and *Alethopteris*, and was able to show that their petioles were identical with the petrified specimens long previously named *Myeloxylon* by

Brongniart. The evidence for this conclusion is fully stated in the "Cours de Botanique Fossile" (Renault, 1883), where it is shown that the type of petiole previously known as *Myeloxylon Landriotii*, was characteristic of *Alethopteris*, while the structure of *M. radiatum* belonged to species of *Neuropteris*, and perhaps also of *Odontopteris*, results which confirmed the acute suggestions already made by M. Grand'Eury.

Some years previously Renault had prepared the way by a detailed study of the structure of the petioles in question (Renault, 1874) which he then re-named *Myelopteris*. The reason for this change in nomenclature was his conviction that these organs belonged to Marattiaceous Ferns, an opinion which he still maintained in 1883, though by that time evidence had already been brought forward in Germany to show that *Myeloxylon* was the petiole of *Medullosa*, a genus of stems then regarded as Cycadean. We now know that the Neuropterideæ or Medulloseæ were seed-bearing plants, approaching the Cycads, but retaining characters indicative of affinity with Ferns in a wide sense. Renault's idea of Marattiaceous relationship, in fact, is still tenable, for the latest view, expressed by a high authority, is that the Pteridosperms (including Neuropterideæ) had a common origin with the Marattiaceæ. Almost at the close of his life, Renault recognised the new position which the question had assumed, for in his last published work, presented to the Academy on May 15, 1904, in maintaining the multiple origin of Phanerogams from different Cryptogamic phyla, he cites the Medulloseæ, and especially *Colpoxylon aetnense* (Renault, 1896), the structure of which he had himself revealed, as probably connecting the Ferns with the Cycads (Renault, 1904).

The plants which Renault, by his anatomical researches, so largely contributed to reconstruct, constituted a most remarkable group. The often massive stems, with a complexity of structure scarcely to be paralleled among recent plants, bore enormous petioles, often 6 inches in diameter, branching out into great compound leaves suggesting some huge *Angiopteris* or *Osmunda*; on the fertile pinnæ of these fern-like leaves were borne the seeds, resembling those of Cycads, and sometimes, as it appears, of an immense size. The strange and unfamiliar appearance presented by a female *Cycas* in fruit, can give us but a faint idea of the bizarre habit of the extinct family.

4. CORDAITEÆ AND POROXYLEÆ.

The wonderful reconstruction of the Cordaiteæ by Renault and Grand'Eury, the former working from anatomical characters, the latter from external features, has already been referred to, and is familiar to all students of Fossil Botany. It was their work which,

for the first time, gave us a clear conception of Palæozoic Gymnosperms. While Grand'Eury, with his admirable restorations, revealed the habit of these great trees, now only distantly recalled by that of some Southern Conifers allied to the Kauri Pine of New Zealand, Renault made known the minute structure of every organ of the plant, and afforded a sure basis of comparison with other groups. The result was to show quite clearly that the characteristic Gymnosperms of Palæozoic times were not, as had been supposed before, members of the Coniferæ, but a quite distinct family, combining, in various respects, the characters of Coniferæ, Cycadaceæ, and the family which we now call Ginkgoales, represented in living vegetation by the Maiden-hair Tree alone. While stem and root on the whole present a Coniferous structure, the leaves, apart from their simple form, are almost purely Cycadean; the very peculiar male catkins (e.g. *Cordaianthus Penjoni*, above referred to) most nearly suggest those of *Ginkgo*, with which the female organs have likewise some analogies, though so far as the seed is concerned, a comparison with Cycads is equally admissible (Renault, 1879).

The investigation of the female fructifications yielded, perhaps, the most striking results of all, for here, in the pollen-chamber of the ovule (in *Cordaianthus Grand'Euryi*) Renault first found the multicellular pollen-grains to which so much interest attaches, and found evidence that their growth and differentiation went on after they had entered the ovule. To this subject we shall return in the following section.

The Cordaiteæ, this highly developed, but at the same time synthetic Gymnospermous family, extends back in time to the Devonian period, a fact always to be borne in mind by the palæobotanist, as showing the enormous antiquity, even of highly organised seed-plants, and thus inculcating caution in our phylogenetic speculations on their origin. Side by side with them, as we now know, lived a great multitude of Fern-like Spermatophyta, with apparently far more primitive characters than the Cordaiteæ, but not, so far as has yet been proved, of greater antiquity. At the present stage of our knowledge we cannot doubt that the Pteridosperms represent most nearly the earliest type of Seed-plant, but this is a morphological inference, and is not as yet immediately given by the geological record.

The family of the Poroxyleæ, discovered by Renault (Renault, 1879), and fully investigated by him in conjunction with Professor Bertrand (1886), is of extreme interest, as tending to connect the Cordaiteæ with lower groups. Our knowledge is here, for the most part, anatomical, though M. Grand'Eury has once more stepped in, and is enabling us to recognise these plants in the form of impressions, and, as he believes, to identify their seeds.

The differences between this group and the Cordaiteæ cannot here be fully discussed; in general vegetative structure there is

an extensive agreement, but the stem retains a "Cryptogamic" character in the presence of strands of centripetal wood. Renault himself regarded the family as standing, on this account, a step nearer to the Lycopods; in the light of our present knowledge we should rather compare them with the Pteridosperms. However that may be, the extraordinarily perfect knowledge of their anatomy, which we owe to Renault and his colleague, has given the group a crucial significance in the discussion of Gymnospermous affinities.

5. FOSSIL POLLEN-GRAINS.

In the course of his work with Brongniart on the wonderfully preserved silicified seeds of Autun and St. Etienne, Renault discovered the constant presence of a pollen-chamber—i.e. a definite excavation in the tip of the nucleus, adapted for the reception of the pollen-grains. Guided by his observations on Palæozoic seeds, he was able to detect the same organs in those of their nearest living allies, the Cycads, in ignorance of the fact that this discovery had already been made by Griffith, thirty, or perhaps even forty, years before. In the pollen-chamber of the various fossil seeds the pollen-grains, which were to effect their fertilisation, are often found in an excellent state of preservation, as we have already seen in the case of *Cordaianthus*. In this position especially, though also when still contained in the microsporangia, the pollen-grains proved, in many instances, to have a multicellular structure. This at least was the interpretation which Renault put upon the septate appearance which they present. Attempts have been made to show that the apparently multicellular structure is due merely to the occurrence of folds in a contracted inner membrane, but recent work has completely confirmed Renault's view, and in many cases, at any rate, there appears to be no doubt that a body consisting of several cells was really present within the pollen-grain. The analogy with the male prothallus and antheridium of a cryptogamic microspore is manifest, and was at once perceived by Renault. In the Gymnosperms of the present day, the corresponding structures, though present, are less conspicuously developed.

This discovery, so interesting in itself, led its author to form certain hypotheses as to the method of fertilisation, which are of remarkable interest in the light of subsequent results. In examining a seed named *Ætheotesta*, probably belonging to a Pteridosperm, Renault, in 1887, observed the minute structure of the multicellular pollen-grains in the pollen-chamber. He found that both in the outer wall of the grain, and in the septa between its cells, there were perforations. He suggests that the latter may represent the traces of insertion of multiple pollen-tubes, or—and

this is the important point—"that they served for the passage of mobile bodies analogous to antherozoids" (Renault, 1887, p. 156).

If the second hypothesis should be confirmed, "it would correspond," he says, "to an interesting phase in the evolution of plants which is absolutely wanting in the recent vegetable kingdom." At the close of the paper he adds: "We do not regard as impossible the existence in the past of pollen-grains, which, instead of effecting fertilisation by means of a tube, discharged into the pollen-chamber of the appropriate seeds antherozoids capable of performing this function" (p. 158).

Thus the study of the phenomena presented by Palæozoic fructifications led Renault to anticipate, by some ten years, the great discovery made at Tokyo by Ikeno and Hirase, that in the lower seed-plants the cryptogamic or animal mode of fertilisation by motile male cells still persists. The hypothesis was not one thrown out at hazard, but was deliberately entertained, as shown by Renault repeating it on other occasions still previous to the Japanese discovery (e.g. Renault, 1896, p. 276). The case affords a striking example, both of the acumen of Renault himself, and of the value of palæobotanical evidence in its bearing even on the more minute points of morphology.

M. Roche informs us that the scientific work left uncompleted at the time of Renault's death, relates chiefly to the fecundation and reproduction of permocarboniferous plants.

6. THE QUESTION OF SECONDARY WOOD.

In Dicotyledons and Gymnosperms, as we all know, both wood and bast possess the power of indefinite growth in thickness, by means of a layer of permanently, or periodically, active tissue, the cambium, which constantly adds new elements to both. On account of this method of increasing the mass of their vascular tissues, the name of Exogens was formerly applied collectively to the two classes in question. The capacity for exogenous growth, or as we now call it, the production of secondary wood and bast, is at the present time, no doubt, a great characteristic of the higher plants, though still by no means limited to them. Among the Vascular Cryptogams now living, instances of secondary growth in thickness are rare (e.g. *Botrychium*, *Isoetes*, and in a smaller degree *Psilotum*), and were not clearly recognised at the time when the structure of fossil plants first became the subject of scientific study. Hence, when the great Brongniart found that in *Sigillaria* and *Calamodendron* exogenous growth certainly took place, he was led to give up the view of their Cryptogamic affinities, and to class them with Gymnospermous Dicotyledons. The secondary wood, in fact, was looked on as a decisive Phanerogamic character, and

plants which possessed it were, *ipso facto*, identified as seed-bearing plants; the only question which remained was to determine the particular seeds which belonged to them, and on this quest much ingenuity was expended.

Brongniart's views were quite justified at the period when they were first expressed, and we cannot perhaps wonder that he, the greatest authority on everything relating to fossil plants, was unwilling to give them up. Although evidence rapidly accumulated showing that Palæozoic Cryptogams, such as *Lepidodendron* among Lycopods and *Calamites* among Equisetales, possessed secondary wood. Renault's loyalty to his great master prevented him, during most of his scientific career, from accepting these results. He endeavoured to draw a sharp distinction between the true Cryptogams, with which he classed *Lepidodendron* and *Calamites*, and the Phanerogams simulating them such as *Sigillaria* and *Calamodendron*. If evidence was adduced to show that a *Lepidodendron* produced secondary wood, Renault denied that it was proved to be a *Lepidodendron*, and transferred it to *Sigillaria*. A Calamite with the same character was placed in the Phanerogamic genus *Anthropitys* or *Calamodendron*. It so happened that our countryman Williamson became the great champion of the Cryptogamic nature of the Sigillarias and Calamodendreae, and ultimately proved beyond doubt that the Lycopods and Equisetales of the Palæozoic generally possessed secondary wood, and were thus adapted to the arborescent habit which they so commonly assumed. Hence a warm controversy sprang up between the English school as represented by Williamson, and the French, among whom Renault was the leading spirit.

M. Zeiller, in his obituary notice of Renault (Zeiller, 1904) says: "His interest in the Equisetineæ and Lycopods was stimulated by his disagreement with Williamson as to the position of the Calamodendreae and Sigillariæ, in which the secondary wood, centrifugally developed, seemed to him, as it did to Brongniart, to constitute a Phanerogamic character." This view is strikingly expressed, for example, in his *Stigmaria* memoir of 1882, where he speaks of the phanerogamic characters of the Sigillarias as "already established" by the structure of their vegetative organs. M. Zeiller continues: "Owing to the very fact of this disagreement, science has been enriched by admirable works from both sides, and if the facts have appeared to confirm the opinion of Williamson, the discoveries on the Pteridosperms recently made in England have gone to show how well founded was Renault's prescience, as to the existence of forms, similar in their outward aspect to certain types of Cryptogams, and yet belonging to Gymnosperms by their fructifications."

Renault's views became considerably modified in his later years, and he convinced himself (for he was very slow to be convinced by

others) that Cryptogams with secondary wood really existed—e.g. in the Calamarian *Macrostachya* (Not. sur les Calamariées, 1898). In fact, he came to regard both the Sigillariæ and the Calamariæ as transitional groups between Cryptogams and Phanerogams, some of their members approaching one side and some the other. Though we cannot now accept his conclusions in detail, the broad idea of the existence of such a “debatable land” in the Palæozoic flora is an eminently fertile one. It is a striking fact that in some Lepidodendrea, plants nearly allied to the Sigillarias, but which Renault would have placed on the Cryptogamic side of the line, organs closely analogous to true seeds have been discovered.

In his latest work (May 1904) Renault speaks of certain Calamariæ as “Cryptogams with cambium” and thus definitely adopts the Williamson position, though, unfortunately, without recognising Williamson’s work in establishing it. At the same time he still inclined to attribute seeds such as *Stephanospermum* to plants of the Calamarian group. There is no objection in principle to this conception of the existence of spore-bearing and seed-bearing members of the same family—it is to a great extent realised, as we now know, among the carboniferous Lycopods. In the case of the Calamariæ, however, the evidence for the occurrence of the seed-bearing habit is as yet very inadequate. It is, in any case, a gratification to an English palæobotanist to realise that, at the close of Renault’s career, there was no longer any fundamental difference of view between himself and his fellow-workers in the same field.

The illustrations of Renault’s great work which I have selected, may serve in some degree to indicate his place in the history of science, but are altogether inadequate to give any idea of the extent of his labours.

Even in the particular field which we have rapidly traversed, investigations of the highest importance have been left untouched, as, for example, his first demonstration of the structure of *Sphenophyllum*, representing a wholly extinct class of Cryptogams; his magnificent investigation of the organisation of Calamarian fructifications; his work on the Cycadoxyleæ, a family perhaps intermediate between Pteridosperms and true Cycads; his detailed anatomical studies on *Sigillaria* and *Stigmaria*; and other researches too numerous to mention.

Besides all this, there is the vast mass of work of his later years on the micro-organisms of Palæozoic age, to which an incredible amount of labour was devoted. The investigation of fossil Bacteria, at any rate, appears a somewhat thankless task; in favourable cases, as, for example, that of *Bacillus vorax* (Renault, 1896, p. 472) occurring in vegetable débris of Lower Carboniferous age, there appears to be no doubt as to the nature of the organism, which

shows the spores enclosed within its cells; in other cases, however, the meagreness of the morphological characters available for the distinction of fossil Bacteria, leaves us in some doubt as to the value of the results attained.

Renault's work further extended to the investigation of Tertiary floras. The remarkable stained wax casts which he obtained of fossil flowers and fruits from the travertine of Sézanne, are an interesting feature of the Museum Collections.

His reputation, however, will always rest mainly on his study of the higher Palæozoic plants by the anatomical method, a line of work the full value of which has only begun to be recognised by botanists within the last few years.

As investigators, Renault and his distinguished English rival Williamson had much in common, not only in their like enthusiasm and devotion to their work, but also in a certain obstinacy when confronted with the opinions of others, combined with complete honesty and openness of mind in accepting the results brought home to them by their own observations.

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