the skeleton figured and described is that of *Euphysetes simus* of India, and will not have the least idea that the outline belongs to one species and the skeleton to another, which are admitted by Professor Owen to be distinct, and are so regarded all through the paper.

Since the above was written I have been informed of a much more serious mistake in the paper. The account of the *Euphysetes simus* begins thus:—"The Cetacean which I have next to describe is represented by drawings of the adult *male* (side view, plate 11, to scale) and *female* (side view, plate 10. fig. 1; upper view, fig. 2; to scale). It is noted as 'a kind of Porpoise' in Mr. Elliot's MS., and is known to the Telugu fishermen of the coast by the name of 'Wonga.' The *male*, measuring 6 feet 8 inches in length, was taken at Waltair, February 28, 1853. The *female* was taken on the 1st of March, 1853, at the same part of the coast; she measured 6 feet in length" (p. 30). "According to the figures, the pectoral fin becomes free 1 foot 1 inch behind the snout in the *male*, and 1 foot 4 inches in the female; but there may be some inaccuracy here" (p. 31). The comparison is continued, and terminates as follows:—"The *vulva* is 3 inches in advance of the vent; the *prepuce* of the male is 9 inches in advance" (p. 32).

Now, after all these details, I am assured that both the drawings above referred to were taken from the same specimen, the only example of the "porpoise" recorded as taken on the Indian shores, that that specimen was a *female*, and, further, that the drawings and bones were accompanied by accurate admeasurements taken from the animal itself when in a fresh state.

XLII.—*On the Temperature of Geological Periods, from indications derived from the observation of Fossil Plants.* By the Count Gaston de Saporta*.

It is by the aid of facts derived not only from the study of ancient organisms, but at the same time from all sorts of observations, that we may hope one day to solve the complex question of the temperature of the globe at periods anterior to that in which we live.

We are still very far from any such result; but, in order to approach it, we must endeavour to apply to the problem a series of partial researches, so as gradually to bring together the elements of a complete and definitive solution. I shall therefore confine myself exclusively within the limits of the vegetable

* Translated from the 'Bibliothèque Universelle: Archives des Sciences,' tome xviii. pp. 89–142.

kingdom, by displaying what we may learn, by the study of plants alone, as to the degree of temperature of the periods to which they belonged. The field, when thus limited, is still immense, and can only be very imperfectly traversed; moreover I have neither the time nor the power to explore it otherwise than for the purpose of placing in it a few landmarks.

For the sake of clearness I shall divide this memoir into three parts:—

In the first I shall enumerate the views of which the examination of fossil plants had led to the most general adoption, until lately, as to the ancient and successive states of the temperature. In a second part I shall take up these same notions, to complete and rectify them, as there may be occasion, by means of the most recent researches. Lastly, in the third I shall establish the legitimate consequences of these observations.

I add this preliminary reflection—that, as we have to do with investigations relating to temperature, the examination of the vegetable kingdom is the more important because, in the present state of things, plants constitute so many delicate instruments, graduated with precision, capable of marking the smallest thermometric variations; this must likewise have been the case in past times, of which the laws appear to have been in constant harmony with those which prevail at the present day.

I.

When, during the first twenty years of this century, fossil plants were first observed, and a certain regularity was found to occur in their mode of living and succeeding each other, the divisions which constitute the scale of strata were still few in number and imperfectly limited. A. Brongniart, who brilliantly inaugurated this science in France, was the immediate disciple of Cuvier; that is to say, he was inclined to assume a certain number of epochs, at the conclusion of which the organisms were completely renewed, whilst within each of these epochs the changes were only partial, relative, and local. However, with the imperfect materials which geologists had then at their disposal, it was impossible for them to determine either the duration or the mode of termination of these biological periods —although they were tacitly inclined to reduce towards unity phenomena of various orders, and consequently to make them coincide with the successive faunas established by Cuvier, each of which they supposed to have characterized exclusively one of the intervals favourable to the development of life, called periods of calm, in opposition to the violent catastrophes which must have separated them.

As regards plants alone, they could already specify a certain

number of facts which A. Brongniart had indicated in his earlier works, and subsequently extended and coordinated in his 'Tableau des Genres de Végétaux fossiles,' in which the views adopted by the author are marvellously condensed. This remarkable work shows clearly what, previously to the investigations of the last twenty years, was the state of the question with which we are now occupied.

At that date, on starting from the existing epoch to penetrate into the past, there were observed, first, in the newest portion of the tertiary age, the arborescent genera which still characterize the northern temperate zone, represented by species not very different from ours, but still so far distinct from these that the idea of attributing them to an order of things different from ours might be adopted without inconvenience. This first totality underwent but little change in passing from one place to another; and, in examining a deposit slightly older or more recent, there was always nearly the same repetition of forms. However, the observations were still recent, the concordance very vague, and the number of undetermined species very considerable; and it is evident that the presence of the indigenous genera was more easy to seize and verify than that of the exotics, which were most frequently left in the shade for want of the power to determine them. It was therefore very natural to draw, from the preponderant existence of the former, the conclusion that the temperature of the period at which they lived did not differ sensibly from that which still prevails under the same latitudes. In this respect the first observations presented a coincidence sometimes due to chance. It will be sufficient for me to cite Armissan, where M. Brongniart, in 1829, indicated a birch, a witch-elm, several pines, a *Smilax*, a moss, and the fructification of a fern similar to that of *Osmunda*—a result which certainly did not denote any diversity in the nature of the climate of that locality in comparison with what it is at present, but a result very different from that to which I have since been led by the profound study of the same flora.

Thus, towards the middle of Tertiary time, the changes observed in the vegetation were easily explained by means of examples derived from certain parts of North America, where there was still to be seen an assemblage of most of the genera which could then be indicated in ancient Europe. The aspect of affairs was changed, however, on quitting the middle for the lower Tertiary times. Palms were then met with, at first rarely, then in increasing number. The impressions of the fronds of these plants early attracted attention by their well-marked character; and at an early period, also, they were regarded as the indication of a climate hotter than ours. The European genera not being

absent, but only less numerous, in the localities where these plants are met with, the idea of a gradual diminution of temperature sprang from their presence the more naturally, as the European genera which still showed themselves side by side with the palms were principally *Smilaces*, pines, *Thuiæ*, and laurels—that is to say, genera which, both in Europe and North America, inhabit especially the southern parts of the two continents, from which the palms themselves are not entirely excluded.

The most ancient Eocene times were then very little known; indeed they are scarcely known now. Certain deposits, such as that of Sheppey, in the London Clay, were ascribed to peculiar causes, such as the action of a current proceeding from the equatorial seas. Nothing, therefore, was opposed to the assumption that the temperature of the Tertiary epoch, at first rather hotter than at present in Europe, had then become lowered in such a manner as gradually to exclude the southern types from this region, and to resemble that which prevails under the same latitudes at the present day.

With the chalk observers passed at once to the unknown, not only in consequence of the strangeness of the forms and their confused occurrence, but also of their rarity, the incompleteness of their series, and the vagueness of the classifications adopted. The Chalk was regarded as a sort of intermediate period, in which the vegetable kingdom, in becoming renewed, had completed itself by the addition of the Dicotyledons, like the animal kingdom by that of the Mammalia; nevertheless the observations were too scanty and too confused to give rise to very precise conclusions; and I must say that the investigations with regard to this epoch do not yet enable us to foresee any solution of the difficulties which pertain to it.

Already, however, some great facts had come to light, which still serve as the basis of our present researches. Before the Chalk the Dicotyledons do not make their appearance, and the Monocotyledons become rare and uncertain; the Cycadeæ and Coniferæ, on the contrary, increase, and the ferns in their turn become a necessary element of the vegetation; the forms, in general, depart more and more from those of the present epoch, even under the tropics, and it is amongst the most restricted of existing groups that we have to seek for similitudes; these points themselves are at last wanting, and towards the base of the Jurassic series the vegetation no longer presents anything but analogies, becoming more and more distant, with those of the actual world.

At the date that I have selected (that is to say, about 1840) the flora of the Secondary formations and those of the Trias and Carboniferous formations were already well known; notwith-

standing the progress since made, the general result has not sensibly varied.

When compared with that of the existing world, this vegetation showed differences so strongly marked that one could hardly help being struck by them. After having observed plants specifically different from those now existing, others were found generically distinct, then others separated from ours even as to their family, and consequently having nothing in common with them but the more and more distant affinities of the class and subkingdom.

It is one of the glories of our times (and this glory belongs almost entirely to M. A. Brongniart) to have collected the scattered elements of a vegetable world so different from our own, to have brought them to light and life, and to have done this with such accurate ideas that they have not since been superseded.

In endeavouring to form an idea of the temperature proper to these most ancient periods of the earth's history, we naturally had recourse to the least singular plants, such as the ferns, then to the Calamites regarded as Equisetaceæ of large size, and to the *Lepidodendra,* arranged among the Lycopodiaceæ; and it appeared to follow, from the exclusive presence of plants belonging to the class of Vascular Cryptogamia, that certain islands at once hot and moist, certain tropical valleys bathed in tepid vapours and immersed in a dense shade, furnished a notion of what Europe must have been like during the period which corresponds with the formation of coal.

In the different composition of an atmosphere more charged with carbonic acid, in the extension of the seas, in the arrangement of the emergent land in the form of low islands, and in the still sensible action of the central heat, conditions were also sought which, when once admitted, accounted for the supposed elevation of the temperature and for that uniformity of climate which permitted the same vegetation to extend uniformly over very large regions, from Spitzbergen to the East Indies, and thence to Australia. Thus the preponderance and the great size of the Vascular Cryptogamia and the abundance of arborescent ferns were amongst the principal arguments invoked in support of a great elevation of temperature, which was afterwards explained by different causes.

Nevertheless, without thinking of it, those who argued in this way placed themselves in a vicious circle, in some respects, when they invoked the influence of the central heat upon the temperature to explain its elevation and the presence of arborescent ferns in Europe, whilst these same plants appeared to other geologists an evident proof of this action of the central heat.

Nor did they consider that, in making the vegetable combinations peculiar to this epoch dependent on the existence of a very elevated temperature, the important fact was left out of consideration, that the other categories of plants not having yet appeared, their absence was a negative phenomenon which deprived the exclusive predominance of Cryptogamic groups of a great part of its significance.

In reality nothing was evident except the existence of a more genial and more uniform temperature than at present—the only rigorous deduction from the facts observed.

But, by assuming for the Carboniferous period a very high degree of heat, a starting-point was established in harmony with the supposed progress of vegetation, since this appeared to have been gradually modified in proportion as the temperature was continually lowered by an insensible gradation.

To sum up. A great initial heat combined with a great climatic uniformity; a diminution at first not very marked, but becoming very sensible towards the commencement of the Tertiary period, still more marked towards its middle, and completely established towards the end of this period; a progress starting from a state very different from our own, and approaching the latter gradually from epoch to epoch: such, it appears to me, is a faithful representation of the most rational inductions that science had formulated. We must now see whether this view is in accordance with the most recent observations.

II.

The domain of fossil botany has been enormously enlarged of late years. One of the most interesting results of this recent progress is, that we can trace the course of a considerable number of genera through several successive stages; and where the species belonging to these genera, as is almost always the case, show a close affinity to those which correspond with them in the present state of things, we are justified in assuming that the fossil species lived under the rule of the same conditions as its living homologue, or at least under very similar conditions.

Thus the existing genera the ancient existence of which it is possible to prove must assist us in the investigation of the temperature proper to the times and places which they seem to characterize; whilst the extinct genera can only furnish us with such information in a very indirect fashion, according to the more or less distant relationship which they bear to those of our own day. On the other hand, when we have to do with a species which closely resembles a living congeneric species, the

analogical conclusions derived from the study of this plant will have the more probability in proportion as the affinity is more evident and the genus of which it forms part has more exclusive adaptations and better-defined habits.

One condition, however, is necessary to make sure of reaching the truth by this course—namely, that the generic affinity of the ancient species be supported by actual proofs, or, at least, that there be very little uncertainty about it. By adopting too readily a multitude of determinations indicated by palæontological botanists during the last few years, we should inevitably be exposed to the risk of building a superstructure without firm bases.

There is another important remark, of which, indeed, we shall have to make immediate application—namely, that certain determinations, although apparently doubtful, are in reality much less so. If, instead of being considered isolatedly, they relate to genera of which the repeated and successive presence is so well established that the fact of their ancient existence cannot be made a matter of doubt, there is then established between the various members of a series of graduated stages a sort of solidarity which causes the eyes and the mind to habitually recognize without hesitation impressions the true nature of which would escape them under other circumstances. The smallest indications are sometimes sufficient to reveal this to practised eyes. It is, moreover, certain that the types which continue characteristic of a region reappear almost always with great persistency in the fossil state in the strata of that region. This is one of the most settled general phenomena that can be appealed to in geology, not only in the world of plants, but also in that of animals of all classes. It is the case with the ancient European flora; and the types of vegetation which now characterize exclusively the northern temperate zone in the two hemispheres are reproduced in the fossil state, not only in the period immediately preceding our present one, but also through a long series of stages, until we reach the point where, discoveries being deficient, the investigation of these types is of necessity interrupted. These types are not the only ones that we can determine with certainty and with advantage to the question before us. Without speaking of those which have decreased in Europe, or which have since abandoned this continent to maintain themselves elsewhere, there exist others which are now observed only in the vicinity of the tropics. The more the affinities of the species of this category can be rigidly defined, the more possible is it to fix the probable degree of temperature which their presence in ancient Europe must lead us to accept for the period at which they lived. Here I find a difficulty

which must not be passed over in silence. What must we conclude if the two series of genera to which I have just referred combine, instead of mutually excluding each other? The examination of this question, one of the most curious of those suggested by the study of the European fossil floras, would be best placed at the end of my notice, when I shall discuss the legitimate consequences of the facts that I may have established; however, as the objection has presented itself, I shall state my opinion on this point, in order that, by at once getting rid of what has a specious appearance, the course that we have to follow may be cleared in advance of all obstacles.

There are, in my eyes, some truths so clear that they cannot, without paradox, be questioned. It follows incontestably, from the totality of the facts known in geology, that the temperature was higher formerly than at the present day in the zone of which the continent of Europe forms a part. The phenomenon of initial elevation of temperature is therefore not under discussion: what we have to seek are the successive degrees of this temperature, the period and the mode of its decline. As regards the fact of its definitive diminution, its results are before us. There were formerly in Europe palm trees, screw-pines, arborescent ferns, Laurineæ, and other exotic forms, which have disappeared to give place to the plants which we have before our eyes, and of which we know the organization to be adapted to the action and periodical return of cold seasons. Thus the fact of the lowering of the ancient temperature evidently follows from the elimination of these first types: therefore this elimination must be regarded as its true sign; and whenever, in a fossil flora, we observe a mixture of European with truly tropical forms, the presence of the latter will be to us a sufficient indication of the maintenance of a high temperature. When the European climate became decidedly too cold, these forms must have disappeared from the middle portions of this continent, and have left only faint traces of their former existence in its southern parts: this, in my opinion, is a certain proof that their coexistence with the forms which have continued indigenous had been possible previously only by the aid of climatic combinations which did not exclude the maintenance of at least a part of the ancient heat.

Thus, to my eyes, the elimination of the tropical genera is the great fact which reveals the moment when the temperature decreased, and even the proportion of this decrement. To us, therefore, the time when this elimination became complete will be that in which, the latitudes being constituted nearly as at the present day, the differences observed no longer depend upon any other than certain purely local causes.

We have now to apply these principles to the kind of investigation that I wish to attempt; and the following is the method that I shall follow. The end proposed being to collect among the fossil floras the indications of the temperature of the various periods, I shall rely upon two groups or series of plants, of which the completely opposite aptitudes alone can give rise to decisive inductions. These two series are, on the one hand, that of the genera now proper to the boreal zone, and, on the other, that of the types of which the homologues are now met with exclusively in the vicinity of the tropics. For the former, of which the date of appearance is still uncertain, but which did not show themselves in Europe until a comparatively recent date, the starting-point to be selected for observing their progress is best placed in opposition to the direction of this progress—that is to say, in the present epoch. On departing from this starting-point, we shall see this group, at first very complete, diminishing gradually, and lastly losing itself in a past state of things which is still very obscure. Must we follow the same course in the observation of the tropical types? I think not. In fact when, ascending the course of ages, we meet with them for the first time, these types are easily misunderstood; their very importance renders it necessary that they should be rigorously defined. Instead of being connected, like the European types, with an order of things still existing in the land, they are directly related to those of previous ages, and the latter, by a train which becomes more and more visible, are themselves connected with antecedent types. On the other hand, we are certain *à priori*, notwithstanding differences of detail, of the comparative elevation of the temperature during the most ancient period of vegetable life; and consequently, by starting from the most ancient stages, and neglecting the genera without any direct analogy with those of the present day, we are certain of arriving at a moment when, the divergences becoming less, genera identical with those now existing will necessarily make their appearance, and furnish us with an approximate scale of the temperature of these distant ages.

Thus we obtain a double starting-point; and the courses to be followed for one and for the other are in inverse directions, since, in order to ascertain the existence of tropical types, we shall descend the course of ages, whilst, on the contrary, we shall ascend it when we have to study the progress of the European types. In both courses of investigation I shall abstain from mentioning any genus the existence of which does not seem to me to be demonstrated, and which would not be identical with existing generic divisions; and I shall always take the latter in the most extended Linnean acceptation.

§ 1. *Examination of the Groups, Genera, and Forms with Tropical Affinities observed in the Ancient Floras.*

The vegetation of the Palæozoic strata does not with certainty include any of the existing genera. The attempts made in Germany by some palæontologists to assimilate to the living ferns a portion of those of the Carboniferous formation seem to be more specious than well founded*. They depend upon a superficial affinity of form rather than upon identity of structure. Moreover the positive analogies which this investigation has sometimes brought out would tend rather to lead us to range the ferns of this early age among the most exceptional tribes of the existing order. It is thus, according to M. Brongniart †, who is so cautious in his determinations, that the genus *Scolecopteris*, Zenk., observed in the same state of chalcedonic petrifaction as the species of *Psaronius*, and, like them, probably contemporaneous with the coal-measures, resembles in the mode of grouping of its capsules of fructification the genus *Angiopteris* among the Marattieæ, and that several species of *Asterocarpus* resemble *Kaulfussia*, or only *Gleichenia* and *Mertensia*. Other species of the same group seem to be allied to *Matonia* in the tribe Cyatheæ. Lastly, the genus *Senftenbergia*, described by Corda, appears to denote the existence of a Schizeacean.

The much smaller proportion than was supposed of arborescent species has weakened one of the arguments most frequently appealed to in favour of the supposed elevation of temperature at this epoch. This applies also to the persuasion still entertained by many geologists that a constant temperature of 25°–30° C. (77°–86° F.) is necessary for the vegetation of tree ferns. This cannot be supposed when we observe that under the tropics it is principally in the hearts of mountain-forests and in the bottom of elevated valleys that most of these plants grow; their region is situated between 400 and 600 metres, and extends even to an elevation of 1000 metres. Moreover, according to the testimony of Humboldt ‡, the arborescent ferns depart from the equator towards the south as far as the forty-sixth and even the fifty-third parallel; they attain to an admirable development in Van Diemen's Land, at Hobart Town (lat. 42° 53′), with a mean temperature of 11°·3 C. (= 54°·34 F.)—that is to say, in an isothermic band of which the temperature is 2°·3 C. (=4°·14 F.) below that of Toulon. It is true, as is remarked

* See especially 'Die Farnkräuter der Jetztwelt zur Untersuchung und Bestimmung der innern Formationen, &c.' von C. Ritter von Ettingshausen. Vienna, 1865.

† Tableau des Genres de Végétaux fossiles, p. 27.

‡ Tableau de la Nature, tome i. p. 166 (Galusky's translation: Paris, 1851).

by this celebrated author, that the difference between the extreme seasons is much more strongly marked in Europe than in Australia, and the climate is less uniform even within the limits of each season*. At Dusky Bay, in New Zealand, according to Dr. Hooker, arborescent ferns grow under a latitude of 46° 8′; and in the Auckland and Campbell Islands they are met with as far as 53°.

It can no longer be asserted that the temperature of the tropics is necessary for the existence of these plants; and therefore it is not to their presence alone that we can appeal for the admission of a high temperature during this first epoch, but must rather consider the general character of the vegetation. The types of this age, of which there still exist some representatives, diminished in size and generically distinct—the Lycopodiaceæ and Equisetaceæ—as well as the ferns themselves, flourish nowhere so much as within the tropics; and it cannot be denied that this neighbourhood is favourable to them, as their number, dimensions, and comparative importance increase in proportion as we advance in this direction. It is from the combination of these indications that we must believe in the existence during this first period of a warm temperature, a dense and cloudy atmosphere, and a permanent and tepid moisture.

The continents were then but slightly varied in surface-features (*accidentés*); the flow of water on the surface of the soil gave rise neither to rivers nor torrents, but to lagoons fed by a multitude of brooks which descended from all the slopes and traversed the bottom of the undulations, as we still see in granitic countries, which, better than any others, have retained the features of this ancient configuration of the surface of the earth. But the vegetation of the Carboniferous period has been pictured too often to render it necessary for us to dwell longer upon it.

On penetrating into the Trias, we meet with the genus *Equisetum*, still diffused throughout all latitudes, although its species now, even in hot countries, are far from attaining the dimensions of its ancient forms. In fact *Equisetum arundinaceum* (Bory), from the shores of the Mississippi, one of the largest of the group, does not approach *E. arenaceum* (Heer), from the Keuper, or even equal some Tertiary species.

In the Jurassic epoch is developed the group of the European Cycadeæ, probably generically distinct from those of the present day; it is, however, to the Cycadeæ growing in the southern parts of the eastern hemisphere, such as *Dion*, *Macrozamia*, and *Ence-*

* At Hobart Town the hibernal and æstival means are represented by 5°·6 and 17°·2 C., whilst at Rome, about 1 degree further from the equator, the annual temperature being 13°·3 C., the hibernal mean descends to 8°, and the æstival reaches 30° C.

phalartos, that the *Zamites*, *Ctenis*, *Pterophyllum*, and *Nilsonia* of the secondary strata most closely approach. And as there is no reasonable doubt that these various genera really formed part of the same group as the existing Cycadeæ, the habits and distribution of the latter in the world of our day may furnish us, by analogy, with valuable details as to the state of Europe at the period when these plants grew there, especially if we take care to select as examples those which most faithfully reproduce the ancient fossil types.

We must therefore compare these principally with *Encephalartos* and *Macrozamia*. The species of the former genus inhabit Southern Africa from 20° to 30° S. lat.; those of the second grow in South-western Australia, about 30° S. lat., and extend as far as 35°. These, therefore, as M. A. Brongniart has pointed out*, are rather subtropical and austral genera than really proper to the equatorial regions; the same remark is applicable to the species of *Cycas* and *Ceratozamia*, which advance in Japan and Mexico far beyond the tropics, to 32° N. lat. The habits of the plants of the group which seem best to reflect those of the fossil Cycadeæ are indicated by M. Miquel in his monograph of the Cycadeæ†. He tells us that the species of *Encephalartos* grow at a considerable distance from the Cape region properly so called, and beyond the limits of the flora characterized by the presence of Proteaceæ and Ericaceæ, under the shelter of a chain of mountains, in a country exposed to the calorific influences of the torrid zone, *but without precisely making part of it*. The first plants make their appearance about Uitenhage, in very limited stations separated by great intervals. Further on the individuals become more numerous, especially towards Amatymbis and Tambookis; they are never met with in the plains, but frequent the mountainous districts. Some prefer stony soils; others seek a rich vegetable mould; lastly, they do not appear upon naked slopes, but in the midst of thick copses of spiny shrubs. They are nowhere abundant, but disseminated in groups; the mountains which they inhabit attain an altitude of 2000 feet, and are dependent on a chain of which the elevation is not less than 1000 feet, and of which the slope directed towards the east and north pours its waters towards Delagoa Bay. Such is the physiognomy of these plants: a faithful image of a world that has disappeared, they carry us back irresistibly towards the Europe of Secondary times, of which they explain to us the vegetation and the aspect; nothing is altered, if we replace with Conifers the Leguminosæ and Rhamneæ of this part of Africa; but nothing compels us to assume for this epoch a temperature

* Tableau des Genres de Végétaux fossiles, p. 59.

† Monographia Cycadearum, p. 40.

higher than that of Africa about the twentieth degree of south latitude—that is to say, an annual mean of 22° C. (=71°·6 F.), the elevation, which rises to 2000 feet, moderating, in the station inhabited by *Encephalartos*, a climate already hotter than that of the Cape.

By the side of the Cycadeæ of the Lias we have to place some other indications, derived from other classes, which must not be neglected. Two species from the Lias of Bayreuth, described by M. Göppert under the names of *Asterocarpus heterophyllus* and *lanceolatus*, resemble the *Kaulfussiæ* belonging to the family Marattieæ, according to M. A. Brongniart; whilst the *Tæniopteris Münsteri* of Göppert, from the same locality, denotes a type very analogous to *Angiopteris*, and certainly belonging to this same group of the Marattieæ. Göppert also indicates *Hemitelites polypodioides* as very analogous to *Hemitelia speciosa* (Kaulf.) from Peru.

The exceptional tribes of the existing state of things, of which we have thus already seen the dawn, consequently reappear with great persistency, and continue to show themselves: they now preferably dwell beneath the tropics; but they pass these limits towards the south, as in the case of the Cycadeæ, and are therefore not exclusively confined to them.

In descending the series, the Oolite of Charmouth presents us with the first important indication of the existence of the Pandaneæ, in the genus *Podocarya* of Buckland, established upon a remarkable fruit, the relations of which with the existing Pandaneæ appear, according to M. Brongniart, to prove that this family had already made its appearance at that epoch.

Above the Oolites, towards the Neocomian, I must indicate the true *Araucariæ**, of which I have seen fruits in a perfect state in the collection of M. Hébert, Professor of Geology at the Sorbonne. The character presented by the union of the seed with the base of the ovuliferous scale cannot deceive us, and establishes the presence of the genus, also indicated by numerous impressions of the twigs figured by M. Dunker in his monograph of the Wealden flora of North Germany.

The *Araucariæ* of the section *Eutacta* form now-a-days a perfectly natural subtropical group, confined to New Holland and some of the islands of the Pacific, advancing towards the north but little beyond 15° S. lat., attaining 29° towards the south in Norfolk Island, and capable of becoming adapted to a temperate

* Besides the *Araucariæ*, we must refer to true species of *Pinus*, of which the cones and seeds have lately been indicated in the fluvio-marine beds of the Neocomian stage of the basin of Paris by M. Cornuel, who has described and figured these organs in the 'Bulletin de la Soc. Géolog. de France, 2me sér. tome xxiii. p. 628, pl. 12.

climate, as is proved by the introduction in our southern districts of *A. excelsa*, which, at Hyères and Nice, bears an annual mean of only 15°–16° C. (=59°–60°·8 F.).

Hitherto, therefore, most of the genera, with one exception, that we have met with do not seem to have required a completely tropical temperature—that is to say, above a mean of 20° C. (=68° F.).

In advancing towards the Chalk, we shall observe at first nearly the same types at the base of this great formation; but in proportion as we ascend this curious and still imperfectly known period, the vegetation insensibly acquires a new character. Dicotyledons make their appearance in an incontestable manner; the Cycadeæ, on the contrary, diminish in number and importance; and when, finally, we reach the richer and better investigated floras of the Upper Chalk, we observe a combination of the following genera:—

Ferns: *Gleichenia*, Sm.—*G. protogæa*, Deb. (Aix-la-Chapelle.) *Lygodium*, Sw.—*L. cretaceum*, Deb. (Aix-la-Chapelle.) *Cyatheites*, Göpp.—*Bonaventurea cardinalis*, Deb. (Aix-la-Chapelle.)

Conifers: *Araucaria*, Juss.—*Dammarites albens*, Göpp. (Chalk of Bohemia.) *Araucaria*, sp. Deb. in litt. (Aix-la-Chapelle.) *Sequoia*, Endl.—*Geinitzia cretacea*, Ung. (Quadersandstein.) *Cycadopsis aquigranensis*, Göpp. (Aix-la-Chapelle.)

Palms: *Palmacites*, Sternb.—*P. varians*, Corda. (Quadersandstein.) *Flabellaria*, Sternb.—*F. chamæropifolia*, Göpp. (Silesia.)

Pandaneæ: *Pandanus*, L.—*P. simildæ*, Stiehl. (Quadersandstein.) *P. austriacus*, Ett., *P. pseudo-inermis*, Ett., and *P. trinervis*, Ett. (Chalk of Gosau.) *Nipadites*, Bow.—*Carpolithes provincialis*, Sap. (Fuveau.)

Myriceæ: *Myrica* and *Comptonia*.—*Comptonites antiquus*, Nilsson. (Chalk of Scania.) *Myrica*, sp., Deb. in litt. (Aix-la-Chapelle.)

Proteaceæ: *Anadenia, Leucospermum, Grevillea, Hakea, Dryandra*, &c.—A very great number of species reproducing the characteristic forms of these various genera and of several others. (Chalk of Aix-la-Chapelle.)

In this series the Pandaneæ, and probably the Ferns also, alone betray clearly tropical aptitudes; the other groups advance at the present day to the north and south far beyond these limits; but the presence of the Pandaneæ is an important fact, which must be taken into account, as in the present epoch their species (which are particularly numerous in islands, such as

Madagascar, Bourbon, and the Moluccas, do not in any case quit the intertropical zone. Strictly speaking, some doubt may attach to certain of these determinations considered separately; but the coexistence of such numerous indications can hardly fail to render it nearly certain that true Pandaneæ existed in Europe during the Cretaceous period, and consequently at the same epoch a mean temperature of at least 20° C. (=68° F.).

To give a better notion of the progress and ultimate decline of tropical types in the Tertiary epoch, which I now approach, I shall divide it into eight successive horizons, conceived chiefly from the point of view of the fossil floras. I shall arrange them as follows, proceeding from the lowest to the highest:—

1. The *Suessonian* of D'Orbigny, including Rilly and the lignites and sandstones of the Soissonais.
2. The *Parisian*, properly so called, including the "Calcaire grossier" and the London Clay.
3. The *Upper Eocene* or *Ligurian* of Swiss authors, including the middle freshwater beds of the basin of Paris and the sands of Beauchamp, with beds of *Cyrena semistriata*,—that is to say, the age of *Palæotherium*.
4. The *Tongrian* or *Oligocene*, corresponding to the age of the sandstones of Fontainebleau.
5. The *Lower Miocene*, corresponding to the limestone of La Beauce and the *Aquitanian* of Swiss authors.
6. The *Upper Miocene*, including the Marine Mollasse of Switzerland and Provence, up to and including Œningen.
7. The *Pliocene*, from Œningen to the close of the Tertiary period.
8. The *Quaternary*.

The following is an enumeration of the tropical genera belonging to each of these horizons, starting from the oldest:—

First Horizon: Travertins of Sézanne and sands of the Soissonnais.

Ferns, Cyatheæ: *Alsophila*, Bronn. *Polypodites thelypteroides*, Brong. *Pecopteris Pomelii*, Brong. *Cyatheites*, sp. plurimæ. (Sézanne.)

Palms: *Flabellaria*, Sternb.—*F. Goupili*, Wat., *F. suessionensis*, Wat. (Soissonais sands.)

Pandaneæ: *Carludovica*?, R. & P.—*C.* sp. nov. (Sézanne.)

Ampelideæ: *Cissus*, L. *Vitigene cissoides*, Sap. (Sézanne.)

Sterculiaceæ.—*Sterculia*, L., *S.* sp. nov. (Sézanne.)

The genus *Alsophila* being indicated with certainty for the

first time in Tertiary formations, and even in the fossil state, I dwell upon this determination. This genus, with only a single exception, includes only arborescent species: in this case more especially it denotes a truly tropical type, because the species from Sézanne are closely allied to the most tropical forms of the genus in both hemispheres, whilst they differ from those which advance furthest towards the south, such as *A. pruinata*, Kaulf. (Chili), and *A. australis* (Tasmania).

The repeated presence of palms in the Soissonais sandstones, and that of a frond at Sézanne too conformable to the bifid type of *Carludovica* not to denote the persistence of the type of the Pandaneæ, constitute a combination of tropical forms which is further increased by a *Cissus* formed upon the model of *C. ferruginea*, Poir., *indica*, Roxb., *tomentosa*, Lam., *repens*, Thw., *adnata*, Wall., and *capensis*, Thunb. (all perfectly tropical forms), by a *Sterculia*, several *Tiliaceæ* and *Laurineæ*, &c.

The *second* of our horizons presents, of tropical types,—

Palms: *Flabellaria*, Sternb.—*F. parisiensis*, Brong. (Calcaire grossier.)
Sabalites, Sap.—*S.* sp. (*Flabellaria maxima*, Ung., Brong.). (Oise, Crisolle.)

Pandaneæ: *Nipadites*, Bow.—Several species observed in the London Clay, in Belgium, and in the Calcaire grossier of Paris.

Sapindaceæ: *Cupanioides*, Bow.—Several species in the London Clay.

Tiliaceæ?: *Apeibopsis*, Heer (*Cucumites*, Bow.). London Clay.

The fossil fruits described by Bowerbank under the name of *Nipadites*, and of which that author was able to examine the structure in the pyritous specimens of Sheppey, differ in no important character from those of *Nipa*, a curious genus which seems to form the connexion between the Palms and the Pandaneæ: it is reduced at present to a single species, *Nipa fruticans*, which inhabits the banks of the Ganges and the marshy parts of Java. The *Nipadites*, first observed in the London Clay and afterwards in Belgium, have lately been met with in the Parisian Calcaire grossier. The working of the mound of the Trocadero has enabled a great number of impressions to be collected in a sandy clay bed, in which there are also observed monocotyledonous leaves analogous to those of certain *Carludovicæ*, but entire, which should, perhaps, be combined with these organs.

The *Cupanioides* of the London Clay reveal the existence of

the Sapindaceæ, which we shall meet with again in the succeeding stages; they are there combined with Palms, Leguminosæ, and Tiliaceæ, of which the generic affinities are still obscure, but their physiognomy is that of corresponding plants under the tropics.

On the *third* horizon, which is known by the rich floras of Monte Bolca, Skopan, Alum Bay, the sands of the Sarthe, and, lastly, the gypsums of Aix, we may indicate, among many others, the following genera:—

Coniferæ: *Araucaria,* Juss.—*A. Duchartrei,* Wat. (Middle sands).

Palms: *Flabellaria,* Sternb.—*F. Lamanonis,* Brong. (Gypsum of Aix.) *F. bolcensis,* Mass. (Monte Bolca.)
Sabalites, Sap.—*S.* sp. n. (Sands of the Sarthe.)

Musaceæ: *Musophyllum,* Ung.—*M. speciosum,* Sap. (Gypsum of Aix.)

Liliaceæ: *Dracæna,* L.—*Dracænites sepultus,* Sap., *D. Brongniartii,* Sap. (Gypsum of Aix.)

Ebenaceæ: *Diospyros,* L.—*D. rugosa,* Sap. (Gypsum of Aix.)

Araliaceæ.—*Aralia,* L.—*A. primigenia,* Heer. (Bolca, Alum Bay.) *A. multifida,* Sap. (Gypsum of Aix.)

Sterculiaceæ: *Sterculia,* L.—*S. labrusca,* Ung. (Monte Bolca, Skopan, Alum Bay.) *S. tenuiloba,* Sap. (Gypsum of Aix.)
Bombax, L.—*B. sepultiflorum,* Sap. (Aix.)

Sapindaceæ: *Sapindus,* L.—*Sapindus pristinus,* Heer. (Monte Bolca.)

Juglandeæ: *Engelhardtia,* Lesch.—*E. decora,* Sap. (Gypsum of Aix.)

Papilionaceæ: *Brachypterum,* Benth.—*B.* (*Micropodium*) *oligospermum,* Sap. (Gypsum of Aix.)
Drepanocarpus, C. Mey.—*D. Dechampii,* Mass. (Monte Bolca.)

Mimoseæ: *Mimosa,* Ad.—*M. deperdita,* Sap. (Gypsum of Aix.)

Most of these genera, especially the more important ones, are determined with certainty:—the genus *Bombax* by the observation of the corollas; the *Aralia primigenia* by that of the fruits. The genera *Engelhardtia, Brachypterum,* and *Drepanocarpus* show theirs. *Diospyros rugosa* presents flowers and detached calyces. All these forms (leaving out of consideration those which are not exclusively tropical, such as the Laurineæ, Myrsineæ, Rhamneæ, Anacardiaceæ, &c.) serve to characterize the hottest regions of India, Africa, America, and Australia.

Upon this horizon a true *Araucaria* makes its appearance for

the last time; the original specimen is in the collection of M. Hébert at the Sorbonne. The other *Araucariæ* or *Araucarites* indicated in the Tertiary formation, and especially *A. Sternbergii*, Ung., are in reality *Sequoiæ*.

The following or *fourth* horizon is one of the most perfectly explored; we place here the floras of Hæring, Sotzka, Saint-Zacharie, Saint-Jean-de-Garguier, Armissan, and even that of Radoboj, in Croatia. The last two localities appear to be more recent than the others; but they are united to the former by too many ties to allow of their advantageous separation. The tropical genera which must be indicated in them are the following:—

Ferns: *Lindsæa*, Dryand.—*L. Cussolii*, Gerv. (Armissan.)
Palms: *Sabalites*, Sap.—*S. major*, Ung. (Hæring, Radoboj, basin of Marseilles, Armissan.)
Liliaceæ: *Dracæna*, L.—*D. narbonensis*, Gerv. (Armissan.)
Araliaceæ: *Aralia*, L.—*A. Hercules*, Sap. (Radoboj, Armissan.)
Sterculiaceæ: *Sterculia*, L.—*S. labrusca*, Ung. (Sotzka.)
Juglandeæ: *Engelhardtia*, Lesch.—*E. decora*, Sap. (Saint-Zacharie.) *E. sotzkiana*, Ett. (Sotzka.) *E. macroptera*, Sap., *E. detecta*, Sap. (Armissan, Radoboj.)
Papilionaceæ: *Calpurnia*, E. Mey.—*C. europæa*, Sap. (Armissan.)
Copaifera, L.—*Cæsalpinites copaiferinus*, Sap. (St. Zacharie, St. Jean-de-Garguier.) *Copaifera armissanensis*, Sap. (Armissan.) *C. radobojana*, Ung. (Radoboj.)
Mimoseæ: *Acacia*, Neck.—*A. sotzkiana*, Ung. (Sotzka.) *A. Bousqueti*, Sap. (Armissan.)
Mimosa, Ad.—*M. Pandoræ*, Ung. (Radoboj.)

These types, selected from among many others as the most certainly determined, are also clearly tropical. The genus *Lindsæa*, for example, scarcely possesses any species beyond the tropics; and the species from Armissan is very nearly allied to a Javan form, *L. javensis*, Bl. The *Dracænæ* and Palms continue to give the mass of plants a very strongly marked equatorial physiognomy. The *Araliaceæ* reproduce the forms of the genus *Areopanax* of Central America. The genus *Engelhardtia*, then at its apogee in Europe, does not now quit the limits of tropical Asia, where, however, it ascends a little upon the mountains both in Nepaul and Java. Lastly, the genera *Calpurnia*, *Copaifera*, *Acacia*, and *Mimosa* are directly allied to types or forms now peculiar to intertropical Africa and Brazil.

The *fifth* stage of our series is a continuation of the preceding; the tropical types which we shall indicate in it are derived from the floras of Manosque and Bonnieux in Provence, of Monod, Hohe-Rhonen, and Eriz in Switzerland, of Brognon near Dijon, of Bovey-Tracey in Devonshire, &c.

FERNS : *Lygodium,* Sw.—*L. Gaudini,* Heer. (Monod, Manosque.)
L. acutangulum, Heer, *L. Laharpei,* Heer, *L. acrostichoides,* Heer. (Monod.)
CYCADEÆ : *Zamites,* Brong.—*Z. epibius,* Sap. (Bonnieux.)
PALMS : *Flabellaria,* Sternb.—*F. latiloba,* Heer. (Vevay, Brognon.)
Sabalites, Sap.—*S. major,* Ung., *S. hæringiana,* Heer. (Switzerland.)
PAPILIONACEÆ : *Pterocarpus,* L.—*P. Fischeri,* Gaud. (Monod.)
Brachypterum, Benth.—*B.* (*Micropodium*) *lignitum,* Sap. (Manosque.)
Campsiandra, Benth.—*C.* (*Pycnolobium*) *tetrasperma,* Sap. (Manosque.)
MIMOSEÆ : *Acacia,* Neck.—*A. sotzkiana,* Ung. (Monod, &c.)

We must remark here, in the first place, the persistence of certain types which might have been thought to have been long before extinct. The *Zamites epibius,* collected at Bonnieux by M. E. Arnaud and described by me two years ago, is proved to be perfectly authentic by the finely schistose structure of the lamina, of lacustrine origin, which contains it; but it is hardly to be distinguished from its predecessor, *Zamites Feneonis,* Brong., from the Corallian. As regards the *Lygodia,* which we have previously indicated in the Chalk, and which are frequent in Switzerland, their presence at Manosque at the same epoch is attested by a fine impression; and even beyond this genus the ferns of that period present a great number of forms of tropical physiognomy, the strict determination of which is prevented by the absence or bad state of their fructification. I may cite, as forming part of this category, the *Pecopteris lignitum,* Heer (*Aspidium lignitum,* Gieb.), which occurs in Germany, England (Bovey), Savoy, and Provence (Manosque), the *Pecopteris Lucani,* Sap., from Brognon, the *Lastrea dalmatica,* Ett., from Promina and Switzerland, and, finally, the *Lastrea stiriaca,* which is distributed through a great number of Tertiary localities. All these ferns are evidently analogous to those of the hottest countries of the existing world.

The Leguminosæ also include several well-characterized tropical genera. One of the most remarkable that I am acquainted

with comes from the schists of the valley of Larguer, near Manosque; it consists of a coriaceous fruit of large size, dehiscent, with the valves open and spread out, and the resemblance of which to those of *Campsiandra angustifolia*, Benth. (a scarcely known Brazilian species), is truly surprising. The genus *Brachypterum* reappearing, the Swiss *Pterocarpus Fischeri*, and several *Acaciæ*, besides various Cæsalpinieæ and Dalbergieæ, form a total the tropical physiognomy of which cannot be overlooked.

The *sixth* horizon is principally represented by the rich floras of Parschlug and Œningen. Here the lowering of the temperature begins to be sensible; but we can still indicate the following as tropical types:—

PALMS: *Calamopsis*, Heer.—*C. bredana*, Heer. (Œningen.)
CONVOLVULACEÆ: *Porana*, Burm.—*P. œningensis*, Al. Br., *P. macrantha*, Heer, *P. inæquiloba*, Heer. (Œningen.)
SAPINDACEÆ: *Sapindus*, L.—*S. falcifolius*, Al. Br. (Œningen.)
MIMOSEÆ: *Acacia*, Neck.—*A. œningensis*, Heer. (Œningen.)
A. parschlugiana, Ung. (Parschlug.)
Mimosa, Ad.—*A. palæogæa*, Ung. (Parschlug.)

The tropical element was therefore far from being banished from the middle of Europe at the epoch of Œningen, the temperature of which has been approximately estimated by M. Heer at 18° C. (=64°·4 F.). Nevertheless, starting from this time, the depression must have been rapid and continuous. In fact our *seventh* horizon, corresponding to the Pliocene, and well known by the floras of Gleichenberg in Styria, of Senegaglia and the Val d'Arno in Italy, and of Schlossnitz in Silesia, no longer contains any really tropical types. I can hardly cite the *Oreodaphne Heerii*, Gaud., nearly identical with *O. fœtens* of the islands of Madeira and the Canaries, where the latter species is now isolated, whilst the rest of the genus is American and prefers the tropical regions of that continent.

Moreover, the subtropical types had declined with almost equal rapidity; the laurels, figs, Ebenaceæ, and Myrsineæ had likewise diminished in number and importance. Of these, however, the Pliocene period still presents some examples; but our *eighth* and last, or quaternary horizon, no longer includes any genera but those belonging to the northern temperate zone.

[To be continued.]