CHAPTER XVIII.

Marine formations of the Eocene period—Strata of the Paris basin how far analogous to the lacustrine deposits of Central France—Geographical connexion of the Limagne d'Auvergne and the Paris basin—Chain of lakes in the Eocene period—Classification of groups in the Paris basin—Observations of M. C. Prevost—Sketch of the different subdivisions of the Paris basin—Contemporaneous marine and fresh-water strata—Abundance of Cerithia in the Calcaire grossier—Upper marine formation indicates a subsidence—Part of the Calcaire grossier destroyed when the upper marine strata originated—All the Parisian groups belong to one great epoch—Microscopic shells—Bones of quadrupeds in gypsum—In what manner entombed—Number of species—All extinct—Strata with and without organic remains alternating—Our knowledge of the physical geography, fauna, and flora of the Eocene period considerable—Concluding remarks.

EOCENE FORMATIONS—PARIS BASIN.

THE geologist who has studied the lacustrine formations described in the last chapter cannot enter the tract usually termed 'the Paris Basin' without immediately recognizing a great variety of rocks with which his eye has already become familiar. The green and white marls of Auvergne, Cantal, and Velay, again present themselves, together with limestones and quartzose grits, siliceous and gypseous marls, nodules and layers of flint, and saccharoid gypsum; lastly, in addition to all this identity of mineral character, we find an assemblage of the same species of fossil animals and plants.

When we consider the geographical proximity of the two districts, we are the more prepared to ascribe this correspondence in the mineral composition of these groups to a combination of similar circumstances in the same era. From the map (No. 56, p. 226) in the last chapter, it will be seen that the united waters of the Allier and Loire, after descending from the valleys occupied by the fresh-water formations of Central France, flow on till they reach the southern extremity of what is called the Paris basin. M. Omalius d'Halloy long ago suggested the very natural idea that there existed formerly a chain of lakes, reaching from the highest part of the central mountain-group of France, and terminating in the basin of Paris, which he supposes was at that time an arm of the sea.

Notwithstanding the great changes which the physical geography of that part of France must since have undergone, we may easily conceive that many of the principal features in the configuration of the country may have remained unchanged, or but slightly modified. Hills of volcanic matter have indeed been formed since the Eocene formations were accumulated, and the levels of large tracts have been altered in relation to the sea; lakes have been drained, and a gulf of the sea turned into dry land, but many of the reciprocal relations of the different parts of the surface may still remain the same. The waters which flowed from the granitic heights into the Eocene lakes may now descend in the same manner into valleys once the basins of those lakes. Let us, for example, suppose the great Canadian lakes, and the gulf into which their waters are discharged, to be elevated and laid dry by subterranean movements. The whole hydrographical basin of the St. Lawrence might be upraised during these convulsions, yet that river might continue, after so extraordinary a revolution, to drain the same elevated regions, and might continue to convey its waters in the same direction from the interior of the continent to the Atlantic. Instead of traversing the lakes, it would hold its course through deposits of lacustrine sand and shelly marl, such as we know to be now forming in Lakes Superior and Erie; and these fresh-water strata would occupy the site and bear testimony to the pristine existence of the lakes. Marine strata might also be brought into view in the space where an inlet of the sea, like the estuary of the St. Lawrence, had once received the continental waters; and in such formations we might discover shells of lacustrine and fluviatile species intermingled with marine testacea and zoophytes.

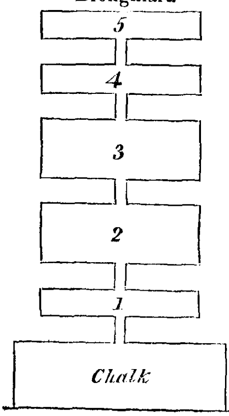
Subdivisions of strata in the Paris basin.—The area which has been called the Paris basin is about one hundred and eighty miles in its greatest length from north-east to south-west, and about ninety miles from east to west. This space may be described as a depression in the chalk (see diagram No. 2, p. 16), which has been filled up by alternating groups of marine and fresh-water strata. MM. Cuvier and Brongniart attempted in 1811 to distinguish five different formations, and to arrange them in the following order, beginning with the lowest:—

1. First fresh-water formation....	Plastic clay. Lignite. First sandstone.
2. First marine formation	Calcaire grossier.
3. Second fresh-water formation ..	Siliceous limestone. Gypsum, with bones of animals. Fresh-water marls.
4. Second marine formation......	Gypseous marine marls. Upper marine sands and sandstones. Upper marine marls and limestones.
5. Third fresh-water formation.	Siliceous millstone, without shells. Siliceous millstone, with shells. Upper fresh-water marls.

These formations were supposed to have been deposited in succession upon the chalk; and it was imagined that the waters of the ocean had been by turns admitted into and excluded from the same region. But the subsequent investigations of

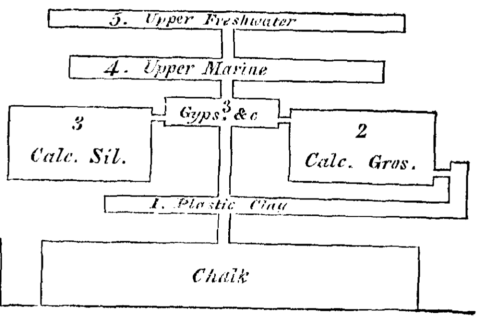
No. 58.

M. Alex. Brongniart.



No. 59.

M. Constant Prevost.



several geologists, especially of M. Constant Prevost *, have led to great modifications in the theoretical views entertained respecting the order in which the several groups were formed; and it now appears that the formations Nos. 1, 2, and 3, of the table of MM. Cuvier and Brongniart, instead of having originated one after the other, are divisible into four nearly contemporaneous groups.

Superposition of different formations in the Paris basin.—A comparison of the two accompanying diagrams will enable the reader to comprehend at a glance the different relations which the several sets of strata bear to each other, according to the original, as well as the more modern classification. We shall now proceed to lay before the reader a brief sketch of the several sets of strata referred to in the above systems.

Immediately upon the chalk a layer of broken chalk flints, often cemented into a breccia by siliceous sand, is very commonly found. These flints probably indicate the action of the sea upon reefs of chalk when a portion of that rock had emerged and before the regular tertiary beds were superimposed. To this partial layer no reference is made in the annexed sections.

Plastic clay and sand.—Upon this flinty stratum, or, if it be wanting, upon the chalk itself, rests frequently a deposit of clay and lignite (No. 1 of the above tables). It is composed of fresh-water shells and drift-wood, and was, at first, regarded as a proof that the Paris basin had originally been filled with fresh water. But it has since been shown that this group is not only of very partial extent, but is by no means restricted to a fixed place in the series; for it alternates with the marine calcaire grossier (No. 2 of the tables), and is repeated in the very middle of that limestone at Veaugirard, Bagneux, and other places, where the same Planorbes, Paludinæ, and Limnei occur †. M. Desnoyers pointed out to me a section in the suburbs of Paris, laid open in 1829, where a similar intercalation was seen in a still higher part of the calcaire grossier.

* Bulletin des Sci. de la Soc. Philom., May, 1825, p. 74.

† Prevost, Sur les Submersions Itératives, &c. Mem. de la Soc. d'Hist. Nat. de Paris, tome iv. p. 74.

These observations relieve us from the difficulty of seeking a cause why vegetable matter, and certain species of fresh-water shells and a particular kind of clay, was first introduced into the basin, and why the same space was subsequently usurped by the sea. A minute examination of the phenomena leads us simply to infer, that a river charged with argillaceous sediment entered a bay of the sea and drifted down, from time to time, fresh-water shells and wood.

Calcaire grossier.—The calcaire grossier above alluded to, is composed of a coarse limestone, often passing into sand, such as may perhaps have been derived from the aqueous degradation of a chalk country. It contains by far the greater number of the fossil shells which characterize the Paris basin. No less than 400 distinct species have been derived from a single locality near Grignon. They are imbedded in a calcareous sand, chiefly formed of comminuted shells, in which, nevertheless, individuals in a perfect state of preservation, both of marine, terrestrial, and fresh-water species, are mingled together, and were evidently transported from a distance. Some of the marine shells may have lived on the spot, but the Cyclostoma and Limnea must have been brought there by rivers and currents, and the quantity of triturated shells implies considerable movement in the waters.

Nothing is more remarkable in this assemblage of fossil testacea than the astonishing proportion of species referrible to the genus Cerithium *. There occur no less than 137 species of this genus in the Paris basin, and almost all of them in the calcaire grossier. Now the living testacea of this genus inhabit the sea near the mouths of rivers, where the waters are brackish, so that their abundance in the marine strata of the Paris basin is in perfect harmony with the hypothesis before advanced, that a river flowed into the gulf, and gave rise to the beds of clay and lignite before mentioned. But there are ample data for inferring that the gulf was supplied with fresh water by more than one river, for while the calcaire grossier occupies the northern

* See the tables of M. Deshayes, Appendix I., p. 26.

part of the Paris basin, another contemporaneous deposit, of fresh-water origin, appears at the southern extremity.

Calcaire siliceux.—This group (No. 3 of the foregoing tables) is a compact siliceous limestone, which resembles a precipitate from the waters of mineral springs. It is, for the most part, devoid of organic remains, but in some places it contains fresh-water and land species, and never any marine fossils. The siliceous limestone and the calcaire grossier occupy distinct parts of the basin, the one attaining its fullest development in those places where the other is of slight thickness. They also alternate with each other towards the centre of the basin, as at Sergy and Osny, and there are even points where the two rocks are so blended together, that portions of each may be seen in hand specimens. Thus in the same bed, at Triel, we have the compact fresh-water limestone, characterized by its Limnei, mingled with the coarse marine limestone through which the small multilocular shell, called milliolite, is dispersed in countless numbers. These microscopic testacea are also accompanied by Cerithia and other shells of the calcaire grossier. It is very extraordinary that, although in this instance both kinds of sediment must have been thrown down together on the same spot, each still contains its own peculiar organic remains*.

These facts lead irresistibly to the conclusion, that while to the north, where the bay was probably open to the sea, a marine limestone was formed, another deposit of fresh-water origin was introduced to the southward, or at the head of the bay. For it appears that during the Eocene period, as now, the ocean was to the north, and the continent, where the great lakes existed, to the south. From the latter region we may suppose a body of fresh water to have descended charged with carbonate of lime and silica, the water being perhaps in sufficient volume to convert the upper end of the bay into fresh water, like some of the gulfs of the Baltic.

Gypsum and marls.—The next group to be considered is

* M. Prevost has pointed out this limestone to me, both in situ at Triel, and in hand specimens in his cabinet.

the gypsum, and the white and green marls, subdivisions of No. 3 of the table of Cuvier and Brongniart. These were once supposed to be entirely subsequent in origin to the two groups already considered; but M. Prevost has pointed out that in some localities they alternate repeatedly with the calcaire siliceux, and in others with some of the upper members of the calcaire grossier. The gypsum, with its associated marls and limestone, is in greatest force towards the centre of the basin, where the two groups before mentioned are less fully developed; and M. Prevost infers, that while those two principal deposits were gradually in progress, the one towards the north, and the other towards the south, a river descending from the east may have brought down the gypseous and marly sediment.

It must be admitted, as highly probable, that a bay or narrow sea, 180 miles in length, would receive, at more points than one, the waters of the adjoining continent; at the same time we must observe, that if the gypsum and associated green and white marls of Montmartre were derived from an hydrographical basin distinct from that of the southern chain of lakes before adverted to, this basin must nevertheless have been placed under circumstances extremely similar; for the identity of the rocks of Velay and Auvergne with the fresh-water group of Montmartre, is such as can scarcely be appreciated by geologists who have not carefully examined the structure of both these countries.

Some of our readers may think that the view above given of the arrangement of four different sets of strata in the Paris basin is far more obscure and complicated than that first presented to them in the system of MM. Cuvier and Brongniart. We admit that the relations of the several sets of strata are less simple than the first observers supposed, being much more analogous to those exhibited by the lacustrine groups of Central France before described.

The simultaneous deposition of two or more groups of strata in one basin, some of them fresh-water and others marine, must always produce very complex results; but in proportion as it is more difficult in these cases to discover any fixed order of superposition in the associated mineral masses, so also is it more easy to explain the manner of their origin and to reconcile their relations to the agency of known causes. Instead of the successive irruptions and retreats of the sea, and changes in the chemical nature of the fluid and other speculations of the earlier geologists, we are now simply called upon to imagine a gulf, into one extremity of which the sea entered, and at the other a large river, while other streams may have flowed in at different points, whereby an indefinite number of alternations of marine and fresh-water beds were occasioned.

Second or Upper marine group.—The next group, called the second or Upper marine formation (No. 4 of the tables), consists in its lower division of green marls which alternate with the fresh-water beds of gypsum and marl last described. Above this division the products of the sea exclusively predominate, the beds being chiefly formed of micaceous sand, 80 feet or more in thickness, surmounted by beds of sandstone with scarcely any limestone. The summits of a great many platforms and hills in the Paris basin consist of this upper marine series, but the group is much more limited in extent than the calcaire grossier. Although we fully agree with M. C. Prevost that the alternation of the various marine and fresh-water formations before described admit of a satisfactory explanation without supposing different retreats and subsequent returns of the sea, yet we think a subsidence of the soil may best account for the position of the upper marine sands. Oscillations of level may have occurred whereby for a time the sea and a river prevailed each in their turn, until at length a more considerable sinking down of part of the basin took place, whereby a tract previously occupied by fresh water was converted into a sea of moderate depth.

In one part of the Paris basin there are decisive proofs that during the Eocene period, and before the upper marine sand was formed, parts of the calcaire grossier were exposed to the action of denuding causes. At Valmondois, for example, a deposit of the upper marine sandstone is found *, in which rolled blocks of the calcaire grossier with its peculiar fossils, and fragments of a limestone resembling the calcaire siliceux, occur. These calcareous blocks are rolled and pierced by perforating shells belonging to no less than fifteen distinct species, and they are imbedded, as well as worn shells washed out from the calcaire grossier, with the ordinary fossils of the upper marine sand.

We have seen that the same earthquake in Cutch could raise one part of the delta of the Indus and depress another, and cause the river to cut a passage through the upraised strata and carry down the materials removed from the new channel into the sea. All these changes, therefore, might happen within a short interval of time between the deposition of two sets of strata in the same delta †.

It is not improbable, then, that the same convulsions which caused one part of the Paris basin to sink down so as to let in the sea upon the area previously covered by gypsum and fresh-water marl, may have lifted up the calcaire grossier and the siliceous limestone, so that they might be acted upon by the waves, and fragments of them swept down into the contiguous sea, there to be drilled by boring testacea.

It is observed that the older marine formation at Laon is now raised 300 metres above the sea, whereas the upper marine sands never attain half that elevation. Such may possibly have been the relative altitude of the two groups when the newest of them was deposited.

Third fresh-water formation.—We have still to consider another formation, the third fresh-water group (No. 5 of the preceding tables). It consists of marls interstratified with beds of flint and layers of flinty nodules. One set of siliceous layers is destitute of organic remains, the other replete with them.

* M. Deshayes, Memoires de la Soc. d'Hist. Nat. de Paris, tom. i. p. 243.—The sandstone is called, by mistake, gres marin *inferieur*, instead of *superieur*, to which last the author has since ascertained it to belong.

† Vol. i. 2d Edit. chap. xxiii.; vol. ii. 1st Edit. chap. xvi.

Gyrogonites, or fossil seed-vessels of charæ, are found abundantly in these strata, and all the animal and vegetable remains agree well with the hypothesis, that after the gulf or estuary had been silted up with the sand of the upper marine formation, a great number of marshes and shallow lakes existed, like those which frequently overspread the newest parts of a delta. These lakes were fed by rivers or springs which contained, in chemical solution or mechanical suspension, such kinds of sediment as we have already seen to have been deposited in the lakes of Central France during the Eocene period.

The Parisian groups all Eocene.—Having now given a rapid sketch of the different groups of the Paris basin, we may observe generally that they all belong to the Eocene epoch, although the entire series must doubtless have required an immense lapse of ages for its accumulation. The shells of the different fresh-water groups, constituting at once some of the lowest and uppermost members of the series, are nearly all referrible to the same species, and the discordance between the marine testacea of the calcaire grossier and the upper marine sands is very inconsiderable.

A curious observation has been made by M. Deshayes, in reference to the changes which one species, the *Cardium porulosum,* has undergone during the long period of its existence in the Paris basin. Different varieties of this cardium are characteristic of different strata. In the oldest sand of the Soissonnais (a marine formation underlying the regular beds of the calcaire grossier), this shell acquires but a small volume, and has many peculiarities which disappear in the lowest beds of the calcaire grossier. In these the shell attains its full size, and many peculiarities of form, which are again modified in the uppermost beds of the calcaire grossier, and these last characters are preserved throughout the whole of the 'upper marine' series *.

Microscopic shells.—In some parts of the calcaire grossier microscopic shells are very abundant, and of distinct species

* Coquilles characterist. des Terrains, 1831.

from those before mentioned of the older Pliocene beds of Italy. We may remind those readers who are not familiar with these minute fossil bodies, that they belong to the order *Cephalopoda*, the animals of which are most free in their movements, and most advanced in their organization, of all the mollusca. The multilocular cephalopods have been separated, by d'Orbigny, into two subdivisions: first, those having a syphon or internal tube connecting the different chambers, such as the nautilus and ammonite; and, secondly, those without a syphon, to which the microscopic species now under consideration belong. They are often in an excellent state of preservation, and their forms are singularly different from those of the larger testacea. We have given a plate of some of these, from unpublished drawings by M. Deshayes, who has carefully selected the most remarkable types of form.

The *natural size* of each species figured in plate 4, is indicated by minute points, to which we call the reader's attention, as they might be easily overlooked.

Bones of quadrupeds in gypsum.—We have already considered the position of the gypsum which occurs in the form of a saccharoid rock in the hill of Montmartre at Paris, and other central parts of the basin. At the base of that hill it is seen distinctly to alternate with soft marly beds of the calcaire grossier, in which cerithia and other marine shells occur. But the great mass of gypsum may be considered as a purely fresh-water deposit, containing land and fluviatile shells, together with fragments of palm-wood, and great numbers of skeletons of quadrupeds and birds, an assemblage of organic remains which has given great celebrity to the Paris basin. The bones of fresh-water fish, also, and of crocodiles, and many land and fluviatile reptiles occur in this rock. The skeletons of mammalia are usually isolated, often entire, the most delicate extremities being preserved as if the carcasses clothed with their flesh and skin had been floated down soon after death, and while they were still swoln by the gases generated by their first decomposition. The few accompanying shells are of those light kinds which frequently float on the surface of rivers together with wood.

M. Prevost has, therefore, suggested that a river may have swept away the bodies of animals, and the plants which lived on its borders, or in the lakes which it traversed, and may have carried them down into the centre of the gulf into which flowed the waters impregnated with sulphate of lime. We know that the Fiume Salso in Sicily enters the sea so charged with various salts that the thirsty cattle refuse to drink of it. A stream of sulphureous water, as white as milk, descends into the sea from the volcanic mountain of Idienne, on the east of Java; and a great body of hot water, charged with sulphuric acid, rushed down from the same on one occasion, and inundated a large tract of country, destroying, by its noxious properties, all the vegetation *. In like manner the Pusanibio, or 'Vinegar river' of Colombia, which rises at the foot of Puracé, an extinct volcano 7500 feet above the level of the sea, is strongly impregnated with sulphuric and muriatic acid, and with oxide of iron. We may easily suppose the waters of such streams to have properties noxious to marine animals, and in this manner we may explain the entire absence of marine remains in the ossifferous gypsum †.

There are no pebbles or coarse sand in the gypsum, a circumstance which agrees well with the hypothesis that these beds were precipitated from water holding sulphate of lime in solution, and floating the remains of different animals. The bones of land quadrupeds however are not confined entirely to the fresh-water formation to which the gypsum belongs, for the remains of a Palæotherium, together with some fresh-water shells have been found in a marine stratum belonging to the calcaire grossier at Beauchamp.

In the gypsum the remains of about fifty species of quadrupeds have been found all extinct and nearly four-fifths

* Leyde Magaz. voor Wetensch Konst en Lett., partie v. cahier i. p. 71. Cited by Rozet, Journ. de Geologie, tom. i. p. 43.

† M. C. Prevost, Submersions Itératives, &c. Note 23.

of them belonging to a division of the order Pachydermata, which is now only represented by four living species, namely by three tapirs and the daman of the Cape. A few carnivorous animals are associated, among which are a species of fox and gennet. Of the Rodentia, a dormouse and a squirrel; of the Insectivora, a bat; and of the Marsupialia, (an order now confined to America, Australia, and some contiguous islands,) an opossum, have been discovered.

Of birds about ten species have been ascertained, the skeletons of some of which are entire. None of them are referrible to existing species *. The same remark applies to the fish, according to MM. Cuvier and Agassiz, as also to the reptiles. Among the last are crocodiles and tortoises of the genera Emys and Trionix.

The tribe of land quadrupeds most abundant in this formation is such as now inhabits alluvial plains and marshes and the banks of rivers and lakes, a class most exposed to suffer by river inundations. Whether the disproportion of carnivorous animals can be ascribed to this cause, or whether they were comparatively small in number and dimensions, as in the indigenous fauna of Australia, when first known to Europeans, is a point on which it would be rash perhaps to offer an opinion in the present state of our knowledge.

We have no reason to be surprised that all the species of vertebrated animals hitherto observed are extinct, when we recollect that out of 1122 species of fossil testacea obtained from the Paris basin, 38 only can be identified with species now living. We have more than once adverted to the fact that extinct mammalia are often found associated with assemblages of *recent* shells, a fact from which we have inferred the inferior duration of species in mammalia as compared to the testacea; and it is not improbable that the higher order of animals in general may more readily become extinct than the marine molluscs. Some of the thirty-eight species of testacea above alluded to, as having survived from the Eocene period to our own times, have now a

* Cuvier, Oss. Foss. tom. iii. p. 255.

wide geographical range, as, for example, *Lucina divaricata*, and are therefore fitted to exist under a great variety of circumstances. On the other hand, the great proportion of the Eocene marine testacea which have become extinct sufficiently demonstrates that the loss of species has been due to general laws, and that a sudden catastrophe, such as the invasion of a whole continent by the sea—a cause which could only annihilate the terrestrial and fresh-water tribes, is an hypothesis wholly inadequate to account for the phenomenon.

Strata with and without organic remains alternating.—Between the gypsum of the Paris basin and the upper marine sands a thin bed of oysters is found, which is spread over a remarkably wide area. From the manner in which they lie, it is inferred that they did not grow on the spot, but that some current swept them away from a bed of oysters formed in some other part of the bay. The strata of sand which immediately repose on the oyster-bed are quite destitute of organic remains; and nothing is more common in the Paris basin and in other formations, than alternations of shelly beds with others entirely devoid of them. The temporary extinction and renewal of animal life at successive periods have been inferred from such phenomena, which may nevertheless be explained, as M. Prevost justly remarks, without appealing to any such extraordinary revolutions in the state of the animate creation. A current one day scoops out a channel in a bed of shelly sand and mud, and the next day, by a slight alteration of its course, ceases to prey upon the same bank. It may then become charged with sand unmixed with shells, derived from some dune, or brought down by a river. In the course of ages an indefinite number of transitions from shelly strata to those without shells may thus be caused.

Concluding remarks.—It will be seen by our observations on Auvergne and other parts of Central France, and on the district round Paris, that geologists have already gained a considerable insight into the state of the physical geography of part of Europe during the Eocene period. We can point to some districts where lakes and rivers then existed, and to the site of some of the lands encircling those lakes, and to the position of a great bay of the sea, into which their surplus waters were discharged. We can also show, as we shall endeavour to explain in the next chapter, the points where some volcanic eruptions took place. We have acquired much information respecting the quadrupeds which inhabited the land at that period, and concerning the reptiles, fishes, and testacea which swarmed in the waters of lakes and rivers; and we have a collection of the marine Eocene shells more complete than has yet been obtained from any existing sea of equal extent in Europe. Nor are the contemporary fossil plants altogether unknown to us, which, like the animals, are of extinct species, and indicate a warmer climate than that now prevailing in the same latitudes.

When we reflect on the tranquil state of the earth implied by some of the lacustrine and marine deposits of this age, and consider the fullness of all the different classes of the animal kingdom, as deduced from the study of the fossil remains, we are naturally led to conclude, that the earth was at that period in a perfectly settled state, and already fitted for the habitation of man.

The heat of European latitudes during the Eocene period does not seem to have been superior if equal to that now experienced between the tropics; some *living* species of molluscous animals both of the land, the lake, and the sea, existed when the strata of the Paris basin were formed, and the contrast in the organization of the various tribes of Eocene animals when compared to those now co-existing with man, although striking, is not, perhaps, so great as between the living Australian and European types. At the same time we are fully aware that we cannot reason with any confidence on the capability of our own or any other contemporary species to exist under circumstances so different as those which might be caused by an entirely new distribution of land and sea; and we know that in the earlier tertiary periods the physical geography of the northern hemisphere was very distinct. Our inability to account for the atmospheric and other latent causes, which often give rise to the most destructive epidemics, proves the extent of our ignorance of the entire assemblage of conditions requisite for the existence of any one species on the globe.