that an extensive series of fossiliferous deposits may have once existed, whose record of the earlier stages of the history of life upon the earth has been either destroyed by denudation or obliterated by internal heat. This being the case, we must carefully distinguish between positive and negative evidence; and we may also fairly apply such principles as can be established by means of the fuller record afforded by the Tertiary deposits, to interpret the more scanty and fragmentary record with which we have to deal in the older rocks. We will now proceed to sketch very briefly the successive stages of the development of animal life as indicated by the materials at our command.

The lowest and most ancient of all the stratified rocks is the Laurentian, consisting of crystalline beds of gneiss, mica-schist, quartzite, and limestone, reaching in Canada the aggregate thickness of 30,000 feet. The whole mass was long thought to be destitute of organic remains, till in one of the beds of limestone in the lower part of the series a curious structure was discovered, which is held by Dr Carpenter and Professor Rupert Jones, who have made a special study of the Foraminifera, to be the fossilized remains of one of that group of the Protozoa. It has been named *Eozoon canadense*, and if really organic (which is denied by some naturalists of eminence) is by far the oldest trace of animal life. The Upper Laurentian deposits, 10,000 feet thick, lie unconformably on the lower, and seem to be entirely destitute of fossils.

The next formation is the Cambrian, largely developed in Wales, Scandinavia, Bohemia, and North America, and consisting of a variety of distinct deposits. But in the very lowest of these (the Longmynd group) abundant organic remains have recently been found, comprising perfectly developed brachiopodous and pteropodous Mollusca, entomostracous Crustacea, and Trilobites. In the overlying beds of the same formation similar forms abound, and are accompanied by sponges, annelids, graptolites (which are supposed to be peculiar extinct Hydrozoa), starfishes, and encrinites. Here also first appear lamellibranchiate Mollusca, belonging to the families *Arcadæ*, *Nuculidæ*, and *Atlantidæ*, and there are even some *Orthoceratidæ*, belonging to the highest order of molluscs—Cephalopoda. The Trilobites are already wonderfully varied, the smallest and largest kinds being found here (one 2 feet long), species with the least and with the greatest number of rings, blind Trilobites, and others with the most largely developed eyes. (Lyell's *Students' Elements of Geology*, pp. 483, 485, 634.)

We next come to the Silurian formation, in which we first meet with corals, of the three great divisions Rugosa, Tabulata, and Perforata,—ostracode Crustaceans, Trilobites in enormous variety, Merostomata—extinct Crustaceans of gigantic size, Echinoidea (*Palæchinus*), and true gasteropodous Mollusca. And lastly, in the Upper Silurian deposits, we find vertebrates, whose first representatives are several genera of fishes belonging to the Ganoid and Plagiostomous groups.

In the succeeding Devonian formation we find an abundance of new families of fishes, a fresh-water mussel of the living genus *Anodon*, and no less than six forms of winged insects. These have been found in the Devonian rocks of New Brunswick, and are considered by Mr Scudder to be ancient forms of Neuroptera.

The Carboniferous formation is very rich in animal as well as vegetable remains; and, along with most of the animals already met with, we find several higher types of great interest. The higher macrurous Crustacea (*Anthrapalæmon*) are here first met with, as are true air-breathing molluscs, numerous specimens of the living genera, *Pupa* and *Zonites*, having been found in the coal-fields of Nova Scotia. Along with these are insects of various orders—Myriapoda, scorpions, spiders, Orthoptera, Neuroptera, Coleoptera, and even Lepidoptera. Here, too, we meet with air-breathing vertebrates—the Labyrinthodonts, ancient forms of Amphibia which occur in considerable abundance and variety. (Lyell's *Students' Elements*, p. 408; *Annales de la Société Entomologique de Belgique*, 1875, tom xviii., where a wing from the coal-measures, closely resembling those of moths belonging to the family *Saturniidæ*, is photographed.)

In the Permian formation, which closes the series of Palæozoic rocks, we have the important addition of true Lacertian reptiles (*Protorosaurus*), which, according to Professor Huxley, differ wonderfully little from some living groups. What are supposed to be Chelonian footprints have been discovered in the Permian sandstones of Dumfriesshire. (Huxley's *American Addresses*, p. 41.)

Entering the Secondary period with the Triassic formation, we at once meet with higher forms of life. Among Crustacea we first find traces of the brachyurous division of Decapods (Etheridge, in Lyell's *Students' Elements*, p. 632) and many new forms of Mollusca. Among reptiles the Dinosauria, Dicynodontia, Plesiosauria, and Crocodilia appear; what seem to be undoubted footprints of birds have been found in the New Red Sandstone of Connecticut (see figures in Lyell's *Students' Elements*, p. 371, and Nicholson's *Palæontology*, p. 389); and all improbability of this early appearance of birds is removed by the fact that a little higher in the same formation remains of a true Mammalian have been undoubtedly discovered. This is the *Microlestes*, founded on well-preserved teeth from a bone bed in the Upper Trias of Würtemberg, and since found also in the Rhætic beds of Somersetshire; while in rocks supposed to be of the same age in North Carolina the lower jaw of an allied form (*Dromatherium*) has been obtained. Both are believed to be Marsupials, and most nearly allied to the *Myrmecobius* of Australia.

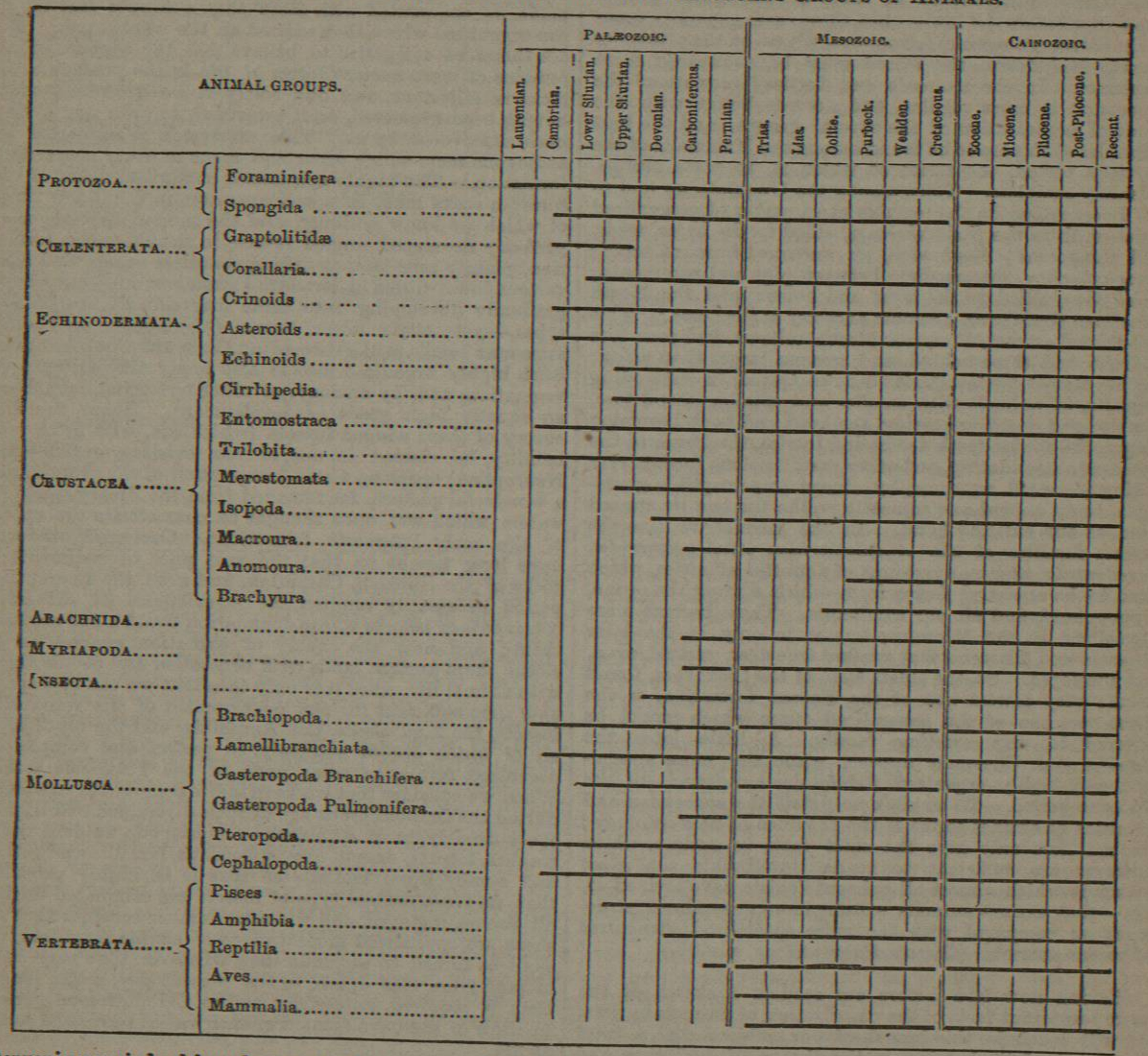
In the Jurassic or Oolitic period, the main forms of life which have already appeared are further developed. Insects of all orders are found, and they can mostly be classed in existing families and even genera, as—*Locusta*, *Nepa*, *Sphinx*, *Termes*, *Ephemera*, *Agrion*, *Æshna*, *Agrion*, *Prionus*, *Libellula*. (Rev. P. B. Brodie, in *Proc. Warwickshire Nat. Hist. Soc.*, 1873.) Among reptiles, *Chelonia* and *Ichthyosauria* are added. Of birds we have the long-tailed and feathered *Archæopteryx*; while no less than eight genera of small Mammalia have been discovered, most of them Marsupials, though some may have been ancestral forms of Insectivora. Many living genera of shells, both marine and fresh-water, first appear; and among fishes, true sharks of the existing family *Notidanidæ*.

In the Cretaceous period, we make a still further approach to living forms. The highest Crustacea (Brachyura) are tolerably abundant, and the living genus *Cancer* appears. Mollusca (Lamellibranchiata and Gasteropoda) are represented by a number of living genera. Malacopterous fishes now appear. Reptiles are still mostly of extinct types — Pterosauria, Ichthyosauria, Dinosauria, &c.; but among birds we find some allied to existing waders, as well as the curious extinct group of Odontornithes, or toothed birds. (Marsh, in *American Jour. of Science and Arts*, vol. x. 1875.)

When we pass over the great asm of time which separates the Mesozoic from the Cainozoic or Tertiary period, we at once come upon a host of new forms closely resembling those which now live upon the earth. The majority of living genera of Mollusca now appear, with a gradually increasing proportion of living species, as we pass from the Eocene to Miocene and Pliocene times; the highest forms of Crustacea are plentiful; Insecta of all orders, and almost all of living genera, abound; fishes of

living genera gradually appear, and true snakes (*Ophidia*) are first met with. Among birds, all the existing orders, many families, and some living genera appear in the Miocene period. Mammalia, however, exhibit the most surprising advance. Ancestral forms of all the existing orders are found in the Eocene formation; in the Miocene, most living families are well developed; while in the Pliocene and post-Pliocene deposits we find the genera and species for the most part closely resembling those that still inhabit the earth. The following diagrammatic table will enable the reader better to comprehend the main facts which we have here endeavoured to set forth. It comprises only the larger or more important groups of animals, and of each of these the known range in time is indicated by a thick line. It has not been attempted to show the breaks which occur in our knowledge of the range of a group, since no one now doubts that where any type appears in two remote periods it must have been in existence during the whole intervening period, although we may have no record of it. Neither has it been attempted to indicate the abundance or scarcity of the group in each period, this being a detail suited only to a special treatment of science of palæontology. It must also be remembered that it is often impossible for us to determine whether the increased prevalence of fossil remains of a particular group is due to a really greater development of the animals, or only to more favourable conditions for their preservation and discovery.

TABLE SHOWING THE RANGE IN TIME OF THE MORE IMPORTANT GROUPS OF ANIMALS.



On considering the successive phases of animal life presented to us by the fossil remains preserved in the rocks, we cannot help perceiving that there has been on the whole a steady advance in organization and an increase in variety and complexity, from the earliest geological periods to the present day. Thus the oldest known fossil belongs to the lowest type of animal life—the Protozoa. Then we have the lower forms of Molluscs,—Brachiopoda and Pteropoda—followed by the Cephalopoda and Gasteropoda.

The Entomostraca, Trilobites, and Phyllopods, come before the higher Decapod Crustacea, and of these the highest form—the Brachyura—appears much the latest. Again, all the aquatic classes of invertebrates appear in abundance before the earliest of the aquatic vertebrates—fishes—make their appearance. These are followed by Amphibia, and later still by true reptiles. The more highly organized birds and mammals appear later and almost simultaneously.

There are, it is true, many anomalies, the higher and more complex organisms in some of the minor groups appearing before the lower; but these cases generally occur in the oldest (Palæozoic) formations, where, on the principles already laid down, the record must be necessarily more imperfect. In the Mesozoic and Tertiary formations the succession is more regular, and accords better with the grade of organization of the several groups, and the best examples of this are to be found among the Mammalia of the Tertiary period, the series of which is, in some groups, tolerably complete. Thus, among the Ungulata we find in the Eocene deposits the remains of a number of generalized types, such as the *Palæotherium*, allied to the horse, tapir, and rhinoceros, *Lophiodon*, an ancestral form of tapir; *Anoplotherium*, intermediate between pigs and ruminants; *Pliolophus*, allied to the tapir and horse; and the North American *Orohippus*, a remote ancestor of the horse.[1] This last-named animal, Professor Marsh tells us, had four toes in front and three behind, and was no larger than a fox; yet an almost perfect series can be traced, in succeeding deposits, of animals with smaller and smaller lateral toes, the size and speed increasing, the head and neck becoming longer, the canine teeth decreasing in size, the bones of the fore-arm consolidating, and other modifications successively taking place till we come, by almost imperceptible gradations, to an animal so completely unlike the one we started from as our existing horse. In like manner we have the extinct families of the *Anoplotheridæ*, *Anthracotheridæ*, *Oreodontidæ*, and many groups of doubtful affinities, which seem to be ancestral forms from which sprung the swine, hippopotami, and all our ruminants. These become more specialized in the Miocene; but it is only in the later Miocene and Pliocene that we find true deer, camels, oxen, and antelopes. So, the oldest form of the Carnivora, found in the very lowest bed of the Eocene formation, is the *Arctocyon*, one of the generalized types which cannot be referred to any existing family. A little later the *Canidæ* and *Viverridæ* appear, while the more specialized and highly organized *Felidæ* are not found till the Miocene period. To exhibit in detail the succession and affinities of extinct forms is the province of palæontology; we can here only give the chief facts in outline, which however are sufficient to render intelligible the great principle which almost all palæontologists have arrived at, viz.—that extinct animals exhibit more generalized structures, as compared with the more specialized structures of recent animals. (Owen's *Palæontology*, p. 406.)

Having now laid before our readers a sketch of the more important facts of the distribution of animals in time, we will conclude this branch of our subject with a brief discussion of its bearing on the theory of evolution, and on the imperfection of the geological record. The abruptness with which animal remains in considerable variety first appear in very ancient deposits is undoubtedly a most remarkable phenomenon. With the exception of the still somewhat doubtful *Eozoon*, the vast series of Laurentian rocks have produced no fossils. But the moment we enter the Cambrian formation we at once have with a somewhat extensive series of complex and varied organisms. Besides the Brachiopoda we have Pteropoda, a by no means low form of Mollusca; while the Trilobites and Phyllopods exhibit a considerable amount of specialization. Almost as early, we have sponges, annelids, star-fishes, encrinites, lamellibranchiates, and Orthoceratidæ,—a variety of divergent and complex types, which, on any theory of development, indicates a very long successsion of ancestral forms. But we must also bear in mind that the few fossiliferous deposits of this early age cannot possibly have made us acquainted with more than a minute fraction of the organisms which then existed on the whole earth. We are therefore compelled to believe that the absence of all remains of more ancient forms of life in the pre-Cambrian rocks is fallacious, and due solely to no record of them having been preserved, or, if preserved, to their not having been discovered by us. This conclusion is supported by analogous facts which occur and recur in every succeeding formation. The highly specialized corals and fishes of the Silurian rocks must have had ancestors in Cambrian times of which we know nothing; and the sudden appearance of perfectly developed winged insects in the Devonian formation, plainly tells us that during countless unrecorded ages various lower forms of terrestrial Annulosa must have been gradually developing into these marvellously specialized types,—yet these lower forms (Myriapods, &c.) only appear as fossils in the succeeding Carboniferous formation. Such highly organized insects also imply the existence of vegetation, and, by analogy, of other terrestrial animals of an equally high grade of development. Hence the discovery of these winged insects (which can, with great probability, be classed in one of our existing orders—the Neuroptera) opens up to the imagination of the evolutionist a wonderful picture, far removed from the dreary waste of waters which was once thought to characterize the epoch of the early Palæozoic formations. Geologists, indeed, have long taught us that the vast piles of sedimentary rocks of the Silurian, Cambrian, and even the Laurentian period necessarily implied the co-existence of extensive continents or islands whose denudation could alone produce them; and now the theory of evolution enables us to clothe these ancient lands with vegetation and people them with animal life, since it is only thus that we can find space and time sufficient for the development of the wonderful insects, the land shells, the Amphibia, and the reptiles,—all of which appear suddenly, in perfect and completely organized forms, in some parts of the Palæozoic series. When we consider that we have indications of the existence during the Carboniferous age of such diversified and highly specialized types of Annulosa as myriapods, spiders, cockroaches, locusts, dragon-flies, ephemeras, lamellicorn-beetles, and bombyciform moths,—so that it is highly probable that no fresh ordinal type of insects has originated during all succeeding ages, and when we further consider that all these are specialized modifications of simple Annulosa, we shall be forced to conclude that, whatever time may have elapsed from that epoch to the present day, a far longer time is required, antecedent to the Carboniferous period, to allow of the development of such varied terrestrial forms of life.

As bearing upon this question it is important to consider how scattered and fragmentary are the few indications of mammalian life older than those of the Tertiary period. Sir Charles Lyell tells us, that up to the beginning of the present century it was a generally received dogma in geology that the Mammalia had not been created before the Tertiary period; and the first discovery of the jaw-bone of a small Marsupial in the lower Oolite caused as much sensation as would now be excited by our finding a

[1] A still more remote ancestral form *Eohippus* has since been discovered in the lowest Eocene deposits of West America. See Huxley's *American Addresses*. p. 90.

Secondary monkey, or (we may add) a Silurian bird or mammal. The following table is abbreviated from that in the *Students' Elements* (p. 315), as it is well calculated to show how scanty and accidental is our knowledge, and how necessarily imperfect must be the geological record in still earlier periods.

Number and Distribution of Fossil Mammalia from Strata older than the Tertiary.

SECONDARY STRATA.	Number of species.	Locality.	First Discovery.
Maestricht chalk......	0	...	...
White chalk.......	0	...	...
Chalk marl	0	...	...
Upper Greensand	0	...	...
Gault.........................	0	...	...
Neocomian (Lower Greensand)............	0	...	...
Wealden.......	0	...	...
Upper Purbeck Oolite.....	0	...	...
Middle Purbeck Oolite ...	25	Swanage.......	1854
Lower Purbeck Oolite....	0	...	...
Portland Oolite............	0	...	...
Kimmeridge clay....	0	...	...
Coral rag....................	0	...	...
Oxford clay.................	0	...	...
Great Oolite................	4	Stonesfield....	1818
Inferior Oolite.............	0	...	...
Lias	0	...	...
Upper Trias (Somerset, N. Carolina)..........	4	Würtemberg.	1847
Middle Trias	0	...	...
Lower Trias	0	...	...
PRIMARY STRATA.			
Permian	0	...	...
Carboniferous	0	...	...
Devonian......................	0	...	...
Silurian......................	0	...	..
Cambrian	0	...	...
Laurentian..................	0	...	...

For an account of the characteristics of these small animals, and for some details of their history, we refer the reader to Sir Charles Lyell's work; it is here only necessary to state the circumstances under which these remains have been preserved and discovered. Fossil remains of land animals are, of course, rarely found except in lacustrine or estuarine deposits; and these are often entirely wanting throughout extensive geological formations. But even where such fossiliferous beds occur, the conditions favourable to the preservation of small Mammalia are exceedingly rare,—the entire series of fresh-water Wealden beds having yielded no trace of them, although we are quite certain that they were then both varied and abundant. Even more remarkable is the fact that the whole 25 species of Purbeck mammals, belonging to 10 genera, were obtained from a single stratum only a few inches thick, and from an area of less than 500 square yards. Yet these small animals must have abounded at this period; and it is impossible to believe that anything but a most imperfect and fractional representation of the mammalian fauna of the country could have been gathered into this narrow graveyard. But this thin stratum occurs amid a mass of fresh-water deposits 160 feet thick, the whole of which have been thoroughly and systematically examined by the officers of the Geological Survey of Great Britain; and though many of the layers contain remains of land organisms—plants, insects, and land-shells—no other part of the whole series has yielded a single fragment of mammalian remains! Having this striking example of the worthlessness of negative evidence, it behoves us to be cautious of rejecting any legitimate conclusions from the facts in our possession, on account of the absence of the direct evidence of fossil remains. The varied and highly-developed Mammalia of the Eocene period really necessitate (to the evolutionist) the long-continued previous existence of this class of animals; and the discovery of isolated species in the Oolite and Trias would (had it been delayed to our time) have been but a confirmation of theoretical deductions.

In his anniversary address to the Geological Society in 1870, Professor Huxley adduces a number of special cases showing that, on the theory of development, almost all the higher forms of life must have existed during the Palæozoic period. Thus, from the fact that almost the whole of the Tertiary period has been required to convert the ancestral *Orohippus* into the existing horse, he believes that, in order to have time for the much greater change of the ancestral Ungulata into the two great divisions of Perissodactyles and Artiodactyles (of which change there is no trace even among the earliest Eocene Mammals), we should require a large portion, if not the whole, of the Mesozoic period. Another case is furnished by the bats and Cetacea, which occur fully developed in the Eocene formation; and these would have required still more time for their modification out of ancestral Insectivora and Carnivora. The Marsupials of the Trias, again, were already differentiated into herbivorous and carnivorous forms; so that on the lowest estimate we must place the common ancestor of the Mammalia very far back in Palæozoic times. Reptiles furnish evidence of the same character. Professor Huxley says, "If the very small differences which are observable between the *Crocodilia* of the older Mesozoic formations and those of the present day furnish any sort of approximation towards an estimate of the average rate of change among the *Sauropsida*, it is almost appalling to reflect how far back in Palæozoic times we must go before we can hope to arrive at that common stock from which the *Crocodilia*, *Lacertilia*, *Ornithoscelida*, and *Plesiosauria*, which had attained so great a development in the Triassic epoch, must have been derived." And if to these indications we add the appearance of two orders of fishes—Elasmobranchs and Ganoids—in the Silurian period, we shall be compelled to place the origin of the whole vertebrate stock at an epoch far beyond that of the lowest fossiliferous rocks of the Cambrian series.

If, then, we bear in mind the very early appearance of so many highly complex organisms, representing all the great types of animal life—almost all the great invertebrate groups in the Cambrian and Lower Silurian, with many Vertebrata and almost all forms of Insecta in the Devonian and Carboniferous periods,—while a large number of these have hardly increased in complexity of organization down to our times, we shall be prepared to admit the extreme probability of Mr Darwin's view, that "before the lowest Cambrian stratum was deposited, long periods elapsed, as long as, or probably far longer, than the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures" (*Origin of Species*, 6th ed. p. 286.)

Professor Ramsay has recently expressed analogous views, founded on an extensive survey of the whole series of geological formations. In a paper "On the comparative value of certain Geological Ages (or Groups of Formations) considered as items of Geological Time" (*Proceedings of the Royal Society*, 1874, p. 334), he says—speaking of the abundant and well-developed fauna of the Cambrian period, a sketch of which we have given at p. 282:—"In this earliest known *varied* life we find no evidence of its having lived near the beginning of the zoological series. In a broad sense, compared with what must have gone before both biologically and physically, all the phenomena connected with this old period seem, to my mind, to be of quite a recent description; and the climates of seas and lands were of the very same kind as those the world enjoys at the present day."

It thus appears that the general geological principle with which we started, of the more complete destruction by denudation and metamorphism of the earlier as compared with the later records of life upon the earth, receives ample support in the apparently sudden appearance of whole groups of complex and specialized forms in some of the earliest rocks; while the general imperfection of the geological record is made manifest by such facts as the very few and isolated remains of Mammalia in the Mesozoic rocks, although we know they must have existed in abundance throughout the whole Secondary and much of the Palæozoic periods. The great lesson we have to learn from the facts of palæontology is, that its negative evidence is at the best of but little value; but when this negative evidence is opposed to general principles established upon a wide basis of physical and biological research, it becomes absolutely worthless. Just in proportion as the series of fossiliferous deposits is more complete, and the fossil remains more abundant and varied, does the evidence for evolution and progressive development become more powerful. The difficulties are almost wholly dependent on incomplete knowledge, and on the assumption (which we have endeavoured to show is entirely unfounded) that the earliest traces of the fossil remains of any animal type which have been discovered can give, even approximately, the period of its first appearance upon the earth.

We find, then, that just as a study of the distribution of animals in space enables us to learn much of the immediately preceding condition of the earth's surface, and especially of the recent changes of land and water,—so a study of the distribution of animals in time, when aided by the modern theory of evolution, gives us some knowledge of the physical condition and life of the earth in times beyond the reach even of geological history. (A. R. W.)

DISTRIBUTION OF VEGETABLE LIFE.

The literature in which the immense multitude of distinct kinds of plants which are dispersed over the earth's surface and form its vegetation has so far been described has necessarily been adapted to the divisions of political geography. The causes which have brought about the formation of such divisions have rarely, however, had anything in common with those which have determined the characteristic features, whether superficial or profound, of the floras of different countries. The great mass of catalogues and descriptive enumerations of the plants of such countries, the boundaries of which are for the most part quite artificial, are therefore ill adapted for bringing out any general conclusions as to the mode in which plants are distributed. It is only by making some kind of analysis of the often heterogeneous contents of such catalogues, and piecing together the results obtained from different sources, that any clue can be obtained to the approximate lines of demarcation of floras which are really naturally limited and characterized. The process is, however, enormously laborious, and, even apart from that, must for a long time to come be exceedingly imperfect in its application, owing to the immense tracts of land—and those with the most varied and copious vegetation—of the natural products of which our knowledge is still most defective.

Numerous attempts have, however, been made, notwithstanding the difficulty of the task, to map out the earth's surface into "regions of vegetation." The real significance of these regions will, of course, entirely depend upon the principles which have been relied upon in forming them. And in this respect the progress of geographical botany has been exactly similar to that of classification. The characteristic distinctions which were first seized upon in either case proved on closer scrutiny to be superficial, and to bring about merely artificial and arbitrary assemblages. The doctrine of evolution has in fact effected the same revolution in both; it has shown in the one that community of descent is the real meaning of a natural classification, it has shown in the other that community of origin is the real key to geographical distribution.

Most of the writers on geographical botany have been content to set aside all considerations of origin and history in attempting to define the limits of botanical regions. They have not attempted to see in the peculiar features which such regions may possess anything more than adaptations to physical conditions working on plants created in great measure where they are found. Although, therefore, the literature of geographical botany has been useful in enabling the reader to realize the local features—the colouring, if one may so express it—of particular countries, the facts have hitherto been presented in a form void of any true significance. And these remarks apply to the system of Schouw (1833), which has been much employed, partially to that of De Candolle, and conspicuously to that more recently published by Grisebach. It is to the writings of Darwin, Hooker, Asa Gray, and Bentham that we must look for a real insight into the origin and dispersion of floras, and for the real causes of the existing distribution of plant life.

The first attempt to review the whole subject of plant-distribution from the modern point of view afforded by evolution is due to Bentham, who made it the subject of a presidential address delivered to the Linnean Society in 1869. Bentham's conclusions are based upon the experience of a long life devoted to systematic botany, and will probably always hold a fundamental position in the study of the subject; at any rate for some time to come, until the distribution of a large number of subordinate groups has been carefully worked out, the main points established by him are not likely to be materially modified.

The general *facies* of vegetation is obviously largely affected by purely physical causes. In the polar regions, arboreal and even shrubby plants become incapable of existence, and only small perennials which are safely covered up by snow during the long winter are able in the brief summer to expand their flowers and ripen their seeds. Putting aside for the moment the severances effected by large bodies of water and mountain chains, it is easy to see that the vegetation of the earth must have always been separable into three great latitudinal zones, two belonging to the north and south hemispheres respectively, and one dividing them lying between the tropics. The constitutents of the vegetation of these zones must always have had a certain homogeneity; very considerable divergences, however, have grown up within the zones themselves, owing to circumstances of geographical isolation. Even without these, distance alone, independently of isolation, would in time be sufficient to effect it. It is also obvious that the precise northern and southern limitations of such hypothetical zones must have varied with secular changes in the earth's climate, and when these changes have taken place over a broken configuration of land and sea, the intermixture of diverse floras must necessarily have become very complicated.

Underlying, however, the tangled fabric of the earth's existing floral covering, we may agree with Bentham[1] in recognizing the existence of three tolerably ancient floras—the Northern, the Tropical, and the Southern.

I. The Northern is characterized by its needle-leaved Coniferæ, its catkin-bearing *Amentaceæ* and other forest

[1] Presidental address to Linnean Society, 1869, p. 18.

trees deciduous in winter, and its vast assemblage of herbaceous types, *Ranunculaceæ*, *Cruciferæ*, &c. These spread over Europe, northern and central Asia, and great part of North America.

II. The Southern is broken up into numerous divergent floras. Their original connection is now traceable only in the common possession by two or more of them of large characteristic groups, such as *Restiaceæ*, *Proteaceæ*, *Diosmeæ*, &c., the subordinate divisions of which have been locally specialized. To this belong the floras of extra-tropical South America, South Africa, and Australia with New Zealand, to which must probably be added an area borrowed from the northern hemisphere in Mexico and California.

III. The Tropical is characterized by the predominance of mostly evergreen arborescent *Polypetalæ* (*Anonaceæ*, *Meliaceæ*, *Leguminosæ*, &c.), and gigantic Monocotyledons, of which Palms, *Scitamineæ*, and *Bambuseæ* amongst grasses are especially striking.

I. The Northern Flora.—This has been long divided into that of Old and New World by the severance of North America from Northern Asia, and by the barrier to an interchange of vegetation in the upheaval of the Rocky Mountain range. Nevertheless its marked continuity (with only a gradual east and west change in the arctic regions, but an increased divergency southwards) requires it to be treated as a whole. The Old and New World divisions of this flora, which, no doubt, began to diverge from the mere influence of distance, have now had that divergence immensely increased by isolation. According to Lesquereux,[1] the essential types of the present arborescent flora of North America are indicated in the Cretaceous rocks of that country, and become more distinct and numerous in the Tertiary; and he believes that the origin of the existing American flora is American. The analogy between the Miocene flora of Central Europe and the present North American flora is unquestioned, and is greater than between the same fossil flora and that now existing in Europe. Lesquereux's conclusion is that the American element in the vegetation of Miocene Europe was derivative, and this is one of many illustrations of the curious observation of Asa Gray that plants have in general a greater tendency to migrate from east to west than from west to east. This Miocene flora was, however, gradually driven back again, and it is only as we travel from Europe to the East that we gradually find its traces getting stronger and stronger. Thus, as Oliver[2] has pointed out, in passing from the Mediterranean to the Levant, the Caucasus, and Persia, we meet with living representatives of the Miocene genera *Chamærops*, *Platanus*, *Liquidambar*, *Pterocarya*, *Juglans*, &c. Along the Himalayas and through China we trace other Miocene genera, Japan forming part of the same botanical region as Eastern Asia. Among the remarkable existing North American types which may be mentioned as reappearing in the Himalayas and Japan are *Aralia quinquefolia*, *Phryma leptostachya*, and *Trillium erectum*. One of the most interesting additional facts which has recently come to light is the occurrence of a species of tulip tree (*Liriodendron*) in Central China, which genus, though a member of the European Miocene flora, has in recent times been regarded exclusively characteristic of America.[3] With respect to other American genera which are not necessarily part of the Miocene flora, the same general principle holds good. Bentham remarks, that while some, like *Astragalus*, have multiplied largely in both continents, "other genera, like *Eupatorium*, *Aster*, *Phlox*, *Solanum*, &c., very numerously represented in America, have transmitted or produced a smaller number in Eastern Asia, gradually diminishing westward till they disappear altogether or attain Western Europe in single species but little altered from American ones."[4] The Europeo-Asiatic genera, on the other hand, such as *Cruciferæ*, *Umbelliferæ*, &c., which are so dominant a feature in the existing Old World Northern flora, appear "to have left but few representatives in America, and those much more modified than the American races left in Asia."

Besides the internal migrations of the various constituents of the great Northern flora, its boundaries have been changed longitudinally under the influence of secular variations of climate alluded to above. The nature of these cannot be better summed up than in the words of Bentham:—[5]

> "Where the chief portion of this great northern flora originated, and whether it may be best termed Scandinavian, or North Asiatic, or Caucasian, is a question for the determining of which we have little or no data; but, as observed by Hooker, it is probably one of the most ancient and widest spread, having at different epochs travelled over a great part of the globe. Shown by the researches of Lesquereux, as well as by the recent ones of Heer and others, to have extended far north during the warmer preglacial times, it must have been slowly driven southwards as the glacial epoch came on, and either then, or at some one or more other periods, have been for a time continuous, in two lines at least, into the southern hemisphere; for it has left traces still discernible, especially in its herbaceous and mountain forms, in the mountains of tropical Asia, down at least to the Indian peninsula, and westward to the Abyssinian and Cameroons mountains of Africa, and, again, down the Andes to the extreme south of America, where it is still luxuriant, and in a less degree in New Zealand, Tasmania, and Victoria. In all these migrations, whilst retaining a general identity, the flora must have undergone continual changes, losing species or other races of limited areas and propagation as their habitations became unfit for them, and gradually forming new ones when favoured by long-continued isolation or other requisite conditions."

The Northern flora has further undergone a specialization into three secondary floras, due to the combined influence of physical and genetic causes.

1. The *Arctic-alpine* flora ("consisting chiefly of plants of small stature, slow growth, and limited means of dispersion, compensated by long lives and great powers of endurance") is perhaps the most interesting of the three subdivisions, both because in its arctic aspect it reduces the divergence of the Old and New World divisions of the Northern flora to a minimum, and more especially on account of the great interest which attaches to the problem of its scattered alpine outliers. With regard to the first point, Hooker found that estimating the whole Arctic flora at 762 species, Arctic East America possessed 379, of which 269 were common to Scandinavia. Of the whole flora 616 species are found in Arctic Europe, and of these 586 are Scandinavian, and this leads Hooker to the striking observation that "the Scandinavian flora is present in every latitude of the globe, and is the only one that is so."[6] Christ objects to Hooker's giving the title of Scandinavian to the Arctic flora, but we must agree with Bentham[7] that Scandinavia "would, according to older rules, have been regarded as the centre of creation for the arctic lands, and may now be termed the chief centre of preservation within the arctic circle, owing perhaps partly to its more broken conformation, and partly to that warmer climate which, while it now admits species which Christ objects to being included in the Arctic flora, was during the glacial period a means of preservation of some colder species which were everywhere else expelled or destroyed."

Just as at present the Arctic is more homogeneous than

[1] *Geological Survey of Montana*, 1871, p. 314.
[2] *Nat. Hist. Rev.* 1862.
[3] Moore, *Journ. of Bot.* 1875, p. 225.
[4] Presidential address, 1869, p. 18; see also Bentham in *Journ. Linn. Soc. Bot.*, xiii. p. 500.
[5] Presidential address, 1869, p. 19.
[6] Hooker, on the "Distribution of Arctic Plants," *Trans. Linn. Soc.*, vol. xxiii. p. 253.
[7] Presidential address, 1869, p. 21.