Art. II.—The Geographical Distribution of Animals and Plants, Geologically considered.

1. *The Geographical Distribution of Mammals.* By Andrew Murray. London. 1866.
2. *The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.* By Charles Darwin, M.A., F.R.S., &c. Second Edition. London. 1860.
3. *The Descent of Man, and Selection in Relation to Sex.* By Charles Darwin, M.A., F.R.S., &c. 2 Vols. London. 1871.
4. *The Malayan Archipelago.* By Alfred Wallace, F.L.S., &c. 2 Vols. London. 1869.
5. *Contributions to the Theory of Natural Selection.* By Alfred Wallace, F.L.S. London. 1870.
6. *The Naturalist on the Amazons.* By Henry Bates. 2 Vols. London. 1863.
7. *The Student's Flora of the British Islands.* By Dr. Hooker, F.R.S. London. 1870.
8. *Migrations Vegetales, in* "Revue des Deux Mondes." By M. Martins. 1870.
9. *Recherches sur le climat et la végétation du pays Tertiare.* By Professor Heer. Paris. 1861.
10. *The Geological Relations of the Existing Fauna and Flora of the British Islands.* By Professor Edward Forbes. London. 1846.
11. *The Atlantis Hypothesis in its Botanical Aspect.* By Professor Oliver, in "Nat. Hist. Review." 1862.
12. *New Holland in Europe.* By Professor Unger. Translation in Seemann's "Journal of Botany." 1865.
13. *The Principles of Geology.* By Sir Charles Lyell, Bart., F.R.S., &c. Tenth Edition. 2 Vols. London. 1868.

THE subject we have chosen for treatment in the present article is one of the deepest interest to naturalists. As yet, however, it is surrounded by much that is vague and disconnected. The facts of which it treats have only fallen into their harmonious arrangement since the publication of the "Origin of Species." Darwin may well claim that only from his point of view can the subject of the Geographical Distribution of

animals and plants be scientifically treated. The manner in which this question has been taken up by naturalists all over the world shows the influence which a great mind has over its fellows. Natural history has received a similar impetus under the Darwinian theory that astronomy did under the older Copernican.

It is our purpose, in the following pages, to briefly review the subject of the distribution of existing animals and plants, in the light of palæontology, as well as of those geological phenomena which have produced such enormous physical changes on the surface of our earth. In doing so it will be plainly seen that the relations of the existing fauna and flora are more intimate as we approach the present epoch. Indeed there is no fact in modern geology so generally admitted as the impossibility of severing the various groups of existing animals and plants from those of bygone ages. As most of our readers are aware, these ages are usually grouped under three great divisions, relatively termed the Primary, Secondary, and Tertiary. These names indicate their relative antiquity. Each division is provisionally subdivided into epochs, and thus the geological nomenclature is made up. But even before Darwin advanced his views, the principal naturalists had been forced to see that the life-systems of these various stages were related to each other, and together formed one grand total which might be regarded as the biological history of our planet. Of these systems the existing one is the last, and bound to the rest by lines of descent. These lines can be traced far away to the dim Laurentian age, but are strongest as the geological student ascends the geological scale towards the present time. The most stubborn of anti-Darwinists has to confess that the tertiary species of animals and plants, relatively few though they be, are nearly related to their present representatives.

Geology has passed through many social phases in its brief history. The classification of Comte is certainly correct when applied to the stony science. It has existed simply as a catalogue of *lusus naturæ*, just as astronomy was hidden under the form of astrology. Then it emerged into daylight, only to be the butt of theological animosity and ridicule. Gaining strength by its grasp of facts, it had subsequently to be ill-treated at the hands of its friends under the form of "Reconciliation" theories, until, like the infant Hercules, it has strangled the snakes in its cradle, and has arisen to impress its indelible influence on almost every phase of modern thought. Unfortunately, the idea that the various geological periods were marked by distinct life-forms —the product of the earlier French school of geological thought —which were successively created and destroyed, has not yet completely died away. There are not wanting eminent natu-

ralists who still cling to this idea, although their number is every year becoming fewer. The natural corollary from this idea is that the *present* creation of animals and plants is also special, and the result of a separate and distinct act of creative power. It will be our aim to show the fallacy of this notion, and to bring to bear upon it the most recent investigations in natural science. In doing so we shall be obliged also to deal with another and equally gross mistake—viz., that the earth's crust contains no "missing links." To no science is geology more indebted than to zoology. Only by its aid have geologists been able to understand the exact relations of extinct to living forms of life. Numerous though these fossil species are, the rocks of Great Britain alone having yielded nearly fourteen thousand, we arrive at the striking discovery that they are all reducible to the same orders and classes as their modern representatives. The natural history classification, intended to embrace the recent fauna and flora, will equally include the faunas and floras of every period of the earth's past history. This proves that the *plan* of their construction, at least, has never been altered. In numerous instances extinct forms have enabled the naturalist to render this classification more complete, by filling up the gaps which before existed, and thus drawing the various orders and classes nearer to each other. Recent researches in palæontology and natural history have been travelling towards the same goal from opposite points. The former has been multiplying the list of existing species found in the fossil state, and the latter has been bringing to light the fact that many so-called extinct forms are still living in abysmal and unexplored depths of the sea. We stated the great benefits which zoology has conferred on geological science, especially in the earlier years of the latter's history; geology has now arrived at a maturity and strength which enables it to repay its foster-mother the debt it owes. By the knowledge of its organic remains it has enabled zoologists to understand many a problem which before was incomprehensible. Its latest act of filial gratitude is to assist naturalists in accounting for the geographical distribution of animals and plants. Not many years ago this was their besetting difficulty. Even the gigantic intellect of Humboldt had to be content with guessing at a truth which has only been made known since his death. The occurrence of animals and plants so unlike each other, in districts where the physical and geographical conditions were so similar, might well prove a hard nut for non-geological naturalists to crack. It has been the necessity of seeking the lineal ancestry of existing species in the geological epochs which approached most nearly to our own, that has caused us to see what perils and migrations they have undergone through the

slowly changing physical conditions. Instead of regarding the present animal and vegetable populations of the globe as a distinct and synchronous creation, separated from any that went before, we are compelled by the sheer weight of facts, to regard them as the direct results. The whole secret of their geographical distribution and isolation, apart from the laws of natural selection which have been in operation, is to be found in an intimate knowledge of the geological changes which have impressed themselves on physical geography.

It is well known that the farther we go back in time, to study the different animals and plants, the more are we struck with their *unlikeness* to anything now living. The primeval forms have been thrust aside by others better fitted to take a leading position in the great battle of life. Analogous functions have been performed by successive and distinct groups; a few types, however, have stood the heat and burden of the fight, and to these we will devote a sentence or two of notice. They bear much the same relation to existing forms that the Celtic words in our language do to the Saxon, Danish, and Norman, which subsequently overlaid them. One geographical peculiarity is always true of these ancient groups—they exist in widely severed latitudes. The most striking fact, perhaps, in the whole life-history of our planet, is that the farther we go back in time, the more lowly organized is the sum total of species, whether of animals or plants. Now it is exactly these forms which have had the greatest geological antiquity. Whilst one type of specialized organism after another has passed away, the humbler forms have maintained their ground unchanged, or nearly so, in organization. It is the moral of the oak and the reed: the storm which felled the former has simply beat the latter to the ground, to spring to its original position after the blast has passed away. These lowly organized types have now the most cosmopolitan distribution, so that, in this respect, they resemble higher forms, which also have a great antiquity. Among the lichens brought by Sir James Ross from the high latitudes of the southern hemisphere, the greater portion were found to be specifically identical with those growing in Europe. Professor Owen mentions one species of Foraminifera (*Webbina rugosa*) which has continued in existence since the Liassic period. We give the following as the most remarkable of the known instances of the geological antiquity of certain groups. The *Nautilus, Terebratula, Rhynconella, Lingula*, &c., have had a continuous range of existence ever since Silurian times at the least. During the Primary epoch, the commonest and most widely distributed fishes were the Ganoids, an order distinguished by being covered with enamelled bony plates, instead of horny scales.

This dominant group gradually dwindled during the latter stages of the Secondary epoch, and was replaced by other orders, which are now as cosmopolitan as the Ganoids once were. But there still exist what we may term "outliers" of this ancient fish-fauna, in the Bony Pike of North American lakes and rivers, in the *Polypterus* of South Africa, and in the recently discovered and rare "Mud Fishes" (*Ceratodus*), of Australia. Our common Sturgeon is nearly related to this interesting group. Günther says that these Ganoids now form only three and a half per cent. of known species of fish. The widely isolated character of this fauna plainly enough indicates its antiquity, and as surely foretells its ultimate extinction. Taking into account its former widely diffused condition, is it not evident that the isolated areas it now occupies are mainly to be ascribed to geological causes? Again, so far as is yet known, the only warm-blooded animals which lived during the entire Secondary epoch (with the exception of such rare forms as the *Archæopteryx*) were Marsupials. They became extinct in Europe during the Mid-tertiary, or Miocene period, although we still find them living in lands as far apart from each other as North America and Australia. There is every reason for believing that the latter country has been dry land since the close of the Secondary age, at the least, so that its characteristic modern mammalia may be traced thus far back in time. The Australian cave breccias yield gigantic extinct forms of the same order and no other. In America, the opossums represent this group, and their peculiar features, when compared with those of their Australian representatives, only too surely indicate the immense period of time which has elapsed since they were blood relations! Another illustration from the more ancient formations, and then we will proceed to notice how the lineage of existing forms becomes clearer as we come to the Tertiary epoch. That many of the Secondary *genera* of shells are still in existence, is well known, among which the commonest are, *Tellina* (which then first appeared), *Cardium*, *Cardita*, *Mya*, *Solen*, *Trochus*, *Pecten* (which had appeared in the Primary epoch), and a multitude of others. But one illustration we cannot forego. In the upper English chalk strata we meet with a species of brachiopod (*Terebratula lineata*) which the best palæontologists recognise as identical with the existing *Rhynconella caput-serpentis*. The antiquity of the latter species might have been guessed at from its peculiar geographical distribution. It is common to both sides the Atlantic, as well as to the South African and Chinese seas. This wide severance of the areas from each other, it cannot be too firmly insisted upon, is in every case illustrative of the antiquity of a species. Dr. Carpenter and Prof. Wyville-Thomson believe we are still

living in a Cretaceous epoch, owing to the cretaceous *facies* of the Abysmal fauna.

As just remarked, when we come to study the relations of the Tertiary fauna and flora to those now in existence, the lineage becomes so striking that in many instances it appears almost like that of father and child. This rule holds good, also, in that we find the relationship to be nearer in proportion as we approach the human epoch. The earlier stages of the Tertiary age are most interesting on account of the distribution of animals over European latitudes whose natural home we have been in the habit of supposing was far away. The commonest of mammalian species peculiar to this era are the Tapir-like animals first made known to the scientific world by the genius of Cuvier. This group is now limited to such widely severed and isolated areas as parts of South America and the Malayan archipelago, two species being met with in the former region, and one in the latter. The tapiroid animals had as cosmopolitan a distribution during the early Tertiary, or Eocene period, as the marsupials, above mentioned, enjoyed during Secondary times. Their present limited areas of occupation are due to the numerous physical changes which have passed over those countries where their bones are found in the fossil condition, so that their geographical isolation is a good index to what has taken place in this respect since the Tapir family was domiciled in Europe. It is more than probable that, since then, the two great continents of India and America have been disjoined. The high grounds of this submerged area are still occupied by the Pacific islands and coral reefs, the very existence of the latter being, according to Darwin, sufficient evidence that the depression is still going on. Even such apparently insignificant animals as land snails have been subjected to the same geographical changes as larger and more important groups. A common snail in the United States (*Helix labyrinthica*) is abundantly found in the fossil state in certain Eocene beds in Hampshire—a sure proof of its having once lived in that county as it is now living in America, and an equally eloquent testimony to the physical changes which have narrowed its distribution to its present localities. The fossil plants of the early Tertiary epoch speak to the same effect as the fossil animals. Unger has shown that the Eocene beds of Europe contain one hundred and seventy-three species closely analogous to forms now growing so far away as New Holland, and the southern hemisphere generally—another illustration that widely dissevered localities of existing species is good evidence of their antiquity. If the latter rule be good, the philosophical student would apply it to every case, whether of animals or plants, even though their remains had not been met with in the fossil condition. As Darwin has shown, the fossil

evidence is extremely fragmentary, nor would the most sanguine of geologists expect the whole fauna and flora of every geological period to be perfectly preserved in the rocks, seeing that the preservation of the forms he meets with is due wholly to accidental causes. A glance at such books as Loudon's "Hortus Britannicus" will show that certain genera include species whose geographical localities are as far asunder in distance as they possibly can be. In our opinion, such cases speak very plainly of their antiquity. A short time ago it was imagined that true woody trees, except the *coniferæ*, did not appear before the Tertiary epoch, when they were regarded as fit associates for the great number of new forms of mammalia then introduced. But the discovery of such well known forms as the Oak, Fig, Myrtle, Walnut, Banksia, Dryandra, &c., in the upper cretaceous deposits of Aix-la-Chapelle, has shown how great is the antiquity of these now almost cosmopolitan genera. Time and space forbid us to do more than glance at the tropical character of the early Tertiary fauna and flora. If we could lay one land surface over another—the condition in which the Hibernian affirmed his rightful inheritance to be—and place a slice of Borneo or Sumatra so as to overlie merrie England, we should have as near an approximation to Eocene conditions in this country as we could imagine!

The middle period in the Tertiary epoch—that commonly known to geologists as the Miocene, bears out our argument still further. Here it is that we first meet with the most abundant evidence of the *direct* ancestry of our living animals and plants, which since then have been distributed over the entire surface of the earth. Of all the fossils of this important period, the vegetable organisms are the most complete, and it is from them that we can derive our most important and correct generalizations. First of all, they point to a much warmer climate—placed by Professor Heer as sixteen degrees higher than the present—existing over Europe. This temperature, however, was not so elevated as during the previous Eocene period, as is very evident when we compare the fossil floras of the two eras. Beds of lignite, of Miocene age, rich in fossil plants, are met with in Switzerland, Germany, Scotland, Ireland, Devonshire, Iceland, Greenland, and Spitzbergen. The high northern character of the last mentioned localities shows us that when these plants grew there, in consequence of the mean elevation of temperature, it is probable that no *ice-cap* existed at the North Pole, to the extreme of which this gorgeous flora may have extended. For it must be recollected that these fossil plants afford every evidence of their having grown on or near the spots where they are now found, and that they were not floated or drifted thither. We find the petals, stamens, pistils,

and even the *pollen* of the flowers preserved. Many of the leaves have their backs covered with "bunt" and "rust"—fungi which affected them then as they attack their representatives at the present day! This alone is strong evidence that the flora is indigenous.

When we come to analyse what may be termed the Geographical character of this Miocene flora—no matter what part of Europe may be selected for the purpose — we are at once struck with its peculiarities. It is not a *European* flora, so much as one now more or less distributed all over the globe. The percentages of the fossil plants enable us even to point out the routes which the vegetable migrations subsequently took, whilst geological processes explain the means by which they became limited to the regions they now occupy. The large number of species we have to deduce from almost wholly precludes the possibility of a mistake. Thus in Switzerland alone the Miocene beds have yielded upwards of eight hundred species of true flower-bearing, or *phœnogamous* plants alone, besides mosses, ferns, &c. The total number of fossil plants catalogued from these beds, cryptogamous as well as phænogamous, is upwards of three thousand. It is the latter on which most reliance can be placed for the purposes we seek, and we shall therefore leave the former more or less out of our calculations. Among this large number of flower-bearing plants, three hundred and twenty-seven species, or nearly one half, were evergreens. Since this gorgeous flora was decidedly European, it has become more or less cosmopolitan, and been scattered by geological agencies nearly all over the world. The majority of the species have migrated to America; next we find genera that remained European. Afterwards, in the order in which they are represented in the fossil state, we find other species which have been transferred to Asia, Africa, and even to Australia. The American types are in the largest proportion. This is the most persistent feature of the Miocene flora wherever we study it in the Old World. Their analogues now grow in the forests of Virginia, North and South Carolina, and Florida. They include such familiar examples as Magnolias, Tulip-trees, Evergreen Oaks, Maples, Plane-trees, Robinias, Sequoias, &c. The higher climature of the mid-Tertiary period is further corroborated by the testimony of the fossil plants now growing elsewhere than in America. Professor Oliver, who so skilfully laid down the relations of the Miocene flora to existing forms, in the *Natural History Review* for 1864, has there shown that we must seek for the European species of the Miocene beds by the shores of the Mediterranean; and the Asiatic types in the Caucasus and Asia Minor generally. Camphor trees, now such very characteristic objects in Japanese

scenery, abound in the fossil state in these strata even as far north as Iceland, Greenland, and Spitzbergen!

The only deposits of the age we are now considering, to be found in England, are at Bovey Tracey, in Devonshire, where the Lignite, or "Brown coal," as it is also called, is worked for the purpose of baking coarse pottery. In this very limited area fifty species of fossil plants have been met with, twenty of which are common to the above-mentioned Swiss deposits. These fifty species include evergreen Oaks, Fig-trees, Vines, Laurels, Dryandras, &c.

In the Isle of Mull we meet with strata of the same age, and again at Antrim, in Ireland; but their floral yield has hitherto been small. In fact, these beds are mainly interesting on account of their possessing evidence of the last active volcanoes in the British isles. The Greenland beds have yielded several hundred species to the zeal of Mr. Whymper, and their general teaching is pretty much the same as those of Switzerland, allowing for difference in latitude.

The fossil Miocene flora of Iceland numbers four hundred and twenty-six species of true flower-bearing plants, exclusive of others. Amongst this great number are such woody types as the Birch, Willow, Juniper, Rose, Oak, Maple, Plane-trees, Vines, Walnuts, &c., all of them now characteristic of genial temperate conditions. The geology of the Aleutian islands—which more or less connect the Old World with the New—indicates a connexion of these two great continents during the Miocene period. All of them possess fresh-water deposits, remarkable for their containing rich stores of fossil plants, marked by the same geographical peculiarities we have already noticed as characteristic of those in Switzerland, and elsewhere. Here we have proof that when the Old World and the New were joined by a continuous tract of land, now more or less occupied by the sea, that land was clothed, owing to the mild temperature, with a rich and varied flora. As if to supplement the teachings of the Swiss lignite beds, as yielded up to a careful study of the plants, the *insects* found associated with them are marked by similar geographical peculiarities, and include genera now as widely scattered as the flora. The Oeningen beds have yielded over nine hundred species of fossil insects, whilst the entire number which has been obtained from all the beds of the upper and lower Miocene formations of Switzerland amount to more than thirteen hundred! Among them we find the white ants (*Termites*), now so peculiar to subtropical regions, as well as dragon-flies of the South African, and not European type. The Miocene strata of Austria have yielded fossil butterflies almost, if not quite, identical with Indian species.

These facts point clearly to the conclusion, that the reason why the Southern States of North America are now occupied by a flora which was *European* during the Miocene age, is that such flora migrated thither by way of that continuous land whose geographical as well as geological outliers are to be found in Japan, Kamschatka, the Aleutian islands, Vancouver's Island, &c. This generalization is borne out by a study of existing plants in some of the localities mentioned. The most significant of the facts is, that the further we go *east* in the Old World, the more numerous relatively do we find living species which occur fossilized in the Swiss lignites. The *Salisburia*—recently introduced into this country for its singularly graceful foliage—is now limited to the Japanese regions, although it occurs in the fossil state in North America. There are more than three hundred existing species of plants common to the Southern portion of the United States and Japan than to Europe. So that in this respect Japan is more nearly related to the New World than it is to that of which it forms an easterly prolongation! The northerly plants common to Europe, Asia, and North America, are all found growing on the Aleutian islands, which, as before remarked, stretch across the North Pacific. It seems almost incredible to suppose that a Continent has been broken up since comparatively recent times; but we shall presently see that other changes, of quite as great geographical importance, have also transpired in the interval.

It may be asked, how it is that the flora which indicates a former land connexion between Asia and America, is now principally confined to the southern states of the latter country? Our next endeavour will be to answer this, and to point out that it was the gradual incoming of the great northern winter, geologically known as the "Glacial Epoch," which drove what previously had been northern and temperate animals and plants into more southerly latitudes. The Pliocene period succeeded the Miocene, and the organic remains peculiar to it are plainly marked by evidence of a gradual refrigeration of climature throughout the whole northern hemisphere. That the plants now living in such areas as South Carolina once had a more northerly extension, is proved by those very species being found fossil in strata of the Pliocene age in Tennessee and elsewhere. This fact not only indicates the way in which such a flora spread southerly, but connects living with Miocene species, and thus clearly establishes *lineage*.

A glance at the more ancient species of animal life, from the mid-Tertiary period upwards, is full of interest, on account of its supplementing what has been clearly pointed out by a careful comparison of vegetable organic remains. We have already

noticed the singular agreement between the Swiss Miocene flora and its entomology, as regards their geographical character. Our next attention will be given to the proofs that the same cause which drove the flora southerly, and isolated it in its present localities—the cold of the Glacial period—operated equally on the animal kingdom, so that its geographical distribution may, in a great measure, be assigned to the same cause. In the Miocene beds of the Sewalik Hills, so admirably and patiently worked out by the late Dr. Falconer, we have numerous evidences of geographical conditions which have since then been wonderfully disturbed, and of animals living in India which have subsequently been distributed elsewhere. The giraffe and rhinoceros were then Indian, although they are now confined to Africa. Did space permit, other peculiarities might be mentioned of a similar nature. During the same period the monkey was a European animal, and it is more than probable that the last survivor of this group is represented by the rare, protected species which inhabits the rock of Gibraltar. The well known "Crags" of Norfolk and Suffolk represent the Pliocene period in Great Britain. Among the hundreds of species of fossil shells they include are forms now living in the West Indian, Indian, and Japanese seas, and in the Pacific Ocean. Nothing could more plainly illustrate the gradual increment of cold, than a comparative study of the southern and northern species of shells found in these three "Crags." At the same time, their elephantine, rhinocerine, and hippotamus remains indicate how abundant these animals were in England before the commencement of the *Glacial* Epoch.

The Ice-cap, which evidently began to form at the North Pole during the earlier part of the Pliocene period, gradually increased its area, and crept further south on all sides. Between the latest "Crag" deposit and the "Drift" beds—the latter of which were formed under undoubted Arctic conditions—we have a sequence of the most unbroken kind, which illustrates, by its increased percentage of northern shells, how the cold was intensifying in this country. At length we had a rigid Arctic climate extending over mid-Europe. The Arctic species of animals and plants accompanied the physical ice invasion, until eventually Europe was peopled by them in the Old World, and the United States of America in the New. The climate can be geologically proved to have intensified in the latter country, as we know it to have been the case in this. There still exist, in both areas, a few animals and plants which plainly tell of a continued land-connexion, and as lucidly point out the era of this land being broken up as occurring just before the Glacial period began, or during its progress. The common *pike* still lives in American, as well as

in English, rivers; the common heather has been found scantily blooming on the hills to the north of Boston, just as it purples the mountains of Scotland and England. Scarcely any difference can be detected between the American and European *beavers*, although the greater extended period of civilization in the Old World has encroached on its haunts, and thus almost rendered it extinct.

The physical and geographical changes which took place during this great northern winter were of a most extensive nature. We have ample evidence that the entire area of Great Britain was eventually submerged, to the depth of at least seventeen hundred feet! Over the greater part of this tract were strewn the thick beds of sand, gravel, and clay, termed by geologists the "Northern Drift." Arctic mollusca then lived in British seas in Arctic proportions. Icebergs from the north, laden with "erratic" boulders, gravel, &c., stranded in the shallower waters, and thus introduced northern plants into Britain and Europe. The subsequent upheaval of the country, until dry land appeared, was doubtless quite as slow a process as that of submergence. In the south of Europe we have proofs of even greater physical disturbances than those which once more made Britain into a sea-bottom; whilst the "drift" beds were forming in this country, limestone beds were being laid down over what is now Sicily, and these were afterwards upheaved to three thousand feet above the sea-level. A great portion of North Africa was then under water, the latter occupying the present desert of Sahara. Here it was that the terrible burning sands were originally accumulated. British mollusca had migrated southerly, driven thither by the encroaching cold, and taken up their positions in Sicilian and African seas, just as the Arctic species had occupied the English area. Hence they are found fossil, both in the Sicilian limestones, and beneath the drifting sands of the African deserts. Most, if not all, the species of Rhinoceri, Hippopotami, Elephants, Hyæna, &c., passed over to Africa and Asia, where their descendants still exist. Only those species remained behind which could adapt themselves to the changed conditions. These appeared on the dry land, and spread themselves over that portion which was uplifted towards the close of the Glacial epoch. As the woolly-haired mammoth (*Elephas primigenius*) and woolly-haired rhinoceros, their remains are met with in post-glacial deposits, whilst in Northern Asia their tusks have accumulated to such a degree, and been so well preserved, as to form the "Ivory Mines" of Siberia! In the deeper and colder portions of the British seas there still exist, as Professor Edward Forbes pointed out, a few species of mollusca which came over during the great Arctic invasion, and, having retained suitable habitats

after the warmer conditions ensued, remained behind, to add the mite of their testimony to the general mass of evidence. Perhaps one of the best illustrations of this influence of the former Arctic climature upon the geographical distribution of animals, is that given by Mr. Andrew Murray, in his elaborate work on the "Geographical Distribution of Mammals." Two species of *seal* are now living, one in the Caspian sea, and the other in Lake Baikal. As is well known, the latter is situated almost in the centre of the great Asiatic continent. As its name implies, it is completely isolated from any other body of water, as is also the case with the Caspian. Baikal is purely a fresh-water lake, whilst the Caspian has only one-third the ordinary saline properties of sea-water. The seals found living in these two great lakes belong, one of them to the same species as that still frequenting the northern shores of Britain, and the other to a species exceedingly abundant in the North Atlantic. We know that a depression of five hundred feet would once more bring the Arctic sea over the areas both of the Caspian and Lake Baikal. And we have seen that, during the Glacial period, Britain was submerged to more than three times that depth. We therefore quite agree with Mr. Murray, that the only way we can account for the presence of these seals in isolated bodies of fresh and nearly fresh water, is by supposing that when Northern Asia was uplifted from the bottom of the glacial sea, the two lowest hollows remained filled with water, in which the seals were shut off from their oceanic fellows. Their habits were subsequently altered, gradually, to suit their new conditions, and these, it would seem, were attended with certain varietal differences which distinguish them from their marine brethren. That they flourish under such apparently anomalous circumstances is evident by the fact that seal fisheries are profitably conducted both in Lake Baikal and the Caspian Sea.

Important though the information thus furnished by the animal kingdom may be on geographical distribution, that afforded by Botany is even still more impressive. The geology of the "drift" beds enables us to understand how it was possible for Arctic floras to pass from Arctic regions so as to occupy the summits of even Equatorial mountains. Mr. Croll, from astronomical deductions, fixes the date of the Glacial period at two hundred and forty thousand years ago, and estimates its duration at one hundred and sixty thousand years. This calculation, although it has a good deal of probability about it, can only be regarded as provisional. There is, however, good reason for believing that the Glacial epoch—which was not the first our northern hemisphere had experienced—was mainly due to cosmical agencies. An enormous amount of physical change could

be wrought in the period assigned by Croll, especially as the rigorous climature, and the encroachment of the northern ice-cap over the available area of occupation, would crowd species more together, and thus render the "struggle for existence" all the keener. It is estimated that the northern shores of the Baltic are being elevated at the rate of about three feet in a century. In one hundred thousand years this would elevate them as high as we know the Sicilian beds have been upheaved since the commencement of the Glacial epoch.

It was after the emergence of Europe from this Arctic sea, that floral migrations began more particularly to spread over her. The climate was still rigorous in its character, the snow-line coming down in the winter, probably to near the sea-level, as it now does in Greenland. Over the available area, arctic plants spread themselves, finding luxuriant habitats in the newly formed subsoils of the "drift." The hairy mammoth, woolly-haired rhinoceros, the Irish elk, the musk ox, reindeer, glutton, lemming, &c., more or less accompanied this flora, and their remains are always found in the post-glacial deposits of Europe, as low down as the South of France. In the New World, beds of the same age contain similar remains, indicating that they came from a *common northern centre*, and were spread over both continents alike.

When the animals and plants of the Arctic and sub-Arctic regions of the Old and New Worlds are compared, one cannot but be surprised at their identity. All, or nearly all, belong to the same genera, whilst many of the species are common to the two great continents. This is most important in its bearing on our theory, as indicating that they radiated from a common centre *after* the Glacial period. When we explore the temperate regions of the same countries, we find the floral and faunal differences increasing, as one would expect in remembering that many of the species date from the Miocene epoch. In equatorial latitudes this contrast reaches its climax. No other theory will explain this peculiarity than that Arctic and sub-Arctic species have spread *since* the Glacial epoch, whereas the southern and equatorial forms are *older* geographically, and were driven to their present areas of occupation by the slowly, but surely, advancing cold of the period in question.

The flora characteristic of Britain is marked by being opposed to extreme cold on the one hand, and intense heat on the other. It is a flora, therefore, which could only have possessed the plains of England after the rigidity of the long-continued glacial cold had given way to warmer conditions. In fact, it is a recent introduction, and there can be little doubt that its original home was Asia Minor. Most of our common English

plants are now equally as common in Japan. Our familiar flora seems to have originated in almost the same centre as Man himself! Possibly much of it may have accompanied his wanderings, as we know it does attend the footsteps of the modern English emigrant. Any one looking over Dr. Hooker's recently published, admirable "Student's Flora of the British Islands," cannot but be astonished to see how geological barriers more or less coincide with the geographical distribution of our commonest British plants. Of these barriers the great Sahara is one, and the northern flanks of the Himalayas another. We have seen that the former was *sea* during the period of the "drift," which, of course, would forbid the northern migration of African species of plants. After its elevation, the burning sands of the desert formed a barrier quite as effective as a sea. Hence, as Mr. Andrew Murray has lucidly remarked, for all practical purposes in zoology and botany, we may regard that part of Africa, north of the Sahara, as a portion of Europe situated in Africa. It has a preponderance of European animals and plants, and was doubtless connected with Europe, by way of Gibraltar, before it was with Southern Africa.

The common flora we have spoken of as now occupying "merrie" England, is botanically known as "Celtic." But, besides this, we have even in this country an admixture of other floras, whilst the continent of Europe is marked by a blended association even more strongly. In this respect, their occupation is not unlike the mixture of Latin and Teutonic races due to the successive disturbances and invasions during the earlier stages of European history. For example, in the Pyrenees we have several species of plants still growing which must have had a continuous European descent from Miocene times. They have been adapted to the physical changes meantime at the expense, perhaps, of specific alteration. The *Ramondia* and *Dioscorea* really belong to Japan and China, and, as M. Martins has observed, to find them growing on the Pyrenees is as striking as if we found a family of Chinese or Japanese people living in the same regions. The Dwarf Palm, again—the only species of its kind left growing in Europe—an inhabitant of southern France, reminds us of pre-glacial circumstances as much as the occurrence of a European monkey on Gibraltar brings to our recollection the former extension of its race, of which it is now the single outlier.

It would not be expected, especially from an evolutionist point of view, that plants whose species have a long ancestry would grow in any great abundance over areas which have been subjected to successive geological changes. We have already spoken of an arctic flora having first occupied the newly-emerged lands of the "Drift"

in Britain, and we return to the subject now for more detailed examination. When the warmer changes ensued which resulted in the present climature, the difference rendered the arctic flora unable to compete with the incoming Asiatic plants to which it was so favourable. Accordingly the former ceded the ground, the only places remaining open to them being the cold sides and summits of the higher mountains, where they would not be likely to be expelled by the newly introduced lowland and warmth-loving flora. Hence it is that we still find them growing on the margins of European glaciers, or on the tops of our English, Welsh, Irish, and Scotch mountains. On the Faulhorn, in the Canton of Berne, at nine thousand feet above the sea-level, there grow one hundred and thirty-two species of flowering plants, of which fifty-one are common to Lapland, and eleven to Spitzbergen. On the Engadine, a high valley in the Canton des Grisons, there are found eighty species of plants unknown to the rest of Switzerland, but very common in the extreme north of Europe. Taking the alpine flora of Switzerland as a whole, we discover that out of a total number of three hundred and sixty species, one hundred and fifty-eight are common to Scandinavia and northern Europe generally. The relation of the European alpine flora to that of the arctic regions may also be obtained by reversing this comparison. Thus, out of six hundred and eighty-five flower-bearing plants found in Lapland, one hundred and eight are also met with on the Swiss Alps. This extension of the arctic flora during the Glacial period is proved in a similar way on the Pyrenees, where we meet with sixty-eight species of plants which are common to Scandinavia. Thus do the very anomalies in natural history assist in the process of their own explanation!

Having rapidly glanced at the immediate influence of the later geological phenomena upon existing zoology and botany, let us next inquire whether the various physical disturbances have been such as to enable us to investigate geographical distribution by the aid of certain general principles? This is not altogether impossible. For example, we may lay it down as a good rule, that islands which are separated from adjoining continents by *shallow seas*, have been insulated within a much more modern period than those separated by *deep seas*. We find that the flora and fauna of islands are related to those of the mainland in proportion to the depth of the intervening waters. Great Britain herself is a good illustration of the principle. She has no fauna peculiar to herself, except the well known Red Grouse, and only one plant, a species of orchid (*Spiranthes*). All the rest are exactly like what we find on the Continent. Our land and fresh-water shells, fresh-water fish, &c., are identical, and as

these could not have crossed the salt sea, it is evident they must have spread over England before she was severed from the European mainland. Deep seas are always indicative of longer periods of time to effect the depression, so that, if an island had been separated from Europe in Miocene times, its fauna and flora would still possess more or less of a Miocene *facies*. Such is the case with Madeira, the Azores, &c.; they were formed as volcanic islands early in the Tertiary period, and peopled by straggling birds, insects, plants, &c., from the adjacent mainland, as Sir C. Lyell has so clearly shown in the later editions of his "Principles." The absence of all mammalia, except bats, proves that this was the process (which Dr. Darwin has so clearly explained in his "Origin of Species") by which such ancient volcanic islands were first stocked. Their areas have been considerably upheaved since then, and beds of volcanic ash are found in them, enclosing shells allied to those which lived on the mainland during the Miocene period. The existing land shells are lineal descendants of these. The plants of Madeira are also marked by similar belated features.

Somewhere about the time that our Norfolk and Suffolk "crags" were being laid down, there were extensive geographical and zoological changes taking place in other parts of the world, besides the northern hemisphere. We have evidence of a similar cold epoch in the southern hemisphere to that which took place in the northern, although it does not seem to have been of so extensive a character, or of so long a duration. Whilst it lasted, however, Antarctic plants were driven northerly, just as in the northern hemisphere they were subsequently forced southerly by analogous agencies. Darwin mentions that *Australian* plants are still found growing on the summits of the mountains of Borneo, and other islands of the Malayan Archipelago. They also extend along the highest parts of the Peninsula of Malacca, and are thinly scattered, on the one hand over the mountainous regions of India, and on the other over similar tracts as far north as Japan. In some of the higher parts of Equatorial regions we find Arctic and Antarctic plants in strange community, the former predominating, perhaps on account of the greater proportion of land in the northern hemisphere. We deduce from this occurrence an oscillation of extreme climates, or glacial epochs, in the northern and southern halves of the globe alternately. Since the Antarctic glacial period concluded, the Malayan Archipelago has been formed by a breaking up of a prolongation of the Indian continent. Previous to this occurrence, there had been a similar extension of Australia in the opposite direction, so as to nearly join the former, and this had shared the same geographical fate, as the islands of New

Guinea, &c., plainly show. The community of fauna and flora is such that we cannot be surprised native tradition should assert that Java, Sumatra, Bali, Lombok, &c., were all formerly united. The mountains of these islands form a continuous chain. The Asiatic animals and plants terminate at Bali, whilst the Australian commence at Lombok, thus showing that the tradition is zoologically wrong, if nearly geographically correct. In 1845, Mr. Earl pointed out that Java, Sumatra, and Borneo all stood on a plateau which was covered only by a shallow sea. The map indicates that this plateau is nowhere more than a hundred yards in depth. Mr. Wallace has last worked at this zoological problem, and with his usual keen perception of causation, has clearly shown how the fauna and flora of the Malayan islands are nearly allied to the Peninsula. Dr. Sclater was the first to notice that the dividing line between the Asiatic and Australian fauna must be drawn down the Straits of Macassar, and Mr. Wallace subsequently showed that this line ought to be continued southwards through the Straits of Lombok. Looking at the islands which seem to act as a series of stepping-stones between India and Australia, it would never be suspected that they could be divided into two such distinct zoological regions. The elephant, rhinoceros, and tapir are found in Borneo of exactly the same species as those inhabiting India. These animals could not have swum across the neighbouring straits, and therefore must have existed over the area before the extended peninsula had been broken up into islands. When we come to Lombok, we have a distinct group of animals and plants from the former. As Mr. Wallace remarks, although the "strait between this island and Bali is only fifteen miles wide, we may pass, in two hours, from one great division of the earth to another, differing as essentially in their animal life as Europe does from America." Through these straits, it has been shown, there runs a very rapid current, which more or less forbids migration from one group of islands to another. This, however, is not the sole cause of the striking difference in the natural history peculiarities of the two areas. The water in the straits is much deeper than in the great submarine plains which connect the islands of India on the one hand, and those of Australia on the other. The marsupials, cockatoos, bush-turkeys, lories, &c., of the Australian group certainly indicate their former connexion with the southern mainland. The conclusion arrived at by Mr. Wallace, and accepted by all philosophical naturalists, is, that the difference between the two groups of islands, as regards their zoological and botanical characters, is to be ascribed to the fact that when India extended uninterruptedly to Bali, and Australia to Lombok, there was still a strait, occupied by a deep and rapid

current, separating them. Hence it is that for ages the two regions have been geographically separated.

South Africa has evidently been dry land since the Secondary Age, and has only suffered from ordinary meteorological influences, unless we allow for a probable elevation of the whole area. The Palestine lakes seem to have been formerly connected with the great fresh-water lakes of Southern and Equatorial Africa. Sixteen species of fish occur in the former, of which five species are common to the latter; whilst only one species is common to the rivers which empty themselves into the Mediterranean. This solitary species may have been accidentally brought by some such agency as that of land birds; but we must look to more fundamental and geographical causes to account for so many species common to bodies of fresh-water situated at such a distance from each other. The raised beaches of the Dead Sea indicate an upheaval of the area, or the shrinking of its brackish waters, probably due to the increment of heat since the gradual waning away of the glacial cold. In the earlier stages of the Tertiary age, it is probable that South Africa may have been connected with India, by way of Madagascar, the Mauritius, and other islands. The *giraffe* originated in India, where its remains are found fossilized in the Sewalik deposits before mentioned. It is now extinct in that country, and met with only in Africa. The intimate connexion between the Indian and Cape buffaloes is employed by some naturalists as an argument in favour of the former terrestrial connexion between these two great countries. Mr. Murray regards the distribution of the *antelopes* as especially favouring this view. There exist altogether about one hundred and fifty species of antelopes, of which five-sixths are African. More than two-thirds of the entire number come from districts *south* of the Sahara, which forms their northern limit, just as we have seen it acts as the southern barrier to the European fauna and flora. Next to Africa, in the representation of the antelopes, comes India. So that it would seem, says Mr. Andrew Murray, as if Africa were the natural home of these creatures, and that they had come into existence there before its severance from India. Another connexion between the two continents is the occurrence of the *camel*, in the fossil state in India, and in the living condition in Africa. Some naturalists imagine there is good reason for believing that Africa was not greatly peopled by carnivorous animals before the Glacial epoch, when most of them were driven thither from higher latitudes by the increasing cold.

South America affords another illustration of a land surface which has been such for long-continued geological periods. The

huge mammalia, such as *Mylodon, Glyptodon, Toxodon, Megatherium*, &c., are all nearly allied to the characteristic groups still living over the same areas. To some of the animals, the Andes act as the principal geographical barrier, whence it would appear that this chain of mountains has been elevated since such species came into existence. The height at which very recent raised beaches have been found on the Andes, is proof of their comparatively late upheaval. Nor should the immense height of these mountains forbid the supposition we have entertained, as we know for a fact that Etna has been formed since the commencement of the Glacial period. Of the two species of *tapir* found in South America, one roams at some height on the mountains, and is covered with woolly hair, thus reminding us of the special adaptation of the *mammoth*, to protect it from the cold moisture, the other species wallows in the tropical rivers which water the forests and plains. Before the Glacial epoch began, four species of the genus *Equus*, or horse, lived in South America. It cannot be said it was not adapted to the country, as the fossil bones indicate it must have abounded in immense numbers; whilst the manner in which the modern horse has run wild since its introduction by the Spaniards, would plainly forbid such an idea. Its extinction, therefore, must have been the result of local geological operations. Contemporary with the native species of American horses there lived other forms, which we are equally in the habit of regarding as peculiar to the Old World. Among these were the elephant, mastodon, rhinoceros, &c., all of whose remains occur in the fossil state in deposits of the same age as those of Europe. Indeed, the *mastodon* would seem to have existed in America long after its extinction in this country. When driven southerly by the encroaching cold of the Glacial period, these animals were unable to cope with the huge arboreal mammalia whose long-continued possession had so suited them to the conditions of existence. The occurrence of the remains of the *camel*, in the fossil state in India, and of other species now living in Africa, and even South America, is a strong proof of the great antiquity of this genus. Indeed, next to the Marsupials and Tapirs, the Camel is one of the oldest living genera. We meet with it first in the early Miocene formations at the foot of the Himalayas. Then in the Pliocene period, a larger species (*Merycotherium*) roamed over Siberia and the easternmost boundaries of Asia, possibly crossing over to America by way of the then continuous land connexion of which the Aleutian islands are now the only relics. We next meet with two fossil species in Kansas, and of two others which evidently ranged over the greater part of the United States. Two fossil genera are peculiar to South America—the only part of the New

World where the camel family now exists, as the Alpaca and Llama testify. But perhaps the best proof of the immense ages that South America has been dry land is afforded by the peculiarities of its living fauna and flora. This is what Mr. Bates, in his "Naturalist on the Amazons," has appropriately termed *arboreal*—that is, adapted almost entirely to a forest existence. Of all the countries in the world, Central America is the most densely wooded, and this seems to have been its character for ages. Its monkeys are distinguished from those of the Old World, not only by the greater breadth between the nostrils, but more especially by their *prehensile* tails, which act the part of a fifth hand, and enable their owners to suspend themselves bodily from the boughs of trees whenever necessary. The Sloths, Opossums, Ant-eaters, and Porcupines are all arboreal; the last three, if not the first, also possessing prehensile tails, like the monkeys, and for a similar purpose. In addition to these we have only to name the Green Pigeons, Toucans, Tree-beetles, Bird-catching spiders, &c., to perceive the extent to which this arboreal adaptation is carried. The flora is equally strong in similar testimony. A great number of the genera are parasitic, either vitally or mechanically, and grow to such a prodigality as frequently to strangle the great trees to which they attach themselves. That a similar forest character distinguished this part of America in Tertiary times is evident from the remains of the gigantic Sloths, or *Megatheria*, which pulled down the trees to browse upon them, instead of climbing them like their modern representatives. Hence the long-continued arid surface of Southern Africa is testified to by the *Antelopes*, on the one hand—and on the other, in the same latitudes in America, there is equally strong proof of an extended forest-life!

We have endeavoured to glance at this deeply important subject by the aid of those philosophical naturalists whose names are affixed to the present article. A great deal of information on this subject requires collection and comparison. It is scattered through the scientific memoirs of most European Societies, and completely hidden away, not only from the general reader, but in a great measure from the scientific world as well. In conclusion, we think it is evident that only a thorough knowledge of Tertiary palæontology and physical geology can explain the anomalies of the distribution of existing animals and plants. We have several times referred to the existence of "natural barriers" to species, indicating that such barriers were related to the spread or otherwise of species. When these have been the result of geological operations, the natural history groups are found to be more or less coincident with them. To Dr. Sclater belongs the chief merit of mapping out the distribution of modern

faunas and floras—although Edward Forbes, in his masterly essay on the "Relation of the Pliocene Fauna and Flora to those of Modern Times," was the first to indicate the direct lineage of existing species. The history of geographical botany and zoology only commenced in 1857, when Dr. Sclater sketched out his six principal regions for the distribution of birds. It might be imagined that creatures like these, gifted with the power of speedily changing their habitats, would be far more irregularly spread than plants, or even animals. But it has been found that, with some slight modifications, the same mapped-out provinces would include the general distribution of quadrupeds, reptiles, insects, land-shells and, to a certain extent, even plants. These six regions, now universally adopted by naturalists, are the following:—1. The *Neo-tropical*, comprising South America, Mexico, and the West Indies. 2. The *Neo-arctic*, including the rest of America. 3. The *Palæo-arctic*, comprehending Northern Asia as far as Japan, and Africa, north of the Sahara. 4. The *Ethiopian*, containing the rest of Africa and Madagascar. 5. The *Indian*, comprising Southern Asia, and the western half of the Malayan Archipelago. 6. The *Australian*, which includes the eastern half of the Malayan Archipelago, Australia, and most of the Pacific islands. The great geological changes of the Tertiary era group more or less round these six centres. Our task is now completed, and our reward will be ample if we have been able to indicate the unity which springs out of comparative diversity. Thus studied, in the dim light of the past as well as in the more effectual illumination of the present, otherwise disjointed and broken facts start together like the "dry bones" in the prophetic vision, and become animated with the life which has filled all creation from its earliest dawn until now.