woodpecker, we shall have noticed all the birds which the ordinary traveller may expect to see in travelling from Pangani to Handei.

I am informed that Magila is a great resort of migratory birds, varying every two or three months in the classes which visit it.

Turning now to the Mammalia we find a most meagre list. Two species of mongoose occur, one the ordinary dull-grey striped form, the other black, with longer hair, and much larger in size, attaining to that of the cat. Leopards and hyenas are found, though by no means abundantly. The spotted hyena occurs at Umba. The footprints of both these animals were sometimes seen on the pathway. At Umba and in the wilderness the lion is found. While we were there Mr. Johnston heard one roar. Antelopes are also said to occur at Umba. Of monkeys, there are three or four species of Cercopithecus and two of Colobus in the woods. Only one individual of the former was seen. Of the latter one species, *C. Kirkii*, has only been seen once alive; but fortunately Dr. Kirk was the observer, and it is now placed in the British Museum.

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## *On the Origin of the Flora of the European Alps.*

By JOHN BALL, F.R.S.

(A Lecture delivered at the Evening Meeting, June 9th, 1879.)

THE title of the lecture announced for this evening may have led some of the audience to expect a lively description of the flora of the Alps which might, if I possessed the requisite literary skill, recall to many amongst you the thrill of intense delight, never to be forgotten, with which you first beheld some of the exquisite forms of vegetable life that adorn the higher region of the mountains. Far different is the task which I propose to undertake this evening. I have to entreat your earnest attention while I attempt to wrestle with a problem of formidable difficulty, and to point out to you the direction in which, as I believe, the solution is to be sought.

As you well know, a scientific revolution, more enduring perhaps in its effects than the great political events of the same period, has been effected within the last quarter of a century. The present order of nature, which once appeared to be a disconnected fragment of the cosmos, is now seen to have its roots in the past. The history of our earth, and of the forms of life that inhabit it, is now regarded as a continuous whole, governed by laws that have operated throughout a period so vast that our minds can only dimly apprehend its immensity. However limited may be our power to trace backwards the sequence of phenomena, owing to our imperfect knowledge of the laws that regulate them, the attempt is no longer deemed hopeless; and men of science, by many different paths, and with various degrees of success, are engaged in the endeavour to connect the story of the present with that of the past conditions of our planet.

A passion for mountain scenery led me from my youth onwards to pass much of my time in the Alps, and to visit other mountain districts, such as the Carpathians, the Pyrenees, and the mountains of Southern Spain, to say nothing of the hills of our own islands. It was impossible to collect, as I did, the plants of all these districts without being struck at once by the resemblances and the contrasts presented by their respective floras, and without being led to endeavour to account for them. More than twenty years ago I began to tabulate the plants of the Alps, so as to show the distribution of each species within the range of the Alps, and on the other mountains of Europe. As the southern side of the main chain has the richest and most varied flora, and was at that time the less fully known, I divided it into fifty districts, and set myself to collect materials from published works, from public and private herbaria, and mainly from my own repeated visits—this part of my work involving, in fact, the preparation of fifty local floras. Though I regard the work of botanical exploration as yet far from complete, I in this way accumulated a great mass of materials, and the question then arose as to what conclusions should be drawn from them.

For many years, in the intervals of other occupations, my mind often reverted, but with little result, to the problem of the origin of the flora of the Alps and of other mountain regions. If I believe that I am now able to offer at least a partial explanation of the difficulties that long seemed to me inexplicable, I feel assured that I owe this altogether to the circumstance that the inquiry was commenced and carried on at the period when the study of natural science received a new direction and a fresh impulse from the establishment of the doctrine that is mainly associated with the name of Charles Darwin. In immediate connection with my own subject, the two masterly essays 'On the Origin, Affinities, and Distribution of the Australian Flora,' and the 'Outlines of the Distribution of Arctic Plants,' which have placed the name of Hooker amongst those of the founders of the doctrine of evolution, served especially to guide my efforts, and to enlarge the sphere of my conceptions.

If they have not in their writings directly discussed the perplexing problem of the origin of the Alpine flora, and if some of their opinions bearing upon it seem to me open to question, I have felt assured that the methods applied by Darwin, and brilliantly illustrated by Hooker, would ultimately lead in the true direction. I venture to think that I have shown myself not less their true disciple in refusing to be bound by their authority on particular points, where it seems that the facts require an interpretation different from that which they have adopted.

As you will presently perceive, the inquiry which I invite you to undertake is a far-reaching one. It will demand a full knowledge of the geographical distribution of plants throughout the earth at the present time; and it will lead us back through the long roll of geological

ages to the earliest records of the presence of organised life on our planet. It is only fitting that I should at once acknowledge a very deep sense of the inadequacy of my own attainments for worthily treating a subject so vast and so intricate. I may perchance be speaking in the presence of some of the few men who are thoroughly competent to undertake such an enterprise; but as none can so well measure its difficulties, none are so likely to make full allowance for my inevitable shortcomings. If I were, however, completely possessed of all that is now known as to the present and the past, I should yet have to confess the insufficiency of my knowledge. The world is, even in a merely topographical sense, in great part unexplored: in a scientific sense, as my friend, Professor Thisleton Dyer, pointed out in his lecture last year, only a small portion can be said to be moderately well known.

It is therefore not unfitting that the bare outline of my views, which is all that I can lay before you this evening, should be addressed to an audience largely composed of those to whose activity we must look for additions to our knowledge which may confirm or correct our conclusions.

I must begin by endeavouring briefly to give you a sketch of the facts which we must seek to explain. I shall bear in mind that this is not an assembly of botanists, and I shall not weary you with technical details, nor inflict on you more than two or three of those Latin names in which botanists are supposed to delight.

In speaking of the flora of the Alps, I include the entire region extending from Dauphiné and Provence to the borders of Hungary, limited to the south-east by the plateau of the Karst. The ranges extending from Croatia into Bosnia and Dalmatia are often spoken of as the Dinaric Alps; but both by their orographic relations and their natural productions they belong to the mountain system of European Turkey. It is not equally easy to fix the limits of the Alps on the northern and southern sides where the mountains gradually subside into the plains. On the south side especially many plants whose natural home is in the low country, have spread into the valleys, and appear here and there as immigrants; while, on the other hand, numerous natives of the warmer slopes (many of them not known to grow elsewhere) do not ascend to the higher zone, but cannot be excluded from the study of the Alpine flora. I have, as a rule, omitted from my lists the plants of the plains that appear in the Alps only as occasional stragglers, but I have included all the other indigenous species, although some of them do not rise more than two or three thousand feet above the sea-level.

I have one more prefatory remark. Everything that I have to say this evening refers only to the distribution of flowering plants. All the tribes which botanists call cryptogams, the ferns and club-mosses, and their allies, the mosses, fungi, and other lower organisms, are propagated

by means of extremely minute bodies, called spores, which are easily carried through the air to vast distances; their distribution is not therefore subject to the same conditions that affect seed-producing plants.

In ascending the Alps from the region of the olive, or the vine, to that of perpetual snow, we find, as you well know, a continuous change in the aspect of the vegetation, and botanists have distinguished various successive zones corresponding to these changes. For our present purpose it will be enough to take account of three well-marked divisions: —a lower zone extending up to the limit of deciduous trees, an upper zone including the higher pine forests and the Alpine pastures, and a glacial region where patches of snow remain through the summer, and only a part of the surface is cleared for two or three months, and even there sharp night frosts frequently recur.

As we mount the outer slopes, the ash, the oak, and the wych elm successively disappear, the beech, the sycamore, the aspen, and the mountain ash forming the last representatives of ordinary tree vegetation, the beech alone forming forests in some part of the Alps. Along with these trees a large number of shrubs and herbaceous plants are left behind, while an almost equal number of species not before seen make their appearance. The common expression which I have used—the limit of deciduous trees—is not indeed strictly correct. The birch, the green alder, and some willows often climb as high as the highest pines, and the beech, in the form of a stunted bush, occasionally goes nearly as high.

In the upper zone of the Alps, coniferous trees form a broad girdle between the snowy crest and the lower slopes, but, chiefly through the agency of man, they have been extensively cleared, and Alpine meadows and pastures, bright in the early summer with hundreds of gay flowers, stretch upwards to the glacial region. The Scotch fir, which reaches in Scandinavia to the North Cape, 300 miles beyond the Arctic circle, is in the Alps left far below by the spruce fir, which in Norway scarcely passes the Arctic circle. In the Alps, the spruce usually ascends to nearly 6000 feet above the sea, and on the south side surpasses that limit by 600 or 700 feet. Higher still the larch and the Siberian fir often surpass the level of 7000 feet. To the glacial region I shall have later to recur.

I now proceed to give you in a few words the vegetable statistics of the Alps. I find in the whole region 2010 species divided into 523 genera, included in 96 natural orders. But of these natural orders there are no less than 36 that are not at all represented in the higher zone, and in the lower, only by a few genera and species of wide range. These 36 orders include 53 genera and 76 species—only an average of about 2 species for each order—and evidently represent groups whose natural home must be sought elsewhere. In addition to the 2010 species I reckon no less than 335 subspecies—forms closely allied to recognised species, but distinguished by differences more permanent and better

marked than what are commonly called varieties. Most of these, as well as a great many which I reckon as mere varieties, are counted as separate species by many French and German botanists.

I shall not read to you the list of the natural orders and the proportionate number of genera and species belonging to each; * but I must say something of the more characteristic of them. The largest number of species are included in three natural orders that are spread throughout every part of the globe. First come the *Compositæ*, with numerous small florets growing on a disc, including such familiar forms as the daisy, aster, marigold, thistle, and dandelion. Of these we have in the Alps no less than 62 different genera, with 250 species and 60 subspecies. Then come the leguminous plants, most numerous in the warmer parts of the earth, but represented by several species even in the polar

* The following are the natural orders represented in the Alpine flora; those printed in italics do not extend to the higher zone:—

| | | | | |
|---|---|---|---|---|
| Ranunculaceæ. | Rhamneæ. | Campanulaceæ. | Plantagineæ. | Coniferæ. |
| *Berberideæ.* | *Sapindaceæ* (Acer). | Vaccinieæ. | Chenopodiaceæ. | *Gnetaceæ.* |
| *Nymphæaceæ.* | *Anacardiaceæ.* | Ericaceæ. | Polygonaceæ. | Orchideæ. |
| Papaveraceæ. | Leguminosæ. | Pyrolaceæ. | Paronychieæ. | Irideæ. |
| Cruciferæ. | Rosaceæ. | *Monotropeæ.* | Thymeleæ. | Amaryllideæ. |
| *Resedaceæ.* | Saxifrageæ. | Plumbagineæ. | *Elæagneæ.* | *Dioscoreæ.* |
| Cistineæ. | Crassulaceæ. | Primulaceæ. | *Urticaceæ.* | *Alismaceæ.* |
| Violarieæ. | *Droseraceæ.* | *Oleaceæ.* | *Cannabineæ.* | Juncagineæ. |
| Polygaleæ. | Halorageæ. | *Asclepiadeæ.* | *Ulmaceæ.* | Potameæ. |
| Caryophylleæ. | *Lythrarieæ.* | Gentianeæ. | Betulaceæ. | Typhaceæ. |
| *Portulaceæ.* | Onagrarieæ. | Polemoniaceæ. | Salicineæ. | *Aroideæ.* |
| *Tamariscineæ.* | Umbelliferæ. | Borragineæ. | Euphorbiaceæ. | *Lemnaceæ.* |
| *Malvaceæ.* | *Araliaceæ.* | *Convolvulaceæ.* | *Buxineæ.* | Liliaceæ. |
| *Tiliaceæ.* | *Corneæ.* | *Solanaceæ.* | Empetreæ. | Melanthaceæ. |
| Hypericineæ. | Caprifoliaceæ. | Scrophularineæ. | *Aristolochieæ.* | Smilaceæ. |
| Lineæ. | Rubiaceæ. | Orobancheæ. | *Cupuliferæ.* | *Asparageæ.* |
| Geraniaceæ. | Valerianeæ. | Lentibularieæ. | *Corylaceæ.* | Junceæ. |
| *Rutaceæ.* | Dipsaceæ. | Selagineæ. | *Loranthaceæ.* | Cyperaceæ. |
| *Ilicineæ.* | Compositæ. | Labiatæ. | Santalaceæ. | Gramineæ. |
| *Celastrineæ.* | | | | |

The following show the number of genera, species, and subspecies belonging to each of the chief natural orders in the general flora of the Alps, and in that of the higher zone above the level of deciduous trees:—

For the Alpine Flora in General.

| Natural Order. | No. of Genera. | Species. | Sub-species. |
|---|---|---|---|
| Compositæ | 62 | 250 | 60 |
| Leguminosæ | 20 | 134 | 24 |
| Gramineæ | 48 | 134 | 13 |
| Cruciferæ | 26 | 115 | 18 |
| Cyperaceæ | 9 | 108 | 5 |
| Caryophylleæ | 17 | 101 | 18 |
| Umbelliferæ | 37 | 94 | 14 |
| Scrophularineæ | 16 | 83 | 10 |
| Rosaceæ | 16 | 82 | 18 |
| Ranunculaceæ | 15 | 71 | 22 |
| Labiatæ | 26 | 67 | 7 |
| Liliaceæ | 13 | 43 | 6 |
| Saxifrageæ | 4 | 42 | 9 |
| Campanulaceæ | 6 | 42 | 4 |
| Orchideæ | 22 | 40 | 6 |
| Primulaceæ | 8 | 36 | 8 |
| Borragineæ | 15 | 31 | 4 |
| Rubiaceæ | 3 | 30 | 9 |
| Salicineæ | 2 | 29 | 3 |
| Junceæ | 2 | 27 | 4 |
| Gentianeæ | 6 | 26 | 6 |
| Geraniaceæ | 4 | 24 | 0 |
| Polygonaceæ | 3 | 24 | 2 |
| Crassulaceæ | 3 | 22 | 10 |
| Euphorbiaceæ | 2 | 20 | 2 |
| | genera | species | sub-species. |
| 25 orders include | 385 | 1675 | 232 |
| 71 remaining orders include | 138 | 335 | 53 |

In the Higher Zone of the Alps.

| Natural Order. | No of Genera. | Species. | Sub-species. |
|---|---|---|---|
| Compositæ | 38 | 145 | 30 |
| Cruciferæ | 17 | 74 | 11 |
| Leguminosæ | 15 | 72 | 6 |
| Caryophylleæ | 10 | 71 | 10 |
| Gramineæ | 16 | 66 | 6 |
| Cyperaceæ | 5 | 63 | 4 |
| Scrophularineæ | 16 | 53 | 8 |
| Rosaceæ | 11 | 49 | 5 |
| Umbelliferæ | 18 | 45 | 7 |
| Ranunculaceæ | 9 | 41 | 7 |
| Labiatæ | 16 | 39 | 4 |
| Saxifrageæ | 4 | 37 | 6 |
| Campanulaceæ | 2 | 30 | 4 |
| Primulaceæ | 6 | 29 | 6 |
| Gentianeæ | 3 | 23 | 1 |
| Orchideæ | 11 | 19 | 2 |
| Junceæ | 2 | 18 | 2 |
| Liliaceæ | 8 | 17 | 0 |
| Crassulaceæ | 2 | 16 | 5 |
| Rubiaceæ | 2 | 16 | 3 |
| Salicineæ | 1 | 16 | 0 |
| Violarieæ | 1 | 12 | 3 |
| Polygonaceæ | 3 | 11 | 0 |
| Onagrarieæ | 2 | 10 | 3 |
| Valerianeæ | 2 | 10 | 0 |
| | genera | species | sub-species. |
| 25 orders include | 220 | 982 | 133 |
| 35 remaining orders include | 59 | 135 | 17 |

regions, and the grasses, no less widely spread in all regions, each of these families having in the Alps 134 species.

After these great orders which predominate in most other parts of the world, the families most numerously represented in the Alps are those which extend widely through the cooler regions, and are everywhere characteristic of, though not usually confined to the mountains. Of these the most conspicuous, both by the number of species and individuals, are the crucifers, the sedge tribe, the *Caryophylleæ*, including the pinks, chickweeds, sandworts, and the like, and the *Umbelliferæ*. These seven orders include nearly one-half of the whole Alpine flora —936 out of 2010 species. Without going into further detail, I must call your attention to some natural groups that are especially characteristic of mountain vegetation throughout the world—the six families which take their names from the rose, the ranunculus, the saxifrage, the primrose, the campanula, and the gentian. These, almost everywhere in the world, adorn the higher mountains, increasing in importance, both in the proportionate number of species and in the brilliancy of their flowers, as we ascend towards the snow region. Of the entire Alpine flora, these six families form about 15 per cent.; in the higher zone they furnish very nearly 20 per cent., and in the highest of all, towards the limits of perpetual snow, about one-third of the species usually belong to them.

In the flora of the upper zone of the Alps I count 1117 different species, which have been arranged in 279 genera and 60 natural orders. The proportion which the natural orders bear to each other is not very different from that which they show in the general flora of the Alps. The *Compositæ* still form about one-eighth of the whole; but the leguminous tribe, the grasses, and the *Umbelliferæ*, show a smaller percentage. The crucifers and the *Caryophylleæ* are comparatively more numerous, as are the six tribes which I have already spoken of as especially characteristic of mountain floras. For the glacial region I shall not attempt to give you accurate figures, for the simple reason that sufficient materials do not exist. I have long since ascertained that the real check to the extension of many species in the highest zone of the Alps is not climatal, but the want of soil and situation suitable to each plant; and where from accidental circumstances these are found, the glacial region is seen not to be so inhospitable as is commonly supposed. Perhaps you will allow me to give an illustration from my own reminiscences.

More than twenty years ago I started one morning from the Æggischhorn with a vague intention of reaching the uppermost end of the Great Glacier of Aletsch, and looking down on the pastures of the Wengern Alp from what is now known as the Jungfrau Joch. The sun was hot, there was much fresh snow on the glacier, and at every step I and my companion, with our heads burning and our feet freezing, sank deep

into the soft, pasty mass. After several hours of this exercise, compared to which the treadmill must be a delightful pastime, I satisfied myself that I should never arrive at the intended point in time to return by daylight, so I resolved that I would alter my plan, and do a little botanising instead.

Those of you who know the Aletsch Glacier—the vastest snow-field in Europe—may well be surprised to hear of anyone attempting to botanise there. Leagues long, the great ice-river, with a channel from 2 to 3 miles wide, flows between steep snow-covered slopes, from which here and there project some teeth of black rock. But I had noticed, just at the point where the two great tributary streams, one flowing from the east, the other from the west, join the main current, that on the southern slope of a ridge bounding the Grünhorn Glacier, there was a steep slope of fine *débris* clear of snow. Following the track of some chamois, I found a way from the glacier to the base of this slope, and ascended it to a range of projecting rocks which, by the Swiss federal map, are about 10,700 feet above the sea. On this slope, at a height of nearly 2000 feet above the much-talked-of Jardin, near Chamouni, and far more widely separated from other spots inhabited by Alpine plants, I gathered over forty species in flower, one of them being the common thyme, another a variety of the still commoner dandelion. I give this as a single instance within my own experience; but until many such spots are examined throughout the whole chain of the Alps, it will be too soon to attempt an enumeration of the glacial flora. If the members of the Alpine clubs of our own and other countries will be prevailed upon to use their eyes as well as their legs, and, better still, to preserve a few specimens that will fit in a pocket-book for future reference and verification, we shall get to know much more than we now do of the vegetation of the highest region. Favourable situations become so rare above the level of 10,000 feet, that no single traveller has many opportunities for observing them; but my own belief is that the number of plants capable of growing and reproducing themselves in the highest region of the Alps is much greater than has been hitherto supposed.

In connection with this matter it will be well to bear in mind the undoubted fact that some, perhaps many, species of plants give rise to races, which are in truth physiological varieties, distinguished by certain inherited tendencies, though not recognisable by outward differences of form. Thus artificial selection has produced in Norway a variety of barley which ripens its seed in less than two months, while the ordinary period is from three to four months, and several different varieties of maize in America and Northern Italy are known to present still greater differences in the time required for the ripening of the grain, or in the amount of summer heat which they demand or tolerate. It is probable that in many instances, such as that of the thyme found growing above the Aletsch Glacier, where plants flourish in the Alps under physical con-

ditions very different from those of their ordinary habitations, such individuals belong to physiological varieties which have acquired or recovered a hereditary capacity for suiting their development to the new conditions.

I forbear to give you other instances of a similar character, but I cannot avoid saying a few words as to the bearing on questions of Alpine vegetation of investigations on which much labour and research have been expended by several eminent men, and especially by Alphonse de Candolle, who has largely developed and improved the methods of his predecessors in the same line of inquiry, and at the same time has recognised some, but, as I think, not all of their inherent defects. Starting from the assumption that there is some minimum degree of temperature above the freezing-point which every species of plant requires in order to accomplish the various processes of its development, it is further assumed that a certain sum of temperature above that minimum will always be employed in achieving the cycle of changes on which depends the life of the plant and the propagation of the species. By careful study of the polar limits of the growth of certain widely diffused species, and a comparison of the periods of vegetation of each of them with the records of monthly mean temperature at various places, it has been sought to discover the sum of temperature appropriate to each, and on which its existence in a wild state is supposed to depend.

Without attempting to deny that in respect to some plants a measure of probable success has been attained, the results in other cases do not seem consistent with the supposition that temperatures, ascertained by the thermometer, in the shade, give much help towards ascertaining the conditions required for the growth of plants. However this may be as to the vegetation of the plains, I feel assured that the method is altogether inapplicable to that of high mountains. The difficulty of estimating the difference between the effects of air temperature in the shade and those of direct exposure to the sun, did not escape the penetration of Humboldt, the true founder of this branch of botanical science; and it has been considered by Alphonse de Candolle. He admits that for Central Europe the difference in summer between the temperature of a thermometer in the shade and one exposed to the sun may be from 5° to 8° Fahr., but assigns various sufficient reasons why the effect produced on plants should be less considerable; and he finally estimates the effective difference of temperature between growth in the sun and in the shade, at 1° of the centigrade scale, or less than 2° Fahr. On this I must remark that no one who has not experienced it seems to have any adequate idea of the intense effect of the sun's rays in the higher regions of the atmosphere, and the few observations contained in a report which I presented to the British Association in 1862, do not seem to have attracted the attention of naturalists. The mean difference shown in summer from fifteen years of careful observation made at Chiswick, between the temperature in the shade and that of a black

bulb thermometer, exposed to the sun, was a fraction less than 7° Fahr. We have no parallel series of observations on high mountains; but some indication of the effects of solar radiation is given by the fact that in fourteen observations, at heights varying from 4000 to 14,000 feet above the sea-level, exposure of a small black bulb thermometer for three minutes in the sun raised its temperature to an average of 40° above that in the shade, and in five observations made at an average height of 12,000 feet, the average difference was 46°.

Still more significant are the observations on the temperature of the soil exposed to the sun contained in the same report. On the slope above the Aletsch Glacier, at a height of about 10,300 feet, I found the temperature at 1 inch below the surface to be 83°, and at 5 inches, about the greatest depth to which the roots of Alpine plants commonly penetrate, the thermometer marked 75°. On another occasion, at the height of about 8400 feet, in the Pyrenees, an ordinary thermometer laid on the surface, near to large patches of snow, marked 107°·6, and when buried to a depth of an inch and a half, stood fixed at 99°.

We are yet very far from being able to estimate the effects of these high temperatures, and of the stimulus of intense illumination, on the growth of Alpine plants; but it may be safely asserted that observations taken with a thermometer in the shade, do little to illustrate the actual conditions of their life.

Let us now proceed to compare the flora of the Alps with those of other regions, and see what light may in that way be thrown upon its history and origin.

The first thing that strikes one in going through the list is the large proportion—more than two-fifths of the whole number—that are to be found in the floras of all parts of temperate Europe, the majority extending indeed to Siberia, and a considerable number even to North America. These are clearly plants that have a considerable power of adapting themselves to varied physical conditions, and whose vigorous organisation has made them victorious in the struggle for existence. Out of 792 species of this class that are present in the Alps, no less than 215 extend to North America, and not a few, especially of the aquatic species, have reached the furthermost ends of the earth in South America, South Africa, Australia, and New Zealand. You must notice that out of this large number of species not one in twelve (only 65 in 792) can be reckoned as plants of the higher mountain region. They are indeed, most of them, common enough in the lower zone of the Alps, but they grow equally freely in the woods and heaths and waste ground of Middle Europe, whence not a few extend northward within the Arctic circle.

If we take away the 727 species which form no special element in the Alpine flora, and also some 50 stragglers from the South—Mediterranean species that have contrived to establish themselves here and there in the mountain valleys—we have left 1157 species in our list, as to which we

must make closer inquiry. Of these, 172 species are to be reckoned as endemic—that is to say, confined to this particular region—of which 42 have spread from the Alps as a centre, either along the Apennine chain or into Croatia or Dalmatia, so that the number of endemic species absolutely limited to the Alps is reduced to 130. To that number many botanists would add ten or eleven well-marked subspecies, while others would double my estimate by reckoning as species numerous forms which I call varieties. Let us now consider the remaining species which are not confined to the Alps, but are mountain plants, only those among them that extend to the Arctic regions being there inhabitants of the low country.

As you might expect, when we come to a comparison with the floras of other mountain regions, we find that the Alps have many elements in common with the Pyrenees and the Carpathians. I must not weary you with figures, and therefore trust you will take my word for the general accuracy of the following summary. Out of 1157 species more than one-seventh are endemic, rather more than half are common to the Alps and the Pyrenees, just two-thirds are common to the Alps and Carpathians, while rather more than one-sixth are common to the Alps and the north of Europe and Asia. A large majority of the latter extend beyond the Arctic circle only in Scandinavia, owing to causes to which I shall have further to allude. It is worth your while to note especially this fact, that of the plants that are common to the Alps and the north of the old continent, the larger number do not extend to all the three great mountain ranges of Central Europe; the Pyrenees possess only about one-third of the whole, while the Carpathians have just two-thirds, and there are about 40 species which are common to the Alps and to Northern Europe, but have not been found either in the Pyrenees or the Carpathians. At the present time the Alps are separated from the higher summits of the Carpathians, and from the Pyrenees, by only a moderate interval of about 200 miles of comparatively low country; but during the middle tertiary period, and perhaps again at a later date, they were divided by arms of the sea that then changed Europe into an archipelago. We find, however, much more difference between the Alps and the Pyrenees than between the Alps and the Carpathians. Counting, as we are bound to do, the Asturian chain as a portion of the Pyrenees, each region has about half of its flora common to the other; the Alps have 172 endemic species and at least 15 genera that are not found in the Pyrenees, while the latter range counts about 100 endemic species with several (six or seven) genera not found in the Alps. With the Carpathians the connection is much closer; that range possesses two-thirds of the Alpine flora, and only from 30 to 40 endemic species. But it has a great many species that must be called Eastern, as they are common to the Caucasus or the Balkan Peninsula, which do not extend to the Alps.

If you will turn your eyes to the large map of the world, you will see that the old continent, from the north-west corner of Spain to Kamtchatka, is traversed by almost continuous mountain ranges, leaving nowhere a gap of more than about 300 miles in a distance of some 8500 English miles. If you follow the line from the Pyrenees through the Alps, the Carpathians, and the Caucasus, to Northern Persia, you come to the western end of the great highland region of Central Asia, and you find that instead of continuing along a single range, nearly half of the Asiatic continent is occupied by mountain chains, having a general direction from west to east, with plateaux between, mostly of great height, but in parts subsiding to a comparatively low level. Of this vast region we know little scientifically except as to the great Himalayan range in the south, and the northern range forming the southern boundary of Siberia, which I shall speak of as the Altai, although that name properly belongs only to a small portion of the collective mass. It is very remarkable that when we compare the Alpine flora with those of other mountain regions not immediately adjoining, we find the closest affinity to be with these mountains of Northern Asia, notwithstanding the vast interval of space that divides them, and the wide differences in their climatal conditions. Fully one-fourth of the species of the Alpine flora are present in the Altai region, as also are about five-sixths of the genera. This is the more noteworthy, as we have in the Caucasus, at a third of the distance that divides the Alps from the Altai, a great mountain mass with a rich Alpine flora, and enjoying a much more favourable climate, where the proportion of species common to the Alps is much smaller. You may reckon that out of every twelve Alpine species, three are to be found in the Altai, and only two in the Caucasus.

The Alpine flora is represented in the Himalaya by a large number of the same genera, but comparatively few of the same species; and I must especially call your attention to the fact that many of the species that are common to the Alps and the Altai, or the Himalaya, extend also to the Arctic regions of the old world. But you must also bear in mind that this holds true only as to some of the species in question, and that many genera not at all represented in the Arctic flora are common to the Alps and the mountains of Asia.

I now approach with some trepidation a branch of my subject where I am unable to follow those whom I have been used to look up to as my masters in natural science. I have briefly to discuss the relations between the Alpine flora and that of the Arctic regions, and the inferences to be drawn from the facts. In the memoir to which I have already referred, Sir Joseph Hooker brought together all the facts then accessible as to the constitution of the Arctic flora, and the distribution of species forming it throughout the rest of the world. Having shown what a large proportion of these are spread throughout Europe, including the Alps, not a few extending even to the south temperate zone, he

sums up a masterly analysis of the facts by the conclusion that this Arctic flora, most fully developed in Scandinavia, flourished there before the glacial period, and was then driven southward across the old and new worlds, returning again northward, and ascending the mountains of both continents, when a more temperate climate offered the necessary conditions of existence. In its general outlines the conclusion thus drawn had already been put forth in the 'Origin of Species,' and was fully accepted by Lyell; so you will perceive what a formidable weight of authority lies in the scale against one who seeks to contend against, or even to modify it.

In the first place, I must remark that of the plants enumerated by Hooker as extending beyond the Arctic circle, nearly one-half are those ubiquitous species which, owing to their power of adapting themselves to very varied external conditions, have spread themselves over the temperate old world, and many of them also throughout temperate America. Whatever significance may be attached to the presence of these plants in the Arctic flora, there seems no reason for supposing that they have originated in that region. At the present time they are more common in the true temperate zone than elsewhere; and if we were to speculate upon their origin from noting the regions in which the groups to which they belong most abound, there are not a few that would be referred rather to the Mediterranean region than to a more northern home. Further, as Hooker has been careful to point out, the climate of Northern Scandinavia is most materially affected by the Gulf Stream—perhaps also by the south-west winds from the Atlantic—and forms a quite exceptional division of the Arctic flora. There, and there alone, forest trees, and even the cultivation of barley, extend far north of the Arctic circle; and as a natural consequence a multitude of other plants have spread into a district which is indeed geographically Arctic, but which by its climatal conditions belongs to the cooler temperate zone. Leaving out of account all the species which in Central Europe are characteristic of mountain vegetation, I have counted 217 species in Hooker's catalogue which nowhere reach the Arctic circle except in Scandinavia, and which nearly all extend to the Mediterranean region; and to these I add 131 more ubiquitous species, which are, indeed, truly Arctic, but are no less truly temperate, being all widely spread throughout the northern hemisphere. We thus find that the list of characteristic or non-temperate Arctic plants must be reduced by at least 348 species. It is true that few of these are absent from the lower zone of the Alps; but it is a curious fact that, although they are all fitted to resist the severity of the Arctic climate, the great majority—fully four-fifths—do not in the Alps ascend to the higher zone, and very few approach to the limit of perpetual snow.

Struck by the fact that nearly all the ubiquitous species which I have struck out from the Alpine and Arctic lists are common to Northern Asia, and by the further fact that there is a closer connection between the

Alpine flora and that of the Siberian mountains than with any other distant range, and finding that what I should call the true Arctic flora is more largely represented in the same region than it is in the mountains of Central Europe, Dr. Christ, of Basel, in a memoir which I should like to discuss more fully if time permitted, comes to the conclusion that Northern Asia is the original home alike of the Arctic flora and of that portion of the Alpine flora that he assumes to have been derived from a distance. For the present I will beg you to defer any conclusion as to the origin of these floras, and merely to note the facts as they present themselves, and bear in mind the following proportions, accurate enough for our purpose.

Of the species included in the Alpine flora, 17 per cent. are common to the Arctic flora, and 25 per cent. are common to the Altai range, while the Arctic flora has 40 per cent. common to the Alps and 50 per cent. common to the Altai, using this as a collective name for the ranges of Northern Asia.

Now if, in deference to the great authorities I have named, I were to admit that every one of the Arctic species common to the Alps had originally reached the mountains of Central Europe by migration from the north, I ask how far that would avail towards an explanation of the origin of the Alpine flora? If we had accounted for 17 per cent. of the species, what should we have to say of the remaining 83 per cent., including at least four generic types peculiar to the Alps, and a very large number not found in the Arctic regions—of the genera present in the higher zone of the Alps only one-half being Arctic? Is it credible that in the short interval since the close of the glacial period, hundreds of very distinct species and several genera have been developed in the Alps, and—what is no less hard to conceive—that several of these non-Arctic species and genera should still more recently have been distributed at wide intervals throughout a discontinuous mountain chain some 1500 miles in length, from the Pyrenees to the Eastern Carpathians? Nor would the difficulties cease there. You would have left unexplained the fact that many of these non-Arctic types which are present in the Alps are represented in the mountains of distant regions, not by the same, but by allied species, which must have descended from a common ancestor: that one species of *Wulfenia*, for example, inhabits one small corner of the Alps, that another is found in Northern Syria, while a third allied species has its home in the Himalaya.

I cannot give you a better illustration of the general problem with which we have to deal than by taking the Saxifrages, perhaps of all generic groups the most characteristic of high mountain vegetation. It is the more convenient to do so that the distribution of the Saxifrages has been very carefully studied by Engler; and, reserving doubts as to a few details, I take his results as they stand.

With comparatively slight differences in the structure of the flower

and fruit, the Saxifrages exhibit the most extraordinary diversities in foliage and mode of growth, so great, indeed, that if the plants were preserved in a fossil state, without the floral organs, it would never occur to the most experienced botanist to refer them to the same genus, scarcely, indeed, to the same natural order. Engler, for the most part following previous writers, groups the 166 species described by him into fifteen sections. No less than eleven of these sections, corresponding to as many different types of vegetation, are represented in the Alps, which show a greater variety than any other mountain region. Of these ten are found in the Pyrenees, nine in the Carpathians, and eight in the Arctic regions. If we go still further afield, we find Saxifrages on the high mountains of the world almost everywhere, except in New Zealand and South Australia. In the Rocky Mountains six of our Alpine groups are represented, besides two others that do not extend to the old world. In the Andes we find five endemic species, all belonging to one group, which has numerous representatives in the Alps and the Pyrenees, two of the Andean being nearly allied to an Arctic species of that group which does not extend to the Alps. In the Himalaya six of the Alpine groups are represented, but for the most part by different species, three-fourths of the whole number being endemic. Finally, a single endemic species has been found in Abyssinia, belonging to a group that extends to the south-east of Europe, and thence through Asia Minor to the Himalaya.*

* The following table shows the results of Engler's researches on the distribution of the Genus *Saxifraga* in the chief mountain regions of the world, and within the Arctic circle. The numbers show the number of different species of each section of the genus hitherto found in each region:—

| Sections. | European Alps. | Carpathians. | Pyrenees. | Arctic Regions. | Caucasus and Armenia. | Himalaya. | Mountains of N. Asia. | Rocky Mountains. | Andes. |
|---|---|---|---|---|---|---|---|---|---|
| Cymbalaria .. | .. | .. | .. | .. | 2 | 1 | | | |
| Tridactylites .. | 3 | 2 | 2 | 2 | 1 | .. | 1 | 1 | |
| Nephrophyllum | 4 | 4 | 1 | 4 | 2 | 4 | 4 | 2 | |
| Peltiphyllum .. | .. | .. | .. | .. | .. | .. | .. | 1 | |
| Isomeria .. .. | .. | .. | .. | 1 | .. | .. | .. | 3 | |
| Miscopetalum .. | 1 | 1 | 1 | .. | 1 | | | | |
| Hirculus .. .. | 1 | .. | .. | 1 | 1 | 11 | 1 | 1 | |
| Boraphila .. .. | 2 | 2 | 2 | 6 | .. | 3 | 9 | 9 | |
| Dactyloides .. | 8 | 5 | 10 | 1 | 1 | .. | 2 | 1 | 5 |
| Trachyphyllum | 3 | 2 | 2 | 6 | 1 | 13 | 5 | 5 | |
| Robertsonia .. | 1 | .. | 3 | | | | | | |
| Euaïzoonia .. | 8 | 2 | 3 | 2 | 1 | | | | |
| Kabschia .. .. | 8 | 4 | 3 | .. | 3 | 2 | | | |
| Bergenia .. .. | .. | .. | .. | .. | .. | 3 | 2 | | |
| Porphyrion .. | 4 | 2 | 3 | 2 | .. | 1 | 1 | 1 | |
| Endemic species in each region | 14 | 3 | 6 | 2 | 3 | 28 | 6 | 7 | 5 |

I have omitted Engler's section *Diptera*, which is peculiar to Japan, and I have added the small group called *Bergenia*, counted by some botanists as a separate genus, but united to *Saxifraga* by all the best authorities. It is very distinct in habit, and apparently confined to the mountains of Central and Northern Asia.

Engler imagines that at the close of the tertiary period six types of Saxifrage were already in existence, from which, as I understand him, he believes that the existing species were developed.

To go no further into detail, I will merely say that to one of these types he refers plants so utterly different as the London-pride of our gardens, the yellow saxifrage of the Alps and the hills of our lake district, the purple opposite-leaved saxifrage of the Alpine snow-region and the tops of our Highland mountains, and the *Saxifraga aizoon*, so common in the Alps, with thick cartilaginous leaves edged with pores from which carbonate of lime is deposited. I venture to think that no one who weighs the evidence as to the probable rate of change of specific types, along with the facts of geographical distribution, can for a moment suppose that types of vegetation so widely different in structure, including in all fifty-six mostly very distinct species, can have been developed from the same original parent within a period nearly so brief as that supposed.

It appears to me, indeed, that even as to species strictly belonging to the same group, it is contrary to every reasonable presumption to suppose that they have been differentiated within a period so very recent. If we suppose that the opposite-leaved saxifrage were carried during the glacial period from the Arctic regions to the mountains of Central Europe, this does not explain the existence of a very distinct species of the same group (*Saxifraga retusa*), scattered at wide intervals throughout the Alps, Carpathians and Pyrenees, but not known elsewhere in the world.

I proceed to another aspect of the question. If we assume that the Arctic flora, or a notable proportion of it, was diffused throughout the mountains of the northern hemisphere since the commencement of the glacial period, the question next arises—where was this flora before it appeared in the Arctic regions?

We have now abundant evidence that at a time geologically recent, in the middle tertiary, probably even in that of the newer tertiary period—the flora of the extreme north was essentially temperate, and that the climate must have been altogether unsuited to the plants now existing there.

I need not enter into the evidence, for the fact is admitted by all. I am not aware that any answer has been attempted to the question that I have just proposed, so that in laying before you the views to which I have been led, I feel free from the task of contending against the weight of authority.

Before going further, I must say a few words as to the bearing of recent discoveries in fossil botany on the subject before us. Among the many new and old truths which we owe to Darwin, must be reckoned the lively sense of the imperfection of the geological record now possessed by most naturalists, but not generally recognised before the

appearance of the 'Origin of Species.' As regards fossil records of the vegetation of mountain regions, however, the case is very much stronger than he has put it; and with few and trifling exceptions, to one of which I shall refer, the documents from which we might have gained any direct knowledge of the mountain vegetation of the past are irrevocably lost. Fossil plants are, under favourable conditions, preserved in shallow lakes or estuaries; but only by the rarest of chances can a plant from the upper mountain region be preserved in such deposits. In attempting to reason about the ancient vegetation of the mountain regions of the earth, we are thus left unaided by direct evidence, and it is unavoidable that our conclusions should be to a great extent speculative.

You are, most of you, aware that flowering plants are divided into two great classes, in one of which the development of the stem takes place from within, as in grasses, lilies, and palms, which are therefore called endogens; while in the other, which includes all deciduous trees and shrubs, and most of the herbaceous plants of Northern Europe, the new leaves and floral organs issue from the outer part of the stem or trunk, these being called exogens. Distinct in some important respects from both classes are what botanists call gymnosperms, including two important natural families, of which the types are the pine and the cycas. In their mode of development the gymnosperms agree with the exogens, differing however in the peculiar structure of their wood; but by the imperfection of their floral organs they approach more nearly to the higher cryptogams than does any other tribe of flowering plants. I think that modern researches, especially those of Professor Williamson of Owens College, have gone far to confirm the views of those who believe that the gymnospermous class were originally developed from a cryptogamic type that is now represented by the club-mosses. Certain it is that the evidence of fossil remains, so far as it goes, proves the existence of many and varied types of gymnosperms throughout the vast period occupied by the deposition of the carboniferous and Permian strata, where no other flowering plants, with the possible exception of a single endogen, have been detected.

During the secondary period endogens are found in fossil deposits, few in number and obscure in their affinities; but the appearance of the higher type of exogenous plants is not disclosed by direct evidence until about the middle of the cretaceous period. Then all at once, in deposits widely spread over the northern hemisphere, we encounter a crowd of species, belonging to very different types, but for the most part so nearly resembling living plants, that palæontologists do not hesitate to refer many of them to existing genera. Whatever doubts may exist as to particular species, this much is certain, that at the middle of the chalk period numerous trees belonging to many very different natural orders, and nearly allied to existing plants of the warm temperate and sub-

tropical zones, existed in Europe and North America, and far north of the Arctic circle in Greenland. From that time to the present day the story of the tree vegetation of the low lands of the northern hemisphere is nearly continuous, though doubtless very incomplete. Very few types have disappeared, many have migrated towards the warmer parts of the earth, while others still hold their ground in the north temperate zone.

In many cases we are able to trace a series of connecting forms between the earliest known species and those of the present day. The general conclusion must be that in spite of vast changes in physical conditions, and the still vaster period of time that has intervened, the amount of change that has supervened in the portion of the earth's vegetation thus disclosed to us has been comparatively slight. But if, at the commencement of the earliest chapter of the history accessible to us, the evolution of the flowering plants, and especially of the exogens, had already proceeded so far, where, I would ask, must we look for the earlier forms, the ancestral types from which our present groups have sprung? and where again for the much more remote forms which served to bridge over the interval, so perplexing to the botanist, between the endogens and the exogens? Impressed by the utter absence of exogenous trees from the earlier fossil deposits, M. de Saporta, one of the best authorities on this subject, is reduced to conjectures, one, as it seems to me, more improbable than another. This type of vegetation might, he suggests, have been gradually developed in some separate corner of the earth, not previously connected with the regions now known to us; or else, under the influence of some unknown cause, the process of evolution was at that period extraordinarily rapid. To my mind there is no alternative between abandoning the doctrine of evolution and admitting that the origin of the existing types of flowering plants is enormously more remote than the period as to which we have direct evidence. The difficulty to be got over is the utter absence of such evidence.

I shall now endeavour to show you the strong probability that the early development of the chief types of flowering plants took place under conditions such that no record could be preserved for us. I shall first point out that the ancient forms of vegetation belonging to the coal measures and earlier palæozoic formations flourished under physical conditions very different from those now obtaining, while at the same period there were portions of the earth where entirely different conditions prevailed, and where we ought to expect that the evolution of vegetable life would follow a very different course. In the history of the earth, regarded as the scene of organic life, there is one event of transcendent importance, to which I think sufficient attention is not commonly given. I allude to the deposition of the coal measures. It is a moderate estimate to fix 10½ billions of tons as the weight of coal in the deposits known to us, and to reckon that a like amount exists in deposits yet undiscovered, or covered up by newer strata, or buried

beneath the sea. That would give 21 billions of tons of coal, containing by estimate 17 billions of tons of carbon, nearly all of which must have been extracted from the atmosphere, where it previously existed in combination with oxygen in the form of carbonic acid gas. In forming that amount of coal, the plants of that period must have set free more than 45 billions of tons of oxygen gas, increasing the quantity previously existing in the atmosphere by about 4 per cent. I shall leave out of account other agencies that have largely diminished the proportion of carbonic acid gas in the air since the palæozoic period, and merely remind you that the whole quantity now existing is estimated at 3 billions of tons, containing 818,000 millions of tons of carbon. The inference to be drawn, which I believe to be an under-statement of the truth, is that during ancient palæozoic times, before the deposition of the coal measures, the atmosphere contained twenty times as much carbonic acid gas, and considerably less oxygen than it does at present. You will believe that it is the want of time, and not of respect for the opinions of a great man, that prevents me from fully discussing the objections to this conclusion stated by Lyell in the later editions of his great work, the 'Principles of Geology.' Suffice it to say that they have not obtained the assent of competent authorities; and with that remark I resume my argument.

You well know that carbonic acid gas is much heavier than the other gases contained in the air, the proportion of weight for an equal volume being about three to two. If the air were at rest, and the proportions of the gases not disturbed by plants and animals, the result would be that the percentage of carbonic acid would diminish as we rise above the sea-level. But the quantity of this gas in the air, as we know it, is so small that it is liable to constant disturbance. Plants consume carbonic acid gas, animals restore it to the air. Where vegetation prevails over animal life and the consumption of fuel by man, as happens in most mountain countries and in the tropics, we should expect the proportion to be diminished; where opposite conditions prevail it should be increased; while in both cases currents in the air tend to disguise the effect. In point of fact, the few observations available on this subject are discordant, and are insufficient to establish any general conclusion as to the present state of things. But in an atmosphere containing twenty times the present proportion of the heavier gas, it can scarcely be doubted that the distribution of the gases in a vertical direction would at least approach to the condition of equilibrium. An accomplished mathematician, my friend Count St. Robert of Turin, has been kind enough to investigate the problem, and to calculate for me the proportion of carbonic acid gas which would be found at successive heights in an atmosphere at rest containing at the sea-level twenty times the present proportion. Omitting fractions, I have shown you in round numbers the approximate results in the table which is exhibited.

The proportion at the present day is taken to be five parts by weight in 10,000. In the older palæozoic times it was

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| At the sea-level | .. | .. | .. | .. | .. | .. | .. | .. | 100 | parts. |
| „ 3,000 metres, or | 10,000 | feet | above | the | sea | .. | .. | 82 | „ | |
| „ 4,000 | „ | 13,000 | „ | „ | .. | .. | 74 | „ | | |
| „ 5,000 | „ | 16,400 | „ | „ | .. | .. | 67 | „ | | |
| „ 10,000 | „ | 32,800 | „ | „ | .. | .. | 12½ | „ | | |

The proportion, which is still large up to a height of 5000 metres, then begins to diminish rapidly, and at double that height it becomes comparatively very moderate, little more indeed than has been sometimes observed in the open air, and perhaps not more than we should find at this moment in the hall where we are assembled.

But it was not only as regards the proportion of carbonic acid gas that the climate of the ancient mountains must have differed from that of the low country. Owing to the high and uniform temperature that prevailed throughout the earth, the air must have been charged nearly to saturation with the vapour of water; and these two constituents, freely allowing the passage of luminous heat, but, as we have learned from Tyndall's researches, nearly opaque to the non-luminous rays, served to maintain the constant high temperature of the lower region. But, as you have seen, different conditions prevailed on the ancient mountains, and especially in the highest regions, now scarcely habitable by organic life. The snow region on the Palæozoic Alps was probably much higher than it is now, even under the equator; in the higher zone the daily alternations of heat and cold, and the influence of the seasons, must have been almost as sensible as at present. Here, then, were conditions of existence incompatible with the organisation of the cryptogams and gymnosperms of the low country, and requiring the same adaptations of the organism to its surroundings that have resulted in the mountain floras of our own period. It is, I urge, on the high mountains of the ancient world that we should look for the origin of the higher types of vegetation, destined ultimately to prevail when the earth gradually assumed its modern condition. During the countless roll of ages that elapsed between the beginning of terrestrial vegetable life and the deposition of the coal measures, the various types of the principal natural orders were gradually differentiated in various parts of the globe, and then gradually distributed, as changes in the earth's surface offered facilities, or interposed barriers. Bearing in mind that the more strictly any species was originally adapted to the colder climate of the higher mountains, the less it will during its subsequent career have been exposed to varied physical conditions, I should expect to find that most of the genera, and perhaps a good many species, of our present mountain floras had come into existence before the close of the carboniferous epoch; and I think that the facts of geographical distribution will ultimately be found to confirm this opinion.

The period, vast in itself, yet short in comparison with the æons that rolled before, between the close of the carboniferous epoch and the later secondary period, when the more highly organised plants begin to appear in fossil deposits, would, if my views be correct, have been employed in the gradual differentiation of tribes adapted to the conditions of life at lower levels than their original home. To this period I should be inclined to refer the probable origin of many natural groups now confined to tropical and subtropical regions, which, being fitted for the then existing conditions, would have at length descended to the lower country, along with some members of earlier orders capable of adapting their development to altered conditions.

We should expect to find that the natural groups which were earliest adapted to the conditions of life in the lower region would be more widely distributed over the earth than those whose evolution in this direction was retarded; not only because the longer period of time would multiply the chances in their favour, but because they would have been able to profit by changes in the distribution of land and sea from which the late comers would have been debarred. Thus it is likely that Brazil, once a great mountain region, afterwards worn down by ages of denudation, was brought into partial relation with the African continent during the early secondary period by an archipelago extending over the equatorial Atlantic. Certain orders and genera would have thus been enabled to cross from one continent to the other, while other groups, not then fitted for the journey, would at a later period, when the archipelago had disappeared, find the ocean an impassable barrier.

During the tertiary period considerable changes of climate occurred in the northern hemisphere, and the influence of latitude upon climate seems to have become much more perceptible at low levels than it was during preceding periods. Along with these changes an increasing number of plants originally adapted only to the mountains would have descended to the plains, those possessing, so to say, the most elastic organisation being the more widely diffused. As the climate of the polar regions gradually approached that which now prevails, a certain proportion of the widely spread Alpine plants growing on mountains sufficiently near to be within the range of means of transport would have been carried to the Arctic regions and diffused more or less widely within that area, leaving behind many others, either less well suited for transport, or less adapted to Arctic conditions, which, it must never be forgotten, differ in many important respects from those of the mountains of lower latitudes.

Last chapter in the long roll of geological history, comes the glacial period. I am not concerned utterly to deny the probability of the opinion sanctioned by such names as those of Darwin, and Hooker, and Lyell, nor yet of that maintained by Dr. Christ and by Grisebach.

I could name a few plants whose present habitat on the mountains of Central Europe may probably date only from the glacial period, and there are a few others that have perhaps come in recent times from the mountains of Northern Asia; but I venture to affirm that the effects of the glacial period both on the distribution of plants and on the climate of Europe have been greatly overrated. Even during the period of maximum cold the highest ridges of the Alps were not completely covered with snow and ice; for we still see by the appearance of the surface the limit above which the ancient ice did not reach, and in the middle zone the slopes that rose above the ancient glaciers had a summer climate not very different from that which now prevails. In my opinion the effect of the glacial period on the growth of plants in the Alps was to lower the vertical height of the zones of vegetation by from one to two thousand feet. Time presses, and I cannot enter on details; but, in direct confirmation of what seems a bold assertion, I must mention an interesting discovery, due not to accident, but to the sagacity of the eminent Italian geologist, Stoppani. Reflecting that at the period of their maximum extension, when the glaciers filled the main valleys of the Alps, small lakes must have been formed by the damming of the streams from lateral valleys, and that such lakes might probably contain organic remains of the animals and plants of that period, Stoppani set himself to search in suitable localities, and was rewarded by finding several examples of the kind in the valleys of the Lombard Alps.* From one of these, along with remains of animals, were taken those of the sycamore, box, mountain elm, and yew, along with one or more leaves which are supposed to belong to an undetermined species of magnolia. Another deposit of the same period has produced remains of the chestnut, spruce fir, hazel, *Trapa natans*—a water plant now rare in lakes in Italy, but commoner on the north side of the Alps—and a walnut, which I believe to be no more than a variety of the common cultivated tree, no longer growing wild in Europe. It must indeed be admitted that during the glacial period the exceptional conditions that give to these islands, and to Scandinavia, an unnaturally mild climate, no longer prevailed, and that increased rainfall, with a moderate diminution of the mean temperature, caused a great extension of glaciers on all the mountains of Northern Europe; but that the climate of Middle Europe was such that the plants of the high Alps could spread across the plains seems to me an improbable supposition.

I fear that I have left myself no time to discuss a branch of my subject which would, I think, enable me to strengthen very much the presumptions in favour of the theory which I have ventured to lay before you. The geographical distribution of plants is a vast subject

* See Stoppani, 'Corso di Geologia,' Milan, 1871–1873, vol. ii. pp. 662, 669. The first locality mentioned is at Pianico in Val Borlezza, near the Lake of Iseo; the second is near Leffe in Val Seriana. Both are at about 1000 feet above the present sea-level.

which can scarcely be touched at all without entering into much detail. It divides itself into many different branches, and I can merely mention some of the leading facts, and trust to your perceiving how closely they bear on the main argument.

If the existing genera and natural orders of plants had been differentiated in modern geological times, during which it appears pretty certain that only one considerable change has taken place in the arrangement of land and water on the earth; we should expect to find some approach to uniformity in the way in which they are distributed throughout the world, since similar causes must have operated during the greater part of the period of their existence. The contrary, however, is the case. A botanist studying the distribution of the widely spread types of vegetation without any previous theory to disturb his mind, would be led to infer the most diverse relations between the main continental masses. Allowing for a large amount of possible extinction of some types in certain areas, the facts seem to me to suggest the probability that vast intervals of time, with corresponding changes on the earth's surface, intervened between the dates at which different orders and conspicuous genera have spread over the world.

I have exhibited to you rough maps, showing the distribution of land and water in Central Europe during three geological periods—those of the oolite, the chalk, and the middle tertiary. It would require an entire additional lecture if I were to attempt to illustrate in detail the bearing of the facts shown in these maps on the relations between the floras of the Alps, the Pyrenees, the Carpathians, and that of another mountain group of which for lack of time I have said nothing—that of the Balkan Peninsula. There are unexpected relations between the floras of different parts of this region, and contrasts between districts not far removed, that are equally unexplainable on the supposition that the existing flora is of geologically modern origin, and therefore of still more recent distribution.

The contrasts shown by the vegetation of neighbouring mountain groups, and even by different portions of the same group, show that a very large proportion of the Alpine flora is not easily diffused by existing means of transport; while the appearance of the same species at very distant points seems to show that its diffusion dates from a time more remote than the earliest shown on the maps before you. You will observe that whatever obstacles now interpose to limit the distribution of plants between the several mountain groups which I have mentioned, must have been intensified during the preceding geological periods, when the present continent was deeply indented by profound bays or broken up into an archipelago. Yet we find several curious instances of the presence of the same species at very remote points, such as a peculiar and very distinct Alpine gentian,* found only in the eastern

* *Gentiana pyrenaica.*

Pyrenees, the north-eastern Carpathians and in Asia Minor, and many species common to the Pyrenees and the eastern Alps, but wanting in the intermediate region.

Equally remarkable is the presence of several species of the genus *Ramondia* in the Pyrenees, in Servia, and in Thessaly, and of an allied genus represented by a single species in the Rhodope Mountains, of late so familiar to your ears. These are the only European representatives of a natural order, one tribe of which, mainly tropical American, is largely developed in the Andes, while the other, to which our outlying European species belong, extends round the whole world, chiefly within the tropics, its mountain types being mostly seen in the Himalaya. It seems probable that the distribution of such species and genera as these was originally effected by the simultaneous or successive elevation of contiguous portions of the great axis of high land that traversed the northern hemisphere in the old world, and that a vast interval of time has since elapsed during which the connecting forms have been extinguished.

I shall notice but one other point connected with plant distribution. If there be any truth in the views that I have been endeavouring to lay before you, we should expect to find that the richest floras, those showing the greatest variety and the largest number of peculiar species, would be found on those mountain masses that have remained at least partly elevated above the sea-level since a remote geological period. No doubt tracts that have been gradually elevated in contiguity with others that may have undergone subsidence would receive from the latter a portion of their vegetable inhabitants; but, as a general rule, any considerable migration of a flora would almost certainly involve the extinction of many species, and the immigrant flora would be poorer than that of the region whence it was derived. For reasons sufficiently explained by Darwin, we should also expect the utmost variety in a region where neighbouring mountain masses had for some long period been isolated, so as to form a group of islands, surrounded by marine channels sufficiently broad to prevent much mutual transport.

It is very remarkable to what an extent this anticipation is confirmed by facts. However great the changes of level may be that have occurred in the Alps, it is sufficiently certain that a portion of the eastern Alps has remained above water since palæozoic times, and highly probable that the same is true of the south-western part of the chain, these, as is well known, possessing a far richer flora than that of the central range. Professor Ramsay has well pointed out that although part of the Alps was elevated 4000 feet during the middle tertiary period, the height of the chain before that event may probably have been as great as it now is; and similar reasoning applies, with more or less force, to other elevatory movements in high mountain chains. With a very few apparent exceptions, all the mountains known to

possess rich and varied floras, with many endemic species, are portions of ancient continental masses that have been at various periods isolated, but never utterly submerged. This holds true of the Pyrenees, the Carpathians, the mountains of the Balkan Peninsula and Greece, and of the Caucasus, while the two regions possessing the richest known mountain floras, Spain and Asia Minor, were for long periods archipelagos whereon the ancient flora was preserved, but subjected on separate islands to much specific modification. On the other hand, we can explain the comparative poverty of other regions by the fact that they have been raised from the ocean within comparatively modern times. Of such, Italy and Sicily supply remarkable examples. It is not a little curious that the comparatively few endemic mountain plants of Italy are found on the Apuan Mountains, which, while the peninsula had not yet been raised from the sea, formed a small island since the early secondary period, and again in parts of the southern Apennines, whose date is probably the same. The apparent exceptions presented by Scandinavia and the British Islands are accounted for by the fact that both appear to have been almost completely submerged, during a comparatively short period, since the deposition of the newer tertiary deposits. As far as I can ascertain, the same connection between a rich flora and the preservation of ancient land holds true in the more distant parts of the world; but there are two remarkable apparent exceptions in the Canary and the Sandwich archipelagos. It seems impossible to account for the peculiarities of the floras of either group without supposing continental connection, or at least some approach to it, at a possibly remote period; but from further discussion of that, as well as many other topics, I must abstain.

Some of those present who may take the pains to consider the arguments that I have laid before you to-night, may possibly object that on very many points the evidence is incomplete, and therefore inconclusive. To that objection I can make no valid reply. During many years in which I have sought to find some solution for the problems presented by mountain vegetation, I have constantly encountered fresh difficulties, due to the imperfection of the available evidence. The tendency to draw positive conclusions from negative evidence is a constant danger for scientific men, and though I may have been on my guard, I cannot be sure that I have escaped it. It is at least certain that until our planet is far more fully known to us than it is, we are constantly liable to error when we assume that anything is not because it has not yet been observed. The task of further exploration and observation must be left to the younger generation, and such a discussion as that of this evening will not be fruitless to science if it stir up recruits to aid in the work, and increase our store of knowledge by fresh facts, whether these serve to confirm or to negative the views of its author.

Before I close, let me give you an example which may serve to show

of how much practical value a single casual observation, such as frequently falls in the way of every traveller, even in Europe, may sometimes be. There is a little flower not uncommon in Norway and the north of Scotland, called *Trientalis*, remarkable because it is the only European plant that, as a rule, has seven stamens, and a corolla with seven divisions. Twenty years ago it was known in the Alps only in two places in the north of Switzerland, and the eminent naturalist, Oswald Heer, mentions it as a plant which must have been carried to the Alps during the glacial period, but which had been unable to extend itself in the new territory. Not long after the appearance of Heer's work, while descending some steep rocks in one of the most unfrequented corners of the southern Alps, within some five hours' walk of the olive and lemon groves of the lake of Garda, I was surprised and delighted to espy the seven-rayed stars of the *Trientalis* issuing from fissures in the granite. About the same time the same species was found in a valley of Friuli, some 80 miles further east, and it is now known in one of the central valleys of Tyrol, and at another point far away in the western Alps of Savoy. Thus a few casual observations have completely altered our ideas as to the probable origin of this plant in the Alps; instead of being a modern intruder, we must now look upon this as one of the ancient families of the country, suffering from untoward circumstances, and threatened with total extinction.

If useful contributions may thus be had from comparatively well-known places in Europe, what large additions to our knowledge may we not expect from men like the members of this Society, who visit new and little-explored parts of the earth? Especially do I solicit their attention for those humble plants that dwell in the highest region of lofty mountains, springing from crevices in the rocks, or fringing with bright colour the edges of the snow-field. Every addition to our knowledge of these is a direct contribution to the ancient history of the earth, and may guide us in the difficult task of reconstructing the record of organic life. It will not diminish the interest of the search if you believe with me that these organisms, exempted from the vicissitudes to which the ancient vegetable world was exposed, may represent the earliest forms of the higher types of plant life; and even that some of the identical species that now adorn the Alpine heights may, during the inconceivably long lapse of geological ages, have looked down unchanged on the revolutions that have slowly destroyed and renewed the various forms of life on the surface of our planet.

Sir Joseph Hooker proposed a vote of thanks to Mr. Ball for the very clever lecture he had delivered. That lecture had given the results of an experience and knowledge of Alpine plants which was certainly not equalled by anyone else in this country, if by anyone in Europe. To this Mr. Ball had added great research, and no small amount of constructive, and it must be acknowledged destructive, ability. His idea of correlating the general features of the Floras of Europe and Asia, and showing how much might be done by travellers in following up the question of the

distribution of Alpine plants in distant countries, was a very happy one. He had done so partly in the hope that the members of the Alpine Club, of which he was for so long the able President, would make as good use of their heads as they hitherto had done of their heels. He had shown how little was known of the constitution of Alpine plants, even of those with which we are most familiar, and many members of the Geographical Society could do essential service to the progress of science in respect of the distribution and conditions under which Alpine plants now grow, by following Mr. Ball's suggestions. He (Sir J. Hooker) felt more difficulty in dealing with the speculative portions of the lecture. On one point at least he must correct an impression which he gathered from what the lecturer had said. Neither Mr. Darwin nor Professor A. Gray nor himself had ever dealt with the problem of the birth-place of the species composing the Arctic or Alpine floras. They had been content to follow the comparatively tame process of taking the plants under the conditions in which they were now placed, and following them in their later migrations to the positions they now occupy. Everyone who lived in London knew the effects of carbonic acid gas on the human frame, and whether or not it was caused by the amount of that gas that Mr. Ball had dealt with, his speculations on the origin of the Floras in question, as affected by the presence of that gas under former conditions of the globe, had really taken his (Sir J. Hooker's) breath away. Nevertheless, there could be no question that speculations, however wild they might appear, so long as they were not in opposition to known facts, were legitimate and worthy of scientific consideration and study. No doubt the attention of palæontologists and physicists would be called to the brilliant and bold speculations which Mr. Ball had advanced, and thus much light might be thrown upon the subject of the conditions under which the European Flora had first appeared.

The PRESIDENT, in seconding the motion, said he should not attempt to add anything to what had been said by Sir Joseph Hooker, because remarks by such an authority could not be added to by anyone who, like himself, could only claim to have a very superficial knowledge of the subjects treated in the lecture.

## GEOGRAPHICAL NOTES.

**Mr. Keith Johnston.**—It is our painful duty to announce the death of this distinguished young geographer, the leader of our East African Expedition, which occurred on the 28th of June, at Berobero. An account of his life and works is given in the obituary, p. 598. We are informed by Dr. Kirk that the Expedition has gone on, under the command of Mr. Thomson, and that it had passed beyond the reach of letters or messengers.

**Progress of the Belgian International Expeditions.**—We learn from Zanzibar that the first Belgian expedition, under Captain Cambier, has been ordered to proceed to Nyangwe in Manyema, there to form the second station, or centre of exploration and civilising influence, according to the scheme of the International Association. M. Cambier broke up his camp in Unyanyembe about the middle of April, and resumed his march towards Ujiji viâ Uyowa, south of the Gombe, but with a diminished party, as Dr. Dutrieux, his assistant, was about to return to Zanzibar. The first station is to be occupied by Captain Popelin, Lieutenant Dutalis, and Dr. Van den Hoevel, and will be situated on