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BOTANICAL GEOGRAPHY

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ELEMENTARY LESSONS

IN

BOTANICAL GEOGRAPHY.

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PREFACE.

THESE Lessons are reprinted from the 'Gardener's Chronicle,' with slight alteration. They were drawn up because there is not already in existence, in any language, any elementary hand-book of Geographical Botany suitable for educational purposes; and the writer felt that it was extremely desirable that gardeners and other learners in biology should be encouraged, as much as possible, to acquire comprehensive and correct ideas of the laws and leading facts of plant-distribution. In the class which he had particularly in view it was intended that each Chapter should form the foundation of a lesson of an hour's duration; and the detail entered into with regard to each subject, unless it be that of the last Chapter, has been compressed within the limits necessary on this plan.

J. G. BAKER.

Richmond,

August, 1875.

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ELEMENTARY LESSONS

IN

BOTANICAL GEOGRAPHY.

Introductory Propositions.

THE distribution of plants over the world at the present time depends principally upon three causes, which are :—

I. Climate, or the way in which heat and moisture are at present spread over the globe.

II. The influence of man in spreading some kinds, and voluntarily or involuntarily restricting the distribution of others.

III. Their past history, or the times and places when and where they have been created or differentiated, and the way in which sea and land, heat and moisture, have been distributed in former times.

First, then, we have climate to consider under the two heads of Heat and Moisture. The distribution of heat over the world depends upon three causes, viz. :—

1. The position which a place occupies with regard to the sun whilst the earth makes its annual revolution.

2. The distribution of the masses of sea and land in its neighbourhood.

3. Its height above sea-level.

CHAPTER I.

On the Heat of a Place as produced by Latitude.

A CIRCLE is always spoken of as divided into 360 degrees. For the earth, in the direction from the equator to the pole, we call these degrees of latitude. Taking the round of the circle in the direction in which the earth moves upon its axis in its daily rotation from east to west, we call them degrees of longitude, and begin to count from Greenwich. Between the equator and the pole at each end we have a quarter of the circle, or 90°. At the spring and autumn solstices—that is to say, near the end of March and of September—the sun is directly opposite the equator as it makes its daily circuit, and day and night are equal all over the world. But the axis of the earth—a line drawn from pole to pole—changes its position with regard to the sun, and to the path of the earth's orbit from day to day. This produces only a small difference in the relative positions of the sun and the equatorial regions, but a great difference in the relative positions of the sun and the country round the poles. This movement of the earth's axis is what produces the great difference which in this country we see and feel between winter and summer. At midsummer the earth moves round the sun opposite a line 23½° north of the equator, which we call the tropic of Cancer. At Christmas it moves round the sun opposite a line 23½° south of the equator, which we call the tropic of Capricorn. Within these tropics the sun at mid-day is always nearly overhead. It rises and sinks without any interval of twilight, and there is very little difference in heat and light between one season and another. At midsummer the sun is directly opposite a line 23½° north of the equator, and consequently so much nearer all points north of the tropic of Cancer, and so much further away from all points south of the tropic of Capricorn. At midsummer we get in the southern part of the north temperate zone nearly as much heat as they are getting at the equator, and in England the day is twice as long as the night. At this time, as viewed from the north pole, the sun does not sink below the horizon for several months together, whilst the heat and light which the northern hemisphere is getting in excess the southern hemisphere has lost, and for just as many months at the south pole the sun is never seen. At Christmas, on the contrary, the sun moves round the tropic of Capricorn, and the condition of things is reversed: their summer is our winter, and their spring is our autumn. At Cape Town it has been shown, by a series of observations continued through several years, that on the average the hottest day in the year is the 4th of January, and the coldest the 6th of August. So that the heat which any place in the world gets, and the course of its seasons, depends largely and primarily upon latitude. The difference between being exposed to a sun shining overhead for twelve hours, and for eight hours to a sun whose rays strike the earth with a moderate degree of obliquity, makes a greater difference than there is between a midsummer day in England and a Christmas day in England.

By geographers the earth is commonly treated as divided into three zones of heat and latitude—a torrid, temperate, and frigid zone. The torrid zone is the district that extends upon both sides of the equator to the two tropics. Over every place within this central belt of 47° of latitude in breadth, the sun is directly vertical at some period of the year, and never far from overhead at mid-day at any season. The temperature of this torrid zone does not vary in the shade from a daily average of from 75° to 90° of Fahrenheit's thermometer from one end of the year to the other. The principal difference in heat is not between summer and winter, but between day and night, between shade and exposure. At Bombay, in 18° north latitude, the daily temperature in the shade rises to an average of 85° at 1 o'clock in the afternoon, and sinks to 75° at 6 o'clock in the morning. In exposed places of course the heat registered in the shade is enormously increased. In the full blaze of sunlight it often rises on the ground to 120° or 130°. It was measured by Sir John Herschel at the Cape up to 159°. In the arid regions of Central Australia, Captain Sturt says that it is sometimes so hot that a match dropped on the soil instantly catches fire. For purposes of Botanical Geography it is very important that the great difference between shade temperatures—which are those that are always given in tables—and the heat that is reached in exposed places, should be carefully kept in mind.

Humboldt invented a plan of connecting together upon a map those places which have the same average annual temperature in the shade, by what he called isothermal lines or isotherms. These isothermal lines run round the world nearly, but by no means exactly, parallel with the lines of latitude. The isotherm of the equator is about 82° Fahr., and they do not sink more than 5° to the tropic in each direction. The temperate zone reaches from 23½° from the equator to 23½° from each pole, so that it is 43° of latitude broad in each hemisphere.

For purposes of Botanical Geography and climate, it is needful to divide the temperate zone of geographers into two—a warm temperate or sub-tropical and a cool temperate zone, because the climate within its bounds varies so greatly. In the north hemisphere Europe, Asia, and America all extend beyond the cool temperate zone into the frigid or arctic zone; in the southern hemisphere Africa, Australia, and New Zealand do not stretch beyond the warm temperate zone, and the South American continent does not nearly reach the arctic circle. As we cross these temperate belts in the direction of the poles, these isothermal lines fall rapidly, the fall growing faster and faster, and the lines consequently closer and closer, as we get into more polar latitudes.

The average annual temperature of Naples is 63°, of Paris 51°, of London 49°, of Stockholm 42°, of St. Petersburg 38½°. In Central Europe one degree of latitude further north is equal to the lowering of average annual temperature one degree of Fahrenheit's thermometer. In England the difference in the temperature of the air in the shade, between day and night, amounts to 13° or 14°; on the ground, in the night, the minimum is 7° or 8° below that of the air, and in exposed places the daily maxima are on average 20° above what they reach in the shade. In the north temperate zone, through the influence of the Gulf Stream, the temperatures of the western shores of Europe are raised all through the year materially above their proper average, — a circumstance which in England makes a great difference in our daily comfort. Virginia, where the annual temperature is 56°, is opposite Lisbon, where it is 62°. Quebec, where the annual average is 42°, is 5° of latitude south of London, where it is 49°, and is opposite the south of France. We may estimate that in Britain and the rest of Western Europe we get, month by month through the year, 10° of heat brought from the tropics by the Gulf Stream, and added to what we get direct from the sun.

But this lowering of the yearly averages is only one point of difference between the temperate and torrid zones. As we cross the temperate belt in the direction of the arctic circle, the difference in heat and light between summer and winter grows greater. It is not until we get at least 10° across it that we ever get snow or ice or hoar-frost at sea-level. In the warmer half of the temperate zone the thermometer never sinks below 32°, and there is no such thing as winter in the sense of a check to vegetation. As we proceed northward, through the cooler half of the temperate zone, snow and ice become more and more abundant, and continue for a longer time, till at the arctic circle we reach a belt where the period of vegetation does not last for more than three months out of the twelve. The arctic zone is reached in the northern hemisphere by land in all the three great continents, but in the southern hemisphere only by the perpetually snow-bound, plantless, antarctic continent. Throughout all its southern, and the greater part of its northern area, there is perpetual snow and ice; man cannot live there, plants cannot grow there, and at the very pole it is supposed that the average annual temperature sinks to Fahrenheit's zero. It is only in a limited part of the arctic zone, principally in a tract in Lapland, that comes under the favouring influence of the Gulf Stream, that any cultivation can be carried on, and that any considerable population can permanently reside. At the north end of Lapland the ground is covered with snow for nine months out of the twelve, and there is continuous day for three months in summer, and continuous night for three months in winter.

At Spitzbergen, in latitude 76°–80°, the sun never rises above the horizon from October 22nd to February 22nd; the average temperature of the three warmest months of the year, taken together, is 34°, and the whole period of vegetation does not last for more than six weeks—beginning in an average year late in July, continuing through August, and ending when September begins.

CHAPTER II.

On the way in which the Distribution of Sea and Land influences the Distribution of Heat.

It is estimated that at least a third of the heat of a vertical sunbeam is absorbed in traversing a cloudless atmosphere before it reaches the sea-level. The more obliquely the beam is received at any point of the earth's surface the greater is the proportion of the heat that is lost. The remainder is absorbed in the air, and although it helps to keep up the general temperature, its effect is to a great extent lost in the upper regions. If there be any haziness or cloud in the air, the effect of the sunbeam on the earth's surface is lessened. In a cloudy sky nearly the whole effect of the sun's heat is spent in warming the air and evaporating the clouds. From this it results that the heat which any tract of country gets depends largely upon the habitual cloudiness or clearness of its atmosphere. Out of 197,000,000 square miles of the earth's surface, 145,000,000 are at the present time taken up by sea, leaving only 52,000,000, or rather more than a third, for the land. Heat acts upon land and water in very different ways. Upon the land the surface in a hot sun becomes intensely heated, but the heat does not penetrate far below the surface, and is not stored up for future use. In Britain the extremes of temperature during the year, which in the air in the shade show a difference of 70°, 80°, or even 90°, are, at 3 feet below the surface, not more than 15° or 20° apart, at 25 feet only 3° or 4°, and at a depth of 50 feet are reduced to nothing. But the heat which falls upon the sea is differently treated. It penetrates the surface to a moderate depth, and is absorbed internally. Water is eminently a non-conductor of heat, so that what is received into its substance is diffused again mainly by agitation, and as this, however violent at the surface, diminishes fast as we sink downwards, the heating-up of a great body of water is a slow process. At a certain depth, varying with latitude, the sea is at a uniform temperature of 39° all through the world. At the equator this temperature is reached at a depth of 7200 feet. Rising in level gradually, it reaches the surface in latitude 56°, the parallel of the Shetland Islands, and there, superficial currents apart, the sea is of a uniform temperature at all depths. Going towards the poles this isotherm of 39° sinks again below the surface, and at the arctic circle has already reached again a depth of 7000 feet. So that, taking the 56th parallel of latitude in both hemispheres as a boundary line, the sea is divided into three basins—one equatorial, in which the temperature falls from above to below, and two polar basins, in which the temperature rises as we descend. The average general temperature of the superficial sea at any parallel of latitude does not differ appreciably from that of the annual average of the air in the shade at the same place. At the equator it is scarcely ever known to rise above 85° in the day and to sink below 83° in the night. As we advance into the temperate zone, where there is a great difference between the heat of the air at different seasons, the sea exercises an important influence. It absorbs heat during the day, and gives it off during the night. It absorbs heat during the summer, and gives it out during the winter, and thus lowers the temperature of the summer and raises that of the winter in its neighbourhood. It was found from a series of observations made by Dr. Cooke at Scarborough, during 1853–4, that the average temperature of the sea was 5½° above that of the air in the shade in December, that it was 7° below it in July and August, and that the two were upon an equality at the end of October and the end of February. We find that, in actual practice on a broad scale, the sea exercises a very important influence in cutting off the extremes of temperature in both directions,—in moderating alike the cold of winter and the heat of summer. In this way we get the climates of the temperate zone separated into two classes—insular climates, marked by a comparatively small difference between winter and summer (or, as it is called in technical meteorology, a small hiberno-æstival variation), and continental climates, in which terrestrial radiation has full sway in both directions, and the difference between winter and summer is large. The influence of nearness to a large mass of ocean is modified by the habitual cloudiness or clearness of the atmosphere of the country, and by the prevalent direction of the wind; but, as the same nearness to the sea which cuts off the extremes of temperature tends also to produce cloudiness, this does not much affect the actual result. Britain furnishes a typical illustration of an insular climate, and there is even an appreciable difference in the annual range of temperature between the west side of the island, which is nearest the great mass of the Atlantic, and the eastern counties, which are nearest the European continent and comparatively small German Ocean. In Cornwall, Devonshire, and the West of Ireland, the annual temperature is 51°–52°, the difference between January and July 20°–21°, and between the average of the three months of summer and the three months of winter 14°–15°. At Greenwich the annual average is 49°, the difference between January and July 25°, and between summer and winter 20°. In the northern island of New Zealand the annual average is 52°, and the difference between January and July 14°. At Cape Town the annual average is 59°, and the difference between January and July 16°. But take a tract in the interior of one of the great continents, and mark the difference. At St. Petersburg the annual average is 38½°, and the difference between the three months of summer and the three months of winter 46°. At Moscow the annual average is 39°, and the difference between January and July 54°. At Montreal the annual average is 44°, and the difference between January and July 52°. On the north-west shores of Hudson's Bay the annual average is 11°, and the difference between January and July 70°. At Yakutsk, where in the heart of the great Asiatic continent occurs the most extreme case of a continental climate that is known, the difference between January and July is said to rise to 100°. We have examples of climates neither characteristically insular nor continental in Spain, France, and Palestine. South of the tropic of Capricorn there are only 4,000,000 square miles of land against 28,000,000 north of the tropic of Cancer; and, as in the southern hemisphere the land is cut up into three pieces, the difference between insular and continental climates has little scope to operate in the south temperate zone; but in the north temperate zone it amounts to this,—that whilst in the insular climates the coldest month of the year falls only 8° or 10° below the annual average, and the warmest month rises only 8° or 10° above it, in the continental type of climate the difference amounts to 25°, 30°, or even 40° or 50° in each direction.

These are all average temperatures in the shade; but there is another point which it is important for us to consider in this connexion, and that is the influence which the sea exerts in cutting off those extreme falls of temperature in winter which are so harmful to plant life. To take an illustration from England:—It was found that during the exceptionally cold night of the Christmas of 1860 the thermometer sunk at Helston to 32°, at Ventnor to 24°, at Scarborough and Liverpool to 16°, at Whitby to 10°, at Shields to 6½°; but inland, at Wakefield, to 2° below zero, at Manchester to 3° below zero, at York to 4° below zero, and at Nottingham to 8° below zero. Here the mitigating influence of nearness to the sea is found to be considerable, but it does not seem to extend more than a few miles inland.

The following list, the figures in which represent monthly average temperatures at sea-level, will give an idea of the heat of the world, as influenced by latitude and nearness to the great ocean masses:—

	Latitude.	January.	July.	Difference between the two.
Torrid or Tropical Zone.	°	°	°	°
Nubia	17-23	68	98	22
Gold Coast	5	79	77	2
Madagascar	11-25	79	72	7
Ceylon	8-10	77	81	4
Mocha	12	77	90	13
Jamaica	18	77	81	4
North Brazil	0	79	77	2
North Temperate Zone.				
Europe and Africa.				
Barbary States	30-36	50-59	77-90	27-31
Spain	36-45	41-50	68-77	27
France	43-50	32 41	64-74	32
Central Europe, from Black Sea to Baltic	45-55	23-32	63-72	40
England	53-55	32-41	50-63	22-27
Moscow	56	14	65	51
Christiania, Upsala, Stockholm	60	23	61	38
Archangel	64	5	59	54
Iceland	64-66	32	50	18
Asia				
Palestine	31-33	50-59	80-85	26-30
Pekin	40	26	77	51
Bogolowsk, foot of Ural	60	5	59	54
Yakutsk	62	-40	61	101
America				
New Orleans	30	59	82	23
Baltimore	39	32	73	41
Montreal	45	18	70	52
Fort Vancouver	50	34	65	31
North-west shore of Hudson's Bay	65	-26-22	44-55	70

	Latitude.	January.	July.	Difference between the two.
South Temperate Zone.	°	°	°	°
Valparaiso	33	68	54½	13½
Buenos Ayres	35	72	54½	17½
Cape Town	35	75	59	16
Sydney	35	70	50	20
New Zealand, north island	35-42	59	45	14
Van Diemen's Land	40-43	59	42	17
New Zealand, south island	41-46	55	41	14
Cape Horn	55	42	34	8
Frigid Zone.				
Spitzbergen	..	5	40	35
Tornea, Lapland	..	5	59	54
Kotzebue's Sound	..	-4	50	54
East coast of Greenland	..	5-14	36-41	30
Arctic Siberia, 130°-140° E. longitude	..	-40	54-59	97

CHAPTER III.

On Heat as influenced by Height above Sea-level.

THE ocean of air in which we live covers sea and land alike, and reaches over the top of the highest mountains. In our latitude at sea-level it balances a column of mercury 30 inches in height. The weight of the column of atmosphere that presses on each square inch of the earth's surface is calculated at between 14 lb. and 15 lb. avoirdupois. A cubic foot of dry air weighs 1¼ oz., so that, were the atmosphere of equal density throughout, its top would be reached in about five miles, a height which is exceeded by the Andes and Himalayas. Such, however, is not its real constitution. Each stratum of air, as we ascend from the earth's surface at sea-level, bears only the weight of the column above it, and being less and less pressed, occupies therefore more and more room in proportion to its weight. This gives us a ready means of measuring heights by the barometer. It is found in round numbers that the column of mercury falls an inch when we climb a hill of the height of 900 feet; and we may easily see, by means of the clock-like faces of our ordinary barometers, that there is a change in the level of the column of mercury equal to the twentieth part of an inch when we carry the instrument from the ground-floor to the top storey of a house fifty feet in height.

With the decrease in the density of the air there is also a regular fall in its temperature. Upon first consideration it would seem likely that the nearer we got to the sun the hotter we should be, and that the tops of the equatorial mountains ought to be the hottest places in the world. But in quitting the earth's surface we are quitting the neighbourhood of a heated body which is fast diffusing its heat by radiation, and are interposing more and more of a medium obstructive of heat between ourselves and the heated surface. It is probable that the temperature of the inter-planetary spaces reaches a degree of cold far beyond what our utmost conceptions can enable us to realise. We have already seen that in the equatorial zone, in clear weather, twice as much of the heat of the sun's rays is received by the earth as by the atmosphere. A large proportion of this is diffused near the great mass of the earth and there absorbed. By a great number of observations which have been made to settle the question, we learn that the rate of decrease in temperature as we ascend mountains may be fairly stated at 1° of Fahrenheit's thermometer for every 300 feet of elevation. So that in the middle of the north temperate zone an elevation above sea-level of 300 feet makes a place as much colder as if it were seventy miles further north. A hill in Surrey 1000 feet high has the same temperature as a place at sea-level in Northumberland. A hill in the Mediterranean basin 10,000 feet high, like Etna, has the same average temperature as a place near sea-level on the arctic circle. This circumstance is well illustrated by the fact that even within the tropics, when we climb a mountain that is high enough, we reach a zone of perpetual snow and ice. This circumstance modifies extremely the heat which different parts of the world possess in virtue of latitude, and makes the distribution of heat, in its relation to the spread of plants, not a matter that is complicated in its principles, and therefore hard to understand, but one in the application of which it is needful to learn and bear in mind a crowd of details.

In regions, therefore, which are equatorial by latitude, we pass through zones of climate corresponding to the warm-temperate, cool-temperate, and arctic in latitude before the snow-line is reached, and in this way sometimes get in a limited tract of country all the variations in average annual temperature which there are in the whole world, each zone inhabited by the plants that are fitted for that particular climate.

The zones of heat, therefore, as they really apply to the earth's surface, may be sketched out and characterised as follows, beginning with the warmest and proceeding outwards and upwards towards the poles and the mountain-tops :—

1. *A Torrid or Intertropical Zone*, including all the land within the two tropics up to about 5000 feet in height, with an average annual temperature of 75° to 82°, and summer rising but little above, and winter falling but little below, the annual average.

2. *A Warm-temperate or Subtropical Zone*, including all the country at sea-level to where snow and ice come to the extent of making a winter which is really appreciable

in the sense of a check to all vegetation. In the southern hemisphere this includes Natal and all Cape Colony except the hills, all extra-tropical Australia and Van Diemen's Land except the hills, the whole of New Zealand except the hills, and in America, La Plata, Buenos Ayres, the southern provinces of Brazil, and the whole of Chili, except the Andes. In the northern hemisphere it extends in Europe to about the 45th parallel of latitude, but in Asia and America scarcely beyond 35°, reaching up to about 5000 feet in the eastern, and 3000 feet in the western Himalayas, but not beyond them to the Tibetan plateau. So that north of the tropic of Cancer it includes the southern half of California, North Mexico, Texas, the southern United States, Barbary, Egypt, and the rest of the Mediterranean basin, Asia Minor, Persia, the northern half of Arabia, the southern half of China, and India except the Peninsula. In tropical Africa the hills of the head of the Nile, Guinea, and Abyssinia reach into it and beyond it; in tropical America the mountains of Brazil and Guiana reach into it, and the Andes far overtop it; in Asia the Neilgherries and hills of Ceylon reach into it, and those of Java and Sumatra overtop it; and in Polynesia those of the Sandwich Islands far overtop it. The average annual temperature may be said to vary in round numbers from 75° to 60°, or even 55°, with the warmest month rising in the continental climates of the northern hemisphere (Barbary, Arabia, Gangetic plain) to nearly or quite as high as in the torrid zone, and the coldest month (January or July, as the case may be) not sinking below an average of 45° or 40°.

8. *A Cool-temperate Zone*, with an average annual temperature of from 60° to 40°, a winter low enough at sea-level to give a decided check to all vegetation, and a summer rising at least high enough to ripen the common cereal grains, Wheat, Oats, Rye, and Barley. In the northern hemisphere it stretches at sea-level from about the 45th parallel of latitude in Europe, and the 35th parallel in Asia and America, up to the arctic circle. So that it includes Iceland, the British islands, the Scandinavian peninsula, Denmark, the northern half of France, all Central Europe north of the Alps and Carpathians, the whole of the great Russian empire, except a narrow arctic belt, the great central plateau of Asia, the northern half of China, Japan, in America a large part of California, the Northern United States, Canada, and the British possessions up to the arctic circle. In the southern hemisphere it includes at sea-level only Patagonia, Terra del Fuego, and a few small islands, such as the Falklands, Marion Islands, and Kerguelen's Land. In the zone warm-temperate by latitude a great many mountain ranges rise into it; in Europe the Pyrenees, Sierra Nevada, Apennines, and the hills of Corsica and Greece; in Africa, the Atlas and peaks of the Canaries; in Asia, the Himalayas up to 10,000–12,000 feet; in America, the Andes of Mexico and their northern continuation in the Rocky Mountains; in the southern hemisphere, the Andes of Chili and mountains of Cape Colony, New South Wales, Victoria and Van Diemen's Land; and in the intertropical zone, the Andes, Camaroons, mountains of

Abyssinia, and the head of the Nile, and some of the Malayan and Polynesian peaks.

4. *An Arctic-alpine or Frigid Zone*, extending at sea-level from the arctic circle to the region of perpetual snow, with an average annual temperature of from 40° down to 32° or 30°, with its upper limit upon the mountains the line of perpetual snow, and its lower the line where cereal cultivation commences. In arctic latitudes this zone has a very short period of vegetation, but this character does not apply so fully where it forms a belt upon mountain ranges rising out of the warmer zones. In Lapland there is a little corn cultivation within the arctic circle; but here the heat is raised by the same exceptional circumstances that make the climate of Britain 10° warmer than corresponding latitudes in America. In the Himalayas and tropical mountains the snow-line is 15,000–17,000 feet above sea-level; on the Alps, Caucasus, Apennines, and Pyrenees, 9000–10,000 feet; in the south of Norway, 5000 feet; and in Iceland and Lapland, 2000–3000 feet. In the Andes cereal cultivation commences at 12,000–13,000 feet, in the Himalayas at 10,000–12,000 feet, in the Alps and Pyrenees at 5000–6000 feet, and in Britain at 1500–1800 feet.

5. *A Zone of Perpetual Snow and Ice*, into which no vegetation reaches, extending at sea-level round the two poles, and into which stretch a long sweep of the Andes, Himalayas, Alps, Rocky Mountains, Dovrefeld, and the peaks of Mount Kilimanjaro, the Sierra Nevada, Pyrenees, Balkan, Caucasus, Altai, Lebanon, Ararat, and many more northern ranges.

The following list of heights and diagrams are intended to help the mind to realise the details of the area and distribution through the world of these zones of heat :—

Approximate Heights of Mountain Ranges, &c., in English Feet.

Europe and North Africa.—Alps, 15,739; Pyrenees, 11,168; Iceland, 5927; Tyrol, 12,822; Auvergne, 6188; Sierra Nevada, 11,483; Apennines, 9521; Corsica, 8767; Etna, 10,874; Greece, 9628; Carpathians, 9912; Schnehatten, Norway, 8120; Ben Nevis, 4380; Snowdon, 3557; Pass of St. Bernard, 8110; Atlas, Marocco, 11,400; Peak of Teneriffe, 12,172; Pico, Azores, 7613; Balkan, 8874.

Temperate Asia.—Kinchinjunga, Sikkim, 28,178; Mount Everest, Nepaul, 29,000; Deodunga, Nepal, 29,002; peak north of Cabul, 20,232; plateau of Tibet, 11,500; great plateau of Central Asia, 4000; Caucasus, 18,493; Ararat, 17,112; Fusí-no-yama, Japan, 12,443; Altai, 11,062; Horeb, 9517; Sinai, 7498; Ural, 5397; Ladak town, Tibet, 9915; Darjeeling, 7165; highest villages in Kumaon, 13,000; Guwahir, Kumaon, 25,669; Demanend, Persia, 21,500; Aleutian Isles, 8593; Kamschatka, 15,763; Syria, 12,000.

Temperate North America.—Mount St. Elias, Russian America, 17,850; Fremont's Peak, Rocky Mountains, 13,570; Mount Jefferson, Rocky Mountains, 15,000; Mount Whitney, California, 15,000; great plateau of California, 6000; Alleghanies, 6476; White Mountains, New Hampshire, 6428; Mount Hooker, Rocky Mountains, 16,730.

Temperate South America.—Aconcagua, Chilian Andes, 23,910; Mount Stokes, Patagonia, 6400; Mount Sarmiento, Terra del Fuego, 6900; Mount Erebus, antarctic continent, 12,400; Mount Terror, 13,884.

Australia and New Zealand.—Mount Edgecumbe, New Zealand, 9630; Mount Egmont, New Zealand, 8840; Victorian Alps, 6500; Mount Kosciusko, New South Wales, 7176; Mount Lindsay, Queensland, 5700; Van Diemen's Land, 5520.

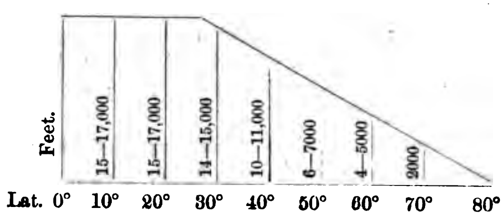
South Africa.—Table Mountain, 3816; Winterberg, 7000; Sneewbergen, Graaf Reinet, 7000—8000. Tristan d'Acunha, 8236.

Tropical Africa.—Mount Kilimanjaro, 20,068; Abyssinia, 15,008; Madagascar, Mount Ambotismene, 11,506; Bourbon, 8340; Camaroons, 13,760; Fogo, Cape Verdes, 9154; Fernando Po, 2469; Mont Woso, Ethiopia, 16,850.

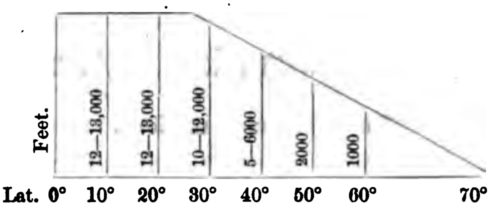
Tropical Asia and Polynesia.—Mount Slamat, Java, 11,930; Mount Ophir, Sumatra, 13,840; Singalary, Sumatra, 15,000; Mouna Roa, Sandwich Isles, 13,953; Neilgherries, 9000; Pulnies, 8000; Dodabetta, Neilgherries, 8760; Ceylon, 8286; Sunda Isles, 12,363; Otaheite, 12,250; Solomon Isles, 12,000; Owhyhee, 10,790.

Tropical America.—Popocatepl, 17,717; Orizaba, 17,374; Volcan de Fuego, Guatemala, 13,160; Roraima, Guiana, 7450; Chimborazo, 21,424; Illimani, Bolivia, 21,140; Sahama, Peruvian Andes, 22,350; Titicaca plateau and lake, 12,847; Quito plateau and city, 9543; Mexico plateau and city, 7570; Santa Fé de Bogota city, 8730; Central Brazil, 7800; Blue Mountains, Jamaica, 7277; Volcan d'Agua, Guatemala, 15,000; Cuba, 6890.

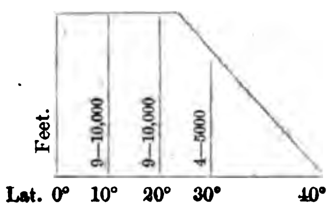
Height of Snow-line in feet; upper Boundary of Arctic-Alpine Zone.



Height to which Cereal Cultivation reaches; upper Boundary of Cool-temperate Zone.



Height up to which Vegetation is not checked by Winter; upper Boundary of Warm-temperate or Subtropical Zone.



CHAPTER IV.

On the Botanical Characteristics of the Zones of Heat.

The Intertropical Zone.

When we have ascertained what is technically called the habitat of a species, whether it be a road-side plant, or a swamp plant, or a parasite, or an inhabitant of woods or meadows, the next thing to do is to study the flexibility of its constitution in regard to heat. Over about half the area of the land, that is to say, within the torrid zone, and for a space beyond its limits, heat plays only a secondary part in plant distribution, because there is always as much heat anywhere as any plant needs to grow with, and there is no danger of its being checked in its growth or killed by cold. Within this tract moisture is the main determining agent in plant distribution, but, taking the earth as a whole, the distribution of heat is the most important element of influence.

Orders, genera, and species, are very different in the flexibility of their constitution, and in the amount of change to which they can adapt themselves. Out of the 200 known natural orders, there is but a small proportion that are thoroughly at home in all the four zones of heat. We have examples of orders that sweep the whole range of the four zones in Compositæ, Leguminosæ, Cyperaceæ, Gramineæ, Ferns, Rosaceæ, Onagraceæ, Naiadaceæ, Scrophulariaceæ, Plantaginaceæ, Saxifragaceæ, Equisetaceæ, and Lycopodiaceæ,—some of which are large orders, and some small, but all of them are thoroughly cosmopolitan, being represented in all latitudes and longitudes. Out of the 10,000 known genera the number that sweep the whole range is very small. We have examples of such in Senecio, Lotus, Rubus, Polygala, Potamogeton, Gnaphalium, Plantago, Typha, Oxalis, and Nasturtium. Of species thoroughly at home in all four it is difficult to find a satisfactory example. Some aquatics, like Ceratophyllum demersum, Potamogeton lucens, pectinatus, and pusillus, are the most thoroughly independent of solar heat of all known plants, and extend their range into all the four zones. Amongst land plants a few annual weeds, Ferns, and small perennial herbs,—such as Cerastium glomeratum, Capsella bursa-pastoris, Sonchus arvensis, S. asper, S. oleraceus, Plantago major, Aspidium aculeatum, Nephrodium Filix-mas, and Athyrium Filix-fœmina,—pass within the bounds of all the four zones, but none of these can fairly be considered as more than stragglers into the warmest. Pteris aquilina is plentiful in the woods on the banks of the Amazon, and gets up into Lapland, but generally stops short on the hills at the upper limit of cultivation. Of species quite at home in the three warmer zones we have many instances amongst water plants, perennial herbs, and annual weeds,—such as Ruppia maritima, Typha angustifolia, Lemna minor, Drosera longifolia, Oxalis corniculata, Bidens bipinnata, Solanum nigrum, Gnaphalium luteo-album, Elephantopus scaber, Mikania scandens, Panicum Crus-galli, Juncus tenuis, Cynodon Dactylon, and Eragrostis poæoides. But none of the plants which are cultivated on a grand scale for the use of man, and no shrubby or woody plants, are sufficiently flexible in constitution to grow in more than two out of these four heat-zones.

Probably at least three-quarters of the known species are concentrated in the two warmer zones. It does not always follow that in any tract of country where there is a luxuriant vegetation there is a great number of species, or that the number of species is always small when the vegetation is poor. We have a good instance to the contrary of the last of these two propositions in Cape Colony, which consists to a large extent of grassy plains and barren sandy deserts, and which yet produces nearly as many species of plants as Europe within about a quarter of its geographical area. We have a case of a small flora constituting a luxuriant vegetation in Ireland, where the number of species is not more than 1000, and where a few heath and swamp species growing in enormous quantity cover large tracts of surface. For about 40° on each side of the equator—that is to say, till we reach the polar boundary of the warm-temperate zone—there is not any lowering of the average number of flowering plants in a given area, and that number is larger than it is anywhere else in the world. But as soon as we pass from the two warmer of the four heat-zones into the region where winter comes in as a real check to vegetation, the number of species begins to lesson, and it goes on lessening in about the same proportion as the winter increases in length and intensity, till at last the flora within the whole round of the arctic circle falls short of 800 flowering plants.

Taking these four heat-zones one by one, the following are their principal characteristics:—

1. *The Torrid, or Intertropical Zone*, includes a belt round the world 3300 miles broad, with the equator for its centre, and, of the total 52,000,000 square miles of land, takes up not less than 21,000,000 square miles, or about two-fifths of the whole, about half of which is included in tropical Africa, and the other half almost equally divided between tropical America and tropical Asia, including along with the latter Polynesia and tropical Australia.

Of this 20,000,000 square miles a large part is not suitable for the production of plants under a continuous torrid heat. In the immense compact mass of tropical Africa in particular there is a vast tract of arid desert, and in the heart of South America there is also much bare sandy desert country; but in the Asiatic and Polynesian portion of the zone the relative distribution of sea and land is eminently conducive to plant growth; and in those regions where moisture and soil are suitable—such as the Gold Coast and Senegal in Africa; in Asia, the jungles of Ceylon, the Bombay ghauts, the Neilgherries, Birma, the Malay peninsula, Java, Borneo, and Sumatra; the numberless islands of Polynesia; in America, the dense primæval forests of the banks of the Amazon and its tributaries, Nicaragua, Panama, the West Indies, and the belt along the coast of Brazil from Pernambuco to

Rio Janeiro, which constitutes the *regio dryadum* of Martius—we have an energy and richness and luxuriance of forest vegetation far beyond that of any other part of the world.

The leading features that give the characteristic general tone to the vegetable physiognomy of the intertropical zone are the following:—1. The richness and luxuriance of the forest-vegetation in these favourable places; huge trees whose evergreen leaves form overhead a covering of perpetual shade, which the sun's rays cannot penetrate, bound together by tangled masses of interlacing woody climbers, and the fallen trunks and rocks overgrown, not, as in temperate regions, by mosses and lichens, but by climbing Ferns, Aroids, Bromeliaceæ, Orchids, and other monocotyledonous and dicotyledonous epiphytes. 2. The large proportion of the total number of plants that are either trees or shrubs, not herbs, even the annuals that spring up during the rainy season,—such as Corchorus, Grewia, Sesbania, Sida, Triumfetta, and Crotalaria,—assuming a half-shrubby character, like the bushes of temperate regions. 3. The variety of the forest vegetation, different kinds of trees, climbers and epiphytes being so mixed up together that it is often difficult for a collector to see to what a fallen fruit belongs, the woods not being made up of a large number of trees of the same kind, like our European Pine woods, Oak woods, and Birch woods, or the same bush covering large tracts of surface, like our Heather, Furze, and Brambles. 4. The absence of greensward, and terrestrial mosses and lichens. 5. The presence of arborescent Ferns and monocotyledons, which are almost confined to this intertropical zone, and several of which—Palms, Bamboos, Tree Ferns, and Pandani—are types that strongly affect the general aspect of the vegetation. 6. The presence in the forests of a crowd of climbing shrubs, principally dicotyledons, a type of form which is almost restricted to this zone. Of these we have examples in Paullinia, Serjania, Gouania, Lygodium, Ficus, Echites, and a crowd of Leguminosæ, Malpighiaceæ, and Bignoniaceæ. 7. The presence of several peculiar types, composed of a large number of species, which possess in common a highly differentiated aspect, as Peppers, Begonias, Gingers, epiphytic Orchids, Bromeliaceæ (confined to America), Figs and Dorstenias. 8. The presence on muddy sea-shores of groves of interlacing trees, with broad entire coriaceous leaves,—as Rhizophora, Bruguiera, Ceriops, Avicennia, and Barringtonia.

We cannot count the whole flora of this zone at less than 40,000 species, already known, out of a total of 100,000 in the world. Only a small proportion of these extend their range beyond one of the three great continents, and a considerable part of its area still remains to be botanically explored, and there are in our herbaria crowds of species yet unnamed and undescribed. The following natural orders are either restricted to this zone, or run out rapidly when its bounds are crossed, *viz.*—Anonaceæ, Menispermaceæ, Capparidaceæ, Bixaceæ, Guttiferæ, Bombaceæ, Dipterocarpaceæ, Vochysiaceæ, Malpighiaceæ, Simarubeæ, Ochnaceæ, Burseraceæ, Meliaceæ, Sapindaceæ, Dalbergieæ, Sophoreæ, Cæsalpineæ, Chrysobalaneæ, Connaraceæ, Melastomaceæ, Lecythideæ, Turneraceæ, Passifloraceæ, Rhizophoreæ, Cinchoneæ, Vernoniaceæ, Eupatoriaceæ, Sapotaceæ, Ebenaceæ, Myrsinaceæ, Apocynaceæ, Loganiaceæ, Cordiaceæ, Gesneraceæ, Cyrtandraceæ, shrubby Verbenaceæ, Acanthaceæ, Lauraceæ, Myristicaceæ, Artocarpeæ, Moreæ, Palms, Pandanaceæ, epiphytic Orchidaceæ, Zingiberaceæ, Marantaceæ, Commelynaceæ, Smilaceæ, Dioscoreaceæ, Podostemaceæ, Burmanniaceæ, Chlorideæ, Paniceæ, Andropogoneæ, Cyatheaceæ, Hymenophyllaceæ, and Marattiaceæ.

Amongst large genera concentrated here not included in the orders already mentioned are Grewia, Sida, Corchorus, Zizyphus, Crotalaria, Tephrosia, Mucuna, Mimosa, Vigna, Eugenia, Loranthus, Blumea, Hyptis, Ipomœa, Plectranthus, Physalis, Phyllanthus, Croton, Coccoloba, Pilea, Elatostemma, Dorstenia, Pisonia, Boerhaavia, Cyperus, Fimbristylis, Eragrostis, Lindsaya, and Adiantum.

Of plants cultivated on a large scale for the use of man the following are more or less characteristic of the intertropical zone. Amongst roots yielding farina,—the Yam, Batatas, Tacca, Arrow-root, Manihot, Caladium, and Colocasia; the various Palms and Cycads, from the pith of which sago is made (Sagus, Phœnix, Corypha, Cycas). Of farinaceous grains,—Rice, Maize, Arachis, Voandezia, Sorghum, Penicillaria, Eleusine coracana, Panicum miliaceum and frumentorum, Poa abyssinica, Trapa, Cajanus, Phaseolus Mungo, and Dolichos Lablab. Amongst nuts,—the Cocoa-nut and Brazil-nut. Amongst fruits,—the

Mango, Custard-apple, Guava, Jambosa, Bread-fruit, Banana, Date, Tamarind, Papaw, Granadilla, Jujube, Averrhoa, and Betel-nut. Amongst dyes and scents,—Vanilla, Gamboge, Indigo, Logwood, and Henna. Amongst oil-yielding plants,—the Oil-Palm (Elais), Sesamum, and Castor-oil. Of beverages,—Coffee and Cocoa. Of spices,—Sugar, Nutmegs, Cloves, Cinnamon, and Capsicum. Of fibre-yielding plants,—Cotton, Corchorus, Broussonetia, and Sanseviera. And amongst valuable woods,—Rosewood, Teak, and Ebony.

CHAPTER V.

On the Botanical Characteristics of the Zones of Heat.

THE WARM-TEMPERATE ZONE.

IN the last chapter we had only time to study the characteristics of the warmest of the four zones of heat, and have, therefore, still the three others to consider.

2. *The Subtropical or Warm-Temperate Zone.*—The tropic of Cancer runs through the middle of Mexico, to the north of the West Indies, strikes Africa mid-way between Morocco and Senegal, runs between Egypt and Nubia, stretches across the north of the great Indian peninsula from Kurrachee to Calcutta, and thence by way of Canton and Formosa, north of the Sandwich Islands. The tropic of Capricorn crosses from the north of Chili to Rio Janeiro, strikes Africa south of Benguela, and crosses to the opposite shore some distance north of Natal, crosses Australia north of all the settled colonies, and runs south of the Friendly and Society Islands. This subtropical or warm-temperate zone includes two belts round the world outside of these, varying in breadth from 900 to 1400 miles, which altogether take up about 13,000,000 square miles of land, or about a quarter of the earth's surface. As compared with either the intertropical or cool-temperate zones, this one is much broken up, and contains no less

than seven considerable dissevered areas: in the northern hemisphere, North Mexico, the Southern United States, and southern half of California; in Asia, Persia, the northern half of Arabia, Affghanistan, Beloochistan, India south of the Himalayas exclusive of the peninsula, the southern half of China, and perhaps we should also say the southern extremity of Japan; in Europe and Africa, the Mediterranean basin: in the southern hemisphere at sea-level, the whole of Cape Colony; in Australia, Queensland, West Australia, South Australia, Victoria, New South Wales and Tasmania; the whole of New Zealand at sea-level; and in America, Chili, Buenos Ayres, La Plata, and the southern provinces of Brazil.

Its general climate is best defined by saying that, whilst in the south it slides into the torrid zone very gradually, and in the continental or excessive climates its summer heat falls scarcely short of that of the equatorial regions, yet this heat comes for one season only, and does not last during the whole four. The winter nowhere sinks down to the point where vegetation experiences a sensible check from cold, but is such that in various warm portions of its area—as, for instance, the Gangetic plain and the oases of the Libyan Desert—the common cool-temperate cereals, especially Wheat, are grown as a crop, which is planted and reaped in the three coldest months, to be followed during the summer by something that needs a subtropical heat, like Cotton, Maize, or Indigo. As compared with the torrid and cool-temperate zones this is, upon the whole, a dry one. A good deal of the region where rain never falls comes within its limits, and the rain in other parts—as, for instance, round the Mediterranean basin—is small in amount, and has a tendency to periodicity in its downfall. Of these continental or dry floras we have examples in those of the Mediterranean basin, the Cape, Australia, Mexico, and the belt across South America from North Chili to Buenos Ayres; and of the other kind, the damp or insular type, in those of the Southern United States, New Zealand, and the Eastern Himalayas, which last, lying as it does at the foot of a great range of mountains facing the South, has a flora the most tropical in its character of all those of this zone.

We might, *à priori*, expect that, under these general conditions of diminished heat and moisture, the flora of this subtropical zone would show a marked diminution in number of species as compared with the torrid tone. But this is not really the case, for we have within its bounds some of the richest and most varied floras in the world. At the Cape, within about a quarter of the area of Europe, nearly 9000 plants have been gathered. We cannot estimate at less than 10,000 species the flora of the Mediterranean basin, taking into it the country up to the Caucasus and bounds of India, as included in Boissier's great 'Flora Orientalis,' now in course of publication. In extra-tropical Australia, with New Zealand, there will probably be 7000 or 8000 plants. The three areas of North India with China, Mexico with the Southern United States, and the subtropical belt in South America, may perhaps be counted as good for 5000 species each; so that as comparatively few of the species of this zone extend into more than one of the six or seven dissevered geographical areas of which it is composed, we may fairly estimate the total flora of the zone as being not short of 40,000 species, or two-fifths of the known number of plants in the world. The diminution of heat and moisture works, not in lessening the number of species, but in reducing the luxuriance of individuals.

The features which give the general tone to the physiognomy of its vegetation are as follows:—1. The most striking positive character of the zone is the abundance of its erect bushes, and low, stunted trees, which are spread through its limits in wonderful quantity and variety, the dry character of its climate telling upon their *facies* in producing compactness of growth, small size and rigidity of leaf, and very often in the development of prickles on the stem and leaf-edges, and of glandular dots upon their foliar surfaces,—such as the Cistaceæ and Labiatæ of the Mediterranean basin; the Myrtaceæ, Rutaceæ, Proteaceæ, Thymeleaceæ, Epacridaceæ, and shrubby Compositæ of the southern hemisphere; and the Brooms and Heaths of both its northern and southern belts. 2. Another positive character of the zone is, that it is the great seat of the terrestrial Orchids, which are usually represented in each geographical area by special generic types. 3. Entire absence of many of the tropical types of form, and great diminution and gradual running-out of those of more flexible constitution, such as Tree-Ferns, Palms, Dracænas, epiphytic Orchids, Peppers and Figs, all of which stop before the polar limit of this zone is reached. 4. Incoming of various striking types shared between this and the cool-temperate zone,—such as Umbelliferæ, Cruciferæ, Cupuliferæ, and Coniferæ. 5. A smaller proportion of woody plants than in the torrid zone, and especially a larger proportion of annuals and of terrestrial mosses and lichens. 6. Incoming of the greensward-producing grasses, —such as Poa, Festuca, Bromus, Holcus, Agrostis, and Anthoxanthum; but the green covering they make is soon burnt up in the summer. 7. Incoming of the temperate cereal grasses,—such as Wheat and Barley, which often yield great crops in a short time; and outgoing of such as Rice, Maize, Cotton, and Indigo.

The following are the principal natural orders and sub-orders which are either characteristic of the subtropical zone, or, at any rate, are much more abundant here than anywhere else:—Cruciferæ, Resedaceæ, Cistaceæ, Sileneæ, Portulaceæ, Berberidaceæ, Pittosporaceæ, Rutaceæ, Diosmeæ, Boronieæ, Rhamnaceæ, Papaveraceæ, Fumariaceæ, Geraniaceæ, Oxalidaceæ, Podalyrieæ, Genisteæ, Stackhousiaceæ, Brunoniaceæ, Ficoideæ, Cactaceæ, Umbelliferæ, Loasaceæ, Lobeliaceæ, Stellatæ, Campanulaceæ, Goodeniaceæ, Dipsaceæ, Valerianaceæ, Calyceraceæ, many tribes of Compositæ, Chamælaucieæ, Leptospermeæ, Myoporaceæ, Selaginaceæ, Labiatæ, Orobanchaceæ, Ericaceæ, Epacridaceæ, Nolanaceæ, Thymelaceæ, Proteaceæ, Paronychiaceæ, Plumbaginaceæ, terrestrial Orchids, Iridaceæ, Liliaceæ, Colchicaceæ, Restiaceæ, Hypoxidaceæ, Amaryllidaceæ, and Hæmadoraceæ.

Amongst large or striking genera that have their head-quarters here, and are not included in the above groups, are Clematis, Althæa, Lavatera, Malvastrum, Rhus, Ilex, Linum, Ononis, Medicago, Trifolium, Trigonella, Coronilla, Acæna, Cliffortia, Fuchsia, Œnothera, Lythrum, Camellia, Aucuba, Escallonia, Gunnera, Cotyledon, Jasminum, Phillyrea, Cyclamen, Scrophularia, Linaria, Verbascum, Petunia, Stapelia, Nicotiana, Verbena, Ephedra, Muhlenbeckia, Podocarpus, Melica, Aristida, Cheilanthes, Pellæa, Nothochlæna, and Lomaria.

The principal plants cultivated on a large scale for human use in the subtropical zone are Rice, Maize, Wheat, Barley, Millet, Lentil, Cicer, various kinds of Bean, Fenugreek; amongst fruits the Vine, Fig, Pomegranate, Olive, Apricot, Peach, Orange, Lemon, and Spanish Chestnut; Saffron, the Gum Arabic Tree, the Vallonia Oak, Cinchona, Tobacco, Aloe, Maguey (Agave), Senna, Castor-oil Plant, Tea, Opium, Clover (Trifolium alexandrinum), the Scented Labiatæ,—such as Marjoram, Thyme, Sage, Basil, Lavender and Rosemary; and the Cucumber, and various kinds of Gourd and Melon.

CHAPTER VI.

On the Botanical Characteristics of the Zones of Heat.

The Cool-Temperate Zone.

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8. *The Cool-Temperate Zone* includes in the northern hemisphere a belt from 1500 to 2000 miles broad, stretching across the three great continents, which embraces an area of about 16,000,000 square miles. In the southern hemisphere, at sea-level, it includes only the Patagonian peninsula and a few small islands, and altogether it takes in about a third of the earth's surface.

The distribution of heat through its area varies far more than it does through the two warmer zones, the two broad general marks which characterize it being that there is always a winter of such a kind as to give a decided check to all vegetation, combined with a summer at least warm enough for the cultivation of the common cereal Grasses and Potatoes, which, with the Cabbage and Turnip, are the hardiest of the plants grown on a large scale for the use of man. As we cross this belt in the direction of the poles the winters lengthen and the summers grow shorter and shorter, subject to the modification caused by the difference between insular and continental climates. In England our deciduous trees are bare of their leaves for half the year; at a height of 4000 to 5000 feet in the Alps the length of the period of the vegetation is said to be 200 days; at 5000 to 6000 feet, where cereal cultivation ceases, 170 days; and at sea-level at St. Petersburg not more than 180 days out of the 365.

The gradual lessening of the average number of plants in a given area, which begins as soon as this zone is entered on its equatorial side, and goes on in proportion to the decrease in the time of vegetation, is one of its most important and noteworthy characteristics. France, including Corsica, is about the same size as Sweden, and the former yields 3600 and the latter 1160 flowering plants; Naples, with 3130 species, is about the same size as Iceland, with 400; Germany, as limited in Koch's 'Synopsis,' with 3368 plants, is about the same size as the whole of Scandinavia, including Denmark, with 1677; Tuscany, with 2366 species, is about the same size as Yorkshire, Northumberland, and Durham, taken together, with 1000; Silesia, with 1288 plants, is about the same size as Spitzbergen, with 107. Except in the heart of Asia the botany of this zone has been explored very thoroughly, and although it includes a third of the earth's surface we cannot estimate its total flora at sea-level at more than 15,000 species, to which, however, a large addition must be made for the plants that ascend into it on the mountains that rise from the countries of the two warmer zones.

The principal marks which give the general tone to the physiognomy of its vegetation are:—1. The concomitants in plant-form of a real winter, a great proportion of the trees with deciduous leaves, standing bare and leafless for half the year or more, according to latitude; and the few evergreens organized so as to resist severe cold, principally Pines with long needle-like leaves, in which the evaporating surface is reduced to a minimum; and plenty of herbaceous perennials that die down in winter to an underground root-stock. 2. Fewness of shrubby climbers, and total absence of the tropical types of form,—such as Palms, Figs, Peppers, Tree-Ferns, Gingers, Bauhinias. 3. The small number of trees and shrubs in proportion to the total number of plants, and the way in which single kinds (*e.g.* Pinus, Fagus, Betula, Quercus, Calluna, Ulex) often grow together in vast quantity. 4. The low floral type of the trees, which are usually achlamydeous or monochlamydeous, and incomplete sexually, with small obscure flowers in dense clusters, which appear in spring before the leaves are fully formed, thus offering a great contrast to the trees of equatorial regions. 5. The abundance and persistence of the greensward-producing grasses, and presence of a constant general covering of grassy verdure. 6. Ferns in the insular climates in the same way as the trees and shrubs, a small number of kinds growing in great quantity. 7. Relative preponderance as compared with the two former zones of terrestrial mosses, and large foliaceous and fruticulose lichens,—such as Cladonia, Peltigera, Parmelia, and Collema.

The orders or sub-orders, which have a decided maximum in the cool-temperate zone, are very few. The principal are Alsineæ, Amentaceæ, Saxifrageæ, Grossularieæ, Primulaceæ, Polemoniaceæ, Hydrophyllaceæ, and Sarraceniaceæ,—the three last mainly or entirely American.

Amongst orders and sub-orders that may be considered as characteristic of this and the warm-temperate zone taken together, are Ranunculaceæ, Fumariaceæ, Cruciferæ, Sileneæ, Trifolieæ, Loteæ, Umbelliferæ, Stellatæ, Cichoriaceæ, Campanulaceæ, Valerianaceæ, Gentianaceæ, Labiatæ, Boraginaceæ, Coniferæ, Chenopodiaceæ, Cupuliferæ, Juncaceæ, Phalarideæ, and Festuceæ.

Amongst striking generic types that have their head-quarters here are Anemone, Ranunculus, Aquilegia, Corydalis, Cardamine, Arabis, Draba, Erysimum, Viola, Acer, Geranium, Astragalus, Vicia, Lathyrus, Stellaria, Arenaria, Lupinus, Prunus, Spiræa, Rosa, Pyrus, Cratægus, Cotoneaster, Potentilla, Fragaria, Ribes, Saxifraga, Chrysosplenium, Parnassia, Heuchera, Sedum, herbaceous Sempervivums, Philadelphus, Deutzia, Heracleum, Angelica, Cornus, Lonicera, Sambucus, Viburnum, Epilobium, Valeriana, Aster, Solidago, Chrysanthemum, Helianthus, Hieracium, Lactuca, Crepis, Leontodon, Vaccinium, Rhododendron, Kalmia, Azalea, Pyrola, Primula, Lysimachia, Pedicularis, Pentstemon, Mentha, Phlox, Gentiana, Asclepias, Fraxinus, Rumex, Rheum, Chenopodium, Atriplex, Ulmus, Fagus, Corylus, Carpinus, Betula, Salix, Populus, Pinus, Juncus, Luzula, Gagea, Lilium, Allium, Scirpus, Carex, Eriophorum, Alopecurus, Phleum, Anthoxanthum, Agrostis, Calamagrostis, Glyceria, Poa, Festuca, Bromus, Triticum, Elymus, Avena, and Hordeum.

The principal plants grown in this zone on a grand scale for the use of man are the common cereal grasses, Wheat, Oats, Barley, and Rye; of fruits, the Plum, Apple, Pear, Peach, Apricot, Cherry, Strawberry, Gooseberry, Red Currant, Black Currant, Quince, Medlar, and Loquat; of garden esculents, the Potato, Cabbage, Turnip, Beet, Bean, Kidney Bean (Phaseolus vulgaris and coccineus), Onion, Leek, Chives, Mustard, Cress; of fibre-yielding plants, Hemp and Linseed; and of forage plants, Vicia sativa, Lolium italicum, Clover (Trifolium pratense, repens, hybridum, and incarnatum), Lucerne and Sainfoin.

One of the most remarkable points about the zone is the wide and dissevered dispersion of many of its characteristic species. Of the 2100 flowering plants of the Northern United States 320 are European; and out of 577 Ferns, Mosses, and Hepaticæ, 355 are European; and out of the plants of this zone that reach within the arctic circle about 100 species also inhabit cool-temperate areas in the southern hemisphere.

CHAPTER VII.

On the Botanical Characteristics of the Zones of Heat.

The Arctic-Alpine Zone.

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4. *The Arctic-Alpine Zone* includes at sea-level all the country from the arctic circle northward to the perpetual snow-line, and upon the mountains of the warmer zones the belt between the upper limit of practicable cultivation and the perpetual snow.

The number of flowering plants and Ferns that grow within the arctic circle does not exceed 800 species, of which not more than 25 per cent. can be regarded as at all characteristic of this particular climate, the other 75 per cent. being plants of the cool-temperate zone, which are flexible enough in constitution to grow here also. The number of plants which inhabit the zone where it occurs as a belt upon the mountains is far greater. We cannot count the characteristic "alpines" of the Alps, Pyrenees, Apennines, Sierra Nevada, and other European ranges, at less than 1000 species, and there must be three or four times as many that ascend into the zone from below, and the characteristic plants of this zone within the tropics and in the southern hemisphere are very rarely the same species as the arctic-alpines of the north.

There is, in fact, a wide difference in the period of vegetation of the plants of this zone near the poles and upon an equatorial hill, and similarly in the place of the line of perpetual snow, which is fixed, not by the average temperature of the year, but by the heat of the summer months. In high latitudes there is a great elevation of the temperature of the summer above that of the winter, with a proportionately higher snow-line as its result, and there is a very short period of vegetation. In Spitzbergen the plants to live need to flower and perfect their seed within six weeks or a couple of months, and the whole island does not yield much over 100 plants of the higher orders. On the equatorial mountains, on the contrary, there is very little difference between the temperature of the different seasons, and consequently no additional heat in summer to melt the snow above where the average annual temperature is at freezing-point. The snow-line is therefore here proportionately lower, and there is a much longer period of vegetation for the plants of this zone, and a much richer alpine flora. The plants known in this zone upon the Andes cannot be fewer than 2000 or 3000 species. There is quite as much difference between the climates to which the different parts of this zone are exposed, as between the different climates, insular and continental, more polar and more equatorial, of the cool-temperate zone.

The general *facies* of the vegetation of this zone is not dissimilar from that of the cool-temperate. It is a flora of low herbaceous perennials, with a considerable scattering in its lower levels of trees and bushes, but the former fast disappearing after its lower bounds are passed, and all the few really characteristic shrubs dwarf and low-growing. The two negative general characters that stamp it most forcibly as compared with the cool-temperate zone are the absence of the plants cultivated on a grand scale for the use of man, and the almost entire absence of annuals.

Within the arctic circle, out of its 800 plants there are nearly 100 that are trees and shrubs. Of these about one-fourth are really characteristic, the other three-fourths being species that ascend here from further south. The following are those that may be considered as characteristic of the zone, viz.:—Rubus arcticus, R. Chamæmorus, Vaccinium uliginosum, Andromeda hypnoides, A. tetragona, A. calyculata, Arctostaphylos alpina, Diapensia lapponica, Azalea procumbens, Rhododendron lapponicum, Osmothamnus fragrans, Phyllodoce taxifolia, Betula nana, Salix lanata, S. Lapponum, S. arbuscula, S. glauca, S. arctica, S. myrsinites, S. reticulata, S. herbacea, and S. polaris.

There are not any orders characteristic of the arctic-alpine zone, unless we count as such Diapensiaceæ. The characteristic genera are all either monotypic or very small,—such as Braya, Eutrema, Kernera, Sibbaldia, Dryas, Homogyne, Adenostylis, Sieversia, Wulfenia, Tozzia, Soldanella, Kœnigia, Oxyria, Chamæorchis, Kobresia, Vahlodea, Phippsia, Lloydia, Pleuropogon, and Woodsia.

Out of the 800 arctic plants only eight are absolutely restricted to the arctic regions; the other species occurring, which are characteristic of the zone—about 200 in number,

—are many of them spread widely upon the mountain summits of the northern hemisphere. A very large proportion of the thousand characteristic alpines of the northern hemisphere are high-climbing species of the large characteristically cool-temperate genera. Of the genera, which include several characteristically alpine species, the following are the principal, viz.:—Ranunculus, Arabis, Draba, Thlaspi, Silene, Alsine, Dianthus, Potentilla, Saxifraga, Senecio, Achillea, Erigeron, Hieracium, Crepis, Campanula, Phyteuma, Gentiana, Veronica, Pedicularis, Primula, Androsace, Salix, Juncus, Luzula, Carex, and Poa.

Under the tropics, as already stated, hardly any of the characteristic arctic-alpines are the same species as those of the northern hemisphere. Many of them belong to characteristically cool-temperate genera, and others are high-climbing species of the genera that belong specially to the countries round the base of the mountains. We find, for instance, that in the Andes of South America there are 478 species of Compositæ known in the alpine region, which belong to sixty-one genera. Not one of these species is known in the northern hemisphere; 182 species belong to eight genera, which in the northern hemisphere have other species which are characteristic of the arctic-alpine zone. Fifty-four species belong to seven genera, which ascend into the cool-temperate zone of the northern hemisphere, but do not climb its mountains, and 237 species belong to forty-nine genera which are not north-temperate at all, but specially South American. Of arctic-alpines of the northern hemisphere which pass down the Andes into the southern hemisphere, we have examples in Draba incana, Lychnis apetala, and Phleum alpinum.

It is scarcely needful to point out that these four zones of heat correspond to our four plans of garden treatment. We provide, for instance, at Kew, for the plants of the intertropical zone in the Palm-house, the large Fern-house, and the central compartments of the new range, but our imitation of a tropical climate must be, of necessity, a very imperfect and clumsy one. We cannot transfer to England the regular rainy and dry seasons, the equal day and night, the trade winds, and, above all, the clear cloudless skies and bright light and burning sunbeams of the equatorial zone. We provide for the plants of the subtropical or warm-temperate zone in the new temperate house, the Cactus-house, the lesser Fern-house, and the ends of the new range, and it is a valuable elementary fact for a young gardener to store up in his memory that a large proportion of the 40,000 plants of this zone are in danger of being killed if frost gets fairly at them. Our principal difficulty with the plants of this zone is with those from the southern hemisphere. These have been accustomed as a rule to bloom in their summer, which is our winter, and refuse when brought here to change their habits. The 20,000 plants of the cool-temperate zone we can accommodate without difficulty in the open air in our herbaceous ground and shrubberies, and arboretum. For the characteristic plants of the arctic-alpine zone we build rockeries and shelter them from the sun, but our long warm summers and dry sandy soil try their constitution severely, so that they need careful watching over and watering, and require that great pains should be taken to imitate their natural stations as closely as possible.

M. Alphonse De Candolle has given names to plants of the different degrees of heat-constitution, which it is sometimes convenient to use, and which, with a modification which I venture to make, by using four stages instead of three, are as follows:—

1. Macrotherm, characteristic of the intertropical zone, and requiring stove-heat with us for its cultivation.

2. Mesotherm, characteristic of the subtropical or warm-temperate zone, and therefore needing to be entirely protected from frost.

3. Meiotherm, characteristic of the cool-temperate zone, and therefore quite hardy in the open air in England.

4. Microtherm, characteristic of the arctic-alpine zone, and therefore needing protection from drought and full sunlight at sea-level in England.

CHAPTER VIII.

On the Manner in which Heat influences the Distribution of Plants.

THE influence of temperature upon the distribution of any plant depends largely upon its season of vegetative activity. Annuals, which run their course from the seed stage to leafing and flowering, and back to the seed stage, in a period varying in length from two to six months, can only be affected by the temperature of that portion of the year during which they are growing. Biennials have to last through the winter, and often concentrate their energies for a large proportion of their existence in storing up materials in their rootstocks, and spring up into flower and seed in a short time when warm weather comes, at the expense of tissue previously elaborated. Trees and shrubs have usually a well-marked time of flowering and fruiting, once a year, and it is the same with a great many perennial and annual herbs, but the season with different species is véry different. Eranthis hyemalis, and the Snowdrop and spring Crocuses, push out their flowers and leaves as soon as the snow melts. Hawthorn and Blackthorn, and our common fruit trees, push out their flowers in April and May, before the leaves are developed or perfected. The flowering of Ragwort and St. John's Wort takes place long after the leaves appear, and marks that the summer equinox is past, and the days are beginning to shorten. Colchicum autumnale produces its flowers regularly in August, but its leaves not until the following spring; while Asters and Chrysanthemums flower regularly at Michaelmas; and Holly and Ivy, and Aucuba, and Cherry-Laurel, are in full leaf all winter; and Lamium album, Poa annua and Capsella bursa-pastoris, may be seen during any month of the twelve in simultaneous leaf and flower. So that the time of the year at which different plants are at all sensitive, and especially sensitive to temperature, varies extremely.

It is evident that, in the first place, plants need very different degrees of temperature to start them into life. The seeds of many of the Microtherms, and even of plants of our middle latitudes, will germinate at a temperature of little over 32°. Of cool-temperate species, for which the experiment has been carefully tried, Sinapis alba has been found to germinate at 32°; Lepidium sativum and Linum usitatissimum at 35° to 36°; Nigella sativa, Iberis amara, Trifolium repens, and Collomia coccinea at 41° to 42°; and Wheat, Barleys, and Oats, at 44° to 45°. With heat added over and above these degrees, the time from the sowing of the seed to its germination is found to be materially shortened. Sinapis alba, which took seventeen days to germinate at 32°, was found by M. Alphonse De Candolle to take sixteen days at 35° to 36°, nine days at 37° to 38°, four days at 42°, three and a half days at 48°, one and three-quarter days at 51° to 52°. Passing to

Mesotherm types, the temperature needed for germination becomes gradually higher. For Maize it is stated to be 48°, and for the Macrotherms at least 50° to 60°, but it may take place at a much higher temperature. Sesamum orientale has been found to germinate in nine days at 51° to 52°, in three days at 62° to 63°, in thirty to thirty-six hours at 68° to 69°, in twenty-one to twenty-two hours at 75° to 76°, in twenty-five hours at 82°, and some even in ten and a half hours at a heat of 104° to 105°.

The start once made, it is evident that plants need a certain amount of heat to enable them to flower and fruit, but that, with some species at any rate, it is immaterial, within surprisingly wide limits, whether the heat come gradually or rapidly; and that if the latter, the times of flowering and seeding are accelerated. Nothing shows us better how flexible in this respect a plant may be than the familiar facts about the sowing and harvesting of the common cereal grains. In the north of India Wheat is a common winter crop, to be followed in summer by Maize or Indigo, and is sown, and the harvest gathered, within three months. In Palestine the Barley ripens at the end of March, and the Wheat by the end of April, November being the month of ploughing and sowing. In Málta and Sicily they sow at the end of November, and harvest through May. In the countries round the north side of the Mediterranean basin they sow early in November, and harvest in June. In Central Europe they sow in October, and harvest in July. On the Yorkshire wolds, and in the Alpine valleys of Switzerland, they have to sow in September, and cannot harvest till the following August; so that the time that elapses between sowing and ripening may be said to vary between the different parts of the tract in which the common cereal grains are cultivated for the use of man, on a grand scale, from 90 to 320 days. If too much heat be applied the embryo refuses to germinate, or if it have germinated already, the leaves, or flowers, or fruit, according to the stage which the plant has reached when the hurtful heat is applied to it, are not developed.

Then, again, it is equally evident that a gradual or sudden access of cold below a certain point—a point which varies with different species—coming when the plant is in a state of vegetative activity, injures or kills it. It may be simply a cold north-east wind in spring, blighting the blossoms of the Apricots, and Apples, and Pears, and whilst destroying the seed for the year, doing no permanent harm to the tree; or it may be a mild frost, at the beginning of winter, cutting off entirely our garden Dahlias, Pelargoniums, and Mesembryanthemums; or a hard frost in the middle of winter, killing the Eucalypti, Araucarias, Hollies, and Aucubas.

It follows, from these familiar facts, that some plants are checked from spreading from warmer latitudes towards the poles by the want of plenty of heat in summer to carry them from the seed stage, round the circle of life, to the seed stage again; and that others, for which the heat of summer is sufficient, are cut off by sudden fits of cold, that catch them at a time of vegetative activity. It is of no use, it seems to me, attempting to treat this last matter in close detail as a question of figures and thermometric degrees, because the different habits of growth of plants, and the different degrees of the wateriness of their sap, dependent upon the hygrometic conditions of the surrounding atmosphere and soil, influence it greatly, and their vegetative action passes through so many intermediate stages between the fulness of life in spring and their nearest approach to a dormant condition. But we may safely distinguish broadly between the two great classes of plants which I have indicated, and which I will call the *heat-lovers* (*Philotherms*) and *cold-fearers* (*Frigofuges*). Annuals are usually heat-lovers; trees and bushes, especially evergreens, are usually cold-fearers; and it follows, from what has been explained already about the characters of the two kinds of climate, that the cold-fearers can work up further from the equator in insular, and the heat-lovers in continental, climates.

We can perhaps understand best this matter of polar limits, and illustrate the difference between the two great classes of plants just indicated, by a rapid glance at the general character of the vegetation of Britain as compared with that of the continent. The range of the plants of Britain, both within the island and outside it, has been studied out and recorded in full detail by my friend and master in geographical botany, Mr. Hewett C. Watson, whose book, entitled 'Cybele Britannica,' contains a record and classification of the enormous mass of facts bearing upon this subject which he has accumulated.

Britain extends over nearly 10° of latitude, and its hills reach a height of 4200 feet. As the high hills are in the northern parts of the island, there is a difference between the climate of its extreme points equal to that caused at sea-level by 22° of latitude. Mr. Watson separates the surface into six zones of heat, the boundary between the third and fourth being the line of the practicable cultivation of grain and Potatoes, which we have already regarded as being equal to the arctic circle at sea-level. Very little of the actual surface of Britain falls on the cold side of this line, because it is only mountain-peaks and ridges that overtop it. Taking these zones in ascending order, the number of plants known in each is as follows, the total number found in Britain as a whole being 1425:—Inferagrarian zone, 1225 species; Midagrarian, 1070 species; Superagrarian, 760 species; Inferarctic, 293 species; Midarctic, 244 species; Superarctic, 111 species.

Arranging the species under "types of distribution," according as they are spread through the whole or part of the island, 532 species are found to be spread at sea-level generally from north to south, 606 to run out so that they do not reach the northern latitudes or climb the hills, and 238 species to have a decidedly northern or montane partiality, the remaining 49 being too local to class fairly as either northern or southern. Out of these 1425 British plants, no less than 460 have a sufficiently wide range of climatic adaptability to be inhabitants also of Lapland, but a large proportion of the 606 species, which are more or less southern in their range within the limits of Britain, are cold-fearers, which are stopped by the cold winters from advancing beyond the middle, or into the middle, of the European continent. The following are a few of these, with mention of how many of the six climatic zones they reach into in Britain, and an outline of their line of polar limit upon the continent:—

Ilex Aquifolium (our common Holly).—Grows in the three warmest of the heat-zones in Britain, its polar limit upon the continent stretching from South Norway to Mecklenburg, Pomerania, Austria, and Thrace.

Erica cinerea (the commonest of our five British Heaths).—Reaches into four zones in Britain, stretching across the continent from Norway and Belgium to Transylvania, and occurs only in a single station (in the neighbourhood of Bonn) in Germany.

Ulex europæus (our common Furze).—Three zones in Britain; runs across the continent from Denmark, Mecklenburgh, and Hanover, to Switzerland and Italy.

Ulex nanus (the dwarf autumnal Furze, so common on our London heaths).—Three zones in Britain; does not extend on the continent beyond Flanders, France, Spain, and Portugal.

Wahlenbergia hederacea.—Two zones in Britain; from Denmark and Belgium to Dalmatia.

Iris fœtidissima.—One zone in Britain; France to Hungary, Tyrol and Constantinople.

Erica ciliaris.—One zone in Britain; West and Central France, Asturias, Galicia, and Portugal.

Trichonema Columnæ.—One zone in Britain; West France, Spain, Portugal, Italy, Dalmatia, Greece.

Adiantum Capillus-Veneris (the common Maidenhair Fern).—One zone in Britain; Belgium, Switzerland, Tyrol, Dalmatia, Turkey, Greece.

Trichomanes radicans.—One zone in Britain; on the continent does not extend beyond Spain.

Hymenophyllum Wilsoni.—Five zones in Britain; Norway, Luxemburg, West France, Tyrol.

The four following are plants of Ireland, which are not known to be wild anywhere in Britain proper:—

Arbutus Unedo (the Strawberry tree, so plentiful about the lakes of Killarney, and so well known in gardens).—France, Tyrol, Dalmatia, Turkey, Greece.

Erica mediterranea.—Gironde, Arragon, Galicia, Portugal.

Dabeocia polifolia (the St. Dabeoc's Heath of Connemara).—West France, Spain, Portugal.

Neotinea intacta (a little inconspicuous Orchis, lately found in Galway).—South France, Spain, Italy, Dalmatia, Greece.

It would be easy to multiply illustrations, but these are enough. We may fairly say that upwards of 300 of the plants of Britain, or more than 20 per cent., belong upon the continent specially to the south-west and south. It will be observed that these lines of polar limit run, not due east and west, but from north-west to south-east, in accordance with the temperature of the winters; and it is quite clear that, taking the British flora as a whole, its most distinctive feature is that it contains a large infusion of cold-fearing or frigofugal plants, which, through our mild winters, can ascend in Britain to an exceptionally high latitude.

The same point is well illustrated by the flora of New Zealand. We find that as a rule the cold-fearing Mesotherm types of the torrid zone reach higher latitudes in the southern than in the northern hemisphere, because, from the distribution of sea and land, the southern climates are more insular in character. The three islands of New Zealand cover the same latitude as Spain and France, and in their indigenous flora are represented the following tropical types, *viz.*—Palms (Areca sapida), one species; Pandanus, one species; Adiantum, six species; Cyatheaceæ, six species; Hymenophyllaceæ, twenty-two species; epiphytic Orchids, four genera and five species;

two Peppers, one Cassytha, two Laurels, five Myrsinaceæ, one Cyperus, four Dracænas, and two panicoid Grasses.

The way in which a characteristically frigofugal, damp-loving, tropical group runs out from the tropical zone into the insular climates, and avoids the continental climates, is well shown by the Tree-Ferns. The only instances in which any Tree-Ferns grow outside the two tropics are the following:—there is one species of Cyathea in Japan, an Alsophila in the Bonin Isles, a Cibotium in South China; and in the East Himalayas one Cyathea, two Hemitelias, seven Alsophilas, and the same Cibotium: in the southern hemisphere there are two Tree-Ferns at the Cape, at least ten in extratropical Australia, eight in New Zealand, two in Lord Howe's Island, one in Raoul Island, two in Chili, and two in Juan Fernandez.

A substantially similar result is given by the study of the distribution of the two other most decidedly tropical Fern groups, Marattiaceæ and Hymenophyllaceæ. Of the latter, out of about 160 known species, there are two in Britain, sixteen in the East Himalayas, two in the Southern United States, ten in South Africa, twenty-six in New Zealand and Australia taken together, and twenty-one in Chili.

On the other hand, we find that in the continental climates many philothermal tropical annuals flourish, and fruits ripen in latitudes far higher than might be expected when the average annual temperature alone is considered, and in places where the winter sinks very low indeed. Our British January only sinks down to an average of 32° at the very north of the island; but in Canada, where the

January average is 15° to 20°, they grow good Peaches and Grapes in the open air, and cultivate Maize and Tobacco in the fields. At Pekin, where the January average is 26°, Grapes and Oranges ripen in the open air; they cultivate on a grand scale such Mesotherm types as Gossypium herbaceum, Dolichos Lablab, Soja hispida, Capsicum annuum, Dioscorea sativa, Sesamum orientale, and Maize; and in the wild flora there are such plants as Nelumbium, Gynandropsis, Pistacia, Grewia, three species of Indigofera, two Acacias, Begonia, Commelyna, two Cyrtandraceæ, Phyllanthus, and two Andropogons.

Other things being equal, it follows from the fact that the cycle of its life is run through in a portion of the year, that an annual can adapt itself to varying climates better than a perennial, and a herbaceous perennial better than a shrub or tree. Of plants characteristic of cool-temperate latitudes, Wheat, Barley, and sometimes Oats, are grown through the plains of India down to the tropic, because they can be sown and reaped during the coldest quarter of the year, and with them are introduced a crowd of the common annual weeds of the same latitudes,—such as Capsella, Chickweed, Euphorbia Helioscopia, Anagallis arvensis, and Veronica agrestis, which also run through the cycle of their lives in the winter quarter. "But in Sikkim (to quote the introduction to Hooker and Thomson's 'Flora Indica,' p. 194) no European fruit of any kind, save the Strawberry, comes to perfection; even the Peach, the only commonly cultivated tree, does not ripen its fruit; and the Apricot, the most abundant West

Himalayan fruit, is unknown. In Central Nepaul, further west, Apples, Figs, Peaches, Quinces, and Apricots, all ripen, but hardly arrive at perfection. Towards the interior of Kumaon, of which the capital, Almora, is 5500 feet above sea-level, Apricots, and all the above fruits, become abundant, with the Pear and Cherry; and from Kumaon, westward, vineyards and large orchards form a conspicuous feature in the interior of all the valleys."

CHAPTER IX.

On the Distribution of Atmospheric Moisture.

All over the earth, the more largely where its beams reach the surface with the least diminution of heat, the sun is continually engaged in evaporating moisture from all exposed surfaces of water. This remains suspended in the atmosphere, and is carried about by the winds in the form of impalpable vapour or of clouds, till the point of saturation is reached, and the moisture falls again to the earth's surface in the form of rain, or snow, or hail. Air becomes lighter, and consequently expands and ascends when it grows hotter, and becomes heavier and falls with cold. The hotter it is, the more moisture it is able to hold in solution. Between the equator and the poles there is a difference of 80° of average annual temperature. In the torrid zone the light, warm, vapour-laden air is ascending continually to the upper regions of the atmosphere, and there flowing outwards north and south towards the poles, and the cold heavy air from the polar regions comes rushing along the surface to fill its place. As the seasons change, the line of the greatest heat in the world gradually moves its position. At the equinoxes of spring and autumn it runs along the actual equator, or near it. In winter it lies south of the earth's equator, about midway between the equator and tropic of Capricorn. Not more than half as much of the tropic of Capricorn as of the tropic of Cancer runs over land, and this makes a material difference, because the more sea the more the intense heat is deadened and absorbed. In summer the great continental area traversed by the tropic of Cancer, a long line of which is removed from the ameliorating influence of the sea, becomes excessively heated; and from the great African Sahara, through Nubia and Arabia to the north of India, runs a tract of intense heat, in which the July average in the shade rises to 90°.

Zone of Periodic Winds and Rains.—It is to this changing line of the greatest heat that the main currents of wind are directed. Within a zone extending for about 30° on each side of the equator the winds blow with great regularity. When they leave the polar regions the tendency of the surface-currents is due north and south, but in their course they become deflected longitudinally in consequence of the earth's motion, and reach the line of greatest heat as north-east and south-east currents. The tropic of Capricorn has its air rarefied by heat in our winter, and this produces within the torrid zone what is called the north-east trade wind or monsoon. The tropic of Cancer has its air still more rarefied by heat in our summer, and this produces the south monsoon. Through these causes this central belt of the world has its winds and rains perfectly steady and regular, and within it there falls the greatest quantity of rain which there is in any part of the world. The rainy season begins some time before the sun reaches the zenith of a place, and continues for some time afterwards. In a belt near the equator there are two rainy seasons: the main one, which lasts three or four months, beginning when the sun, in its progress to a vertical position, has crossed the equator; and a shorter one, which lasts four or six weeks, when the sun is coming again from the tropic to the equator. Nearer the two tropics the countries have only one rainy season, which begins when the sun approaches the tropic, and one dry season, the year being divided between the two. The rain pours down in torrents, in a way of which we can form no notion from our experience in temperate countries. Our London rainfall is 2 inches a month, but in the tropics an inch a day is not an uncommon average for the whole rainy season. On the banks of the Rio Negro, Humboldt collected as an ordinary rain 1¾ inch in five hours. In Cayenne, Admiral Roussin collected, between the 1st and 24th of February, 12½ feet, and in one night, between 8 P.M. and 9 A.M., measured 10¼ inches. In the Himalayas of Khasia as much as 600 inches are said to fall in a single year. The rain, however, does not commonly pour down without intermission night and day, and day after day, as is sometimes the case in the English lake country. The ordinary succession of atmospheric phenomena is as follows:—The sun rises in a cloudless sky. Towards noon some faint clouds appear on the horizon, which increase rapidly in density and extent, and are soon followed by thunder and violent gusts of wind, accompanied by heavy rain. Towards evening the rain abates, the clouds disappear, the sun sets in a serene sky, and during the night no rain falls. The annual quantity of rain which falls upon any particular place depends greatly upon local circumstances, just as it does in the temperate zones, and is greatest where hill-ridges are placed so as to catch the clouds, and smallest in tracts that lie to landward of such ridges. To take our illustrations from India, where the south monsoon blows laden with the copious vapours raised by the equatorial sun from the broad expanse of the Indian Ocean, we find that in the Eastern Himalayas the rainfall varies from 200 to 600 inches a year, and that at Mahabaleshwar, where the clouds drift against the high ridge that lines the west side of the peninsula, it is 248 inches, but that at Courtallum it is only 40 inches, at Bangalore 35 inches, at Cape Comorin 30 inches, and at Bellary, in Mysore, 22 inches, which is as low as in any part of England.

Zone of Periodic Winds without Rain.—Outside the zone of periodic winds and rains comes a double belt, one girdling the world in the northern, and the other in the southern hemisphere, the breadth and area of which is greatly modified by local circumstances, within which no rain ever falls. These belts are estimated to include altogether an area of 5,000,000 square miles, but it is impossible to make any calculation that is at all precise, because round the tracts that are entirely rainless are regions in which rain falls but rarely, which again pass gradually into the two rainy zones, through countries like Southern Palestine and the Gangetic plain, which, though usually rainy, are liable at intervals to years of drought. These belts of rainless land near the tropics contain some of the most hopelessly dreary country which the world can show. Beginning with the west of the old continent we have along the tropic of Cancer, in Africa, the Sahara or great desert, on the southern border of which the rains cease at 16° north latitude, and begin again on the north at 28°. Passing further east the southern rains cease in the countries on the banks of the Nile between 18° and 19°, and the northern begin between 27° and 28°. Passing into Asia, there is a great rainless tract in Arabia, of which we do not know the exact bounds, and it reaches through Beloochistan over into the delta of the Indus, where it does not cover more than 4° of latitude. From this point the rainless zone turns to the north-east, and extends to 30° north latitude. Crossing the great Himalayan chain it includes the high tableland of Tibet, but does not appear to reach into the Chinese empire. In South Africa there is a sandy desert rainless tract on the north of the Orange River, between 24° and 28° south latitude, and a great part of the interior of Australia seems to be nearly or quite rainless. In North America the rainless belt includes the Californian peninsula, and extends round the northern end of the Sierra Madre chain, past Chihuahua and Monterey to the shores of the Gulf of Mexico, between latitudes 24° and 26°. In South America it includes between latitudes 23° and 27° the northern province of Chili, and, through an extensive low tract in the interior of the continent belonging to the territory of the Argentine Confederation, rain is very infrequent and small in quantity.

Zone of Variable Winds and Rains.—From about latitude 30° on each side of the equator to the poles extends a region of ever-changing and variable winds, and of rain that is irregularly distributed throughout the whole year. Sometimes in these middle latitudes—in Britain, for instance—we fall within the sway of the south-rushing polar current deflected to the east by the earth's rotation, and sometimes within that of the north-rushing current from the equator, deflected to the west by the rotation which it shared with the earth at the zone from which it started. In Britain this south-west wind comes to us laden with vapour from the great mass of the Atlantic, and makes Ireland and our western shores unusually damp and rainy. The relative temperatures of sea and land in the temperate zones are continually changing with the seasons. In summer and autumn the Atlantic is colder than the European continent, and this has a tendency to produce a west current at the surface. In winter and spring the Atlantic is warmer than the continent, and this has a tendency to produce an east wind. Sometimes one of these varying tendencies gains the predominance and sometimes another, and the result is constant and often rapid change and variety. The heat and moisture which the wind brings with it depend entirely upon where it comes from, and what it has passed on its way. A west wind blows to us from the Atlantic, and usually brings rain; an east wind brings up the fog of the German Ocean; and in winter and spring the prevalent north-easter brings the cold and often the snow of Russia and Norway. At the seaside, unless it be overpowered by a general current, there is a breeze from off the sea during the day, and a breeze from off the land during the night. The quantity of rain that falls in this zone at different points is extremely variable, and depends upon the position of a place with regard to mountain masses and the seas from which the vapours come. In England the rainfall is greatest on the west side of the island, and smallest on the east. The difference within a short distance is sometimes very striking. There are 140 inches a year at Borrowdale, in the Lake district, and not more than 20 inches at Shields and Sunderland, which are directly opposite on the east coast. But the habitual humidity of the atmosphere often varies but little between places, the rainfall of which is very different. The number of days upon which more or less rain falls varies in England from 100 to 300, but in the Mediterranean region the number of days is fewer, the quantity is smaller, and there is an almost regular period of entirely dry weather in summer. Taking the north temperate zone as a whole, there is, as a rule, least rain in places away from hills in the interior of continents, and most in insular and mountainous situations. The following list gives the annual rainfall in inches at the places mentioned:—

Zone of Periodic Rains.—Singapore, 97; Kandy, 52; Sierra Leone, 86; Madras, 44; St. Helena, 45; Rangoon, 84; Bombay, 75; Calcutta, 76; Rio Janeiro, 59; Havannah, 91; Poonah, 25; St. Domingo, 107; Mahabaleshwar, near Bombay, 254; Cherra Pongee, Khasia, 592.

Zone of Variable Rains: Insular Climates.—Charlestown, 54; Madeira, 27; Coimbra, 118; Seathwaite, Borrowdale, 141; Cahirciveen, Kerry, 59; Westport, Galway, 46; Isle of Man, 37; Dublin, 29; Oxford, 26; Washington, 41; London, 24; Bergen, 88; Edinburgh, 24; Rotterdam, 22; Palermo, 22; Toulon, 18; Marseilles, 23; Padua, 36; Sitka, 87; Manchester, 36; Montpellier, 32.

Zone of Variable Rains: Mountainous Countries.—St. Bernard, 58; Geneva, 31; Berne, 46; Milan, 38; Lausanne, 40.

Zone of Variable Rains: Continental Climates.—Hobart Town, 18; Pekin, 26; Tiflis, 19; Paris, 22; St. Petersburg, 17; Upsala, 18; Prague, 14; Cracow, 13; Coblentz, 22; Nertschinck, 16; Gottingen, 26; Stockholm, 20.

CHAPTER X.

On the Botanical Characteristics of the Zones of Moisture.

As, in speaking of heat, we have had to speak of four groups of plants which have a special constitution in respect to the amount of heat they require, so now, in speaking of moisture, we have to separate plants into three groups, according to their needs as regards aërial humidity. These groups are,—1st, Xerophilous plants, which can live in climates in which the air contains habitually very little moisture; 2nd, Hygrophilous plants, which can only live in climates in which there is habitually a great deal of atmospheric moisture; and 3rd, Noterophilous plants, intermediate in constitution between those of the other two groups.

Broadly stated, the grand influence which the distribution of moisture over the earth's surface exercises upon the distribution of plants is that the earth is girdled round in and near the borders of the two rainless zones, which run like a belt round the earth near the two tropics, and separate the region of the periodic rains from the region of irregular rains, by two broad belts of country, in which the Xerophilous plants predominate more decidedly than they do in any other part of the world, and that they run out from these belts into the interior of the continents, both towards the equator and the poles, avoiding the insular climates.

The concomitants in plant-form of the Xerophilous type of constitution are as follows:—In Dicotyledons,—1st, leaves becoming thick and fleshy, with pulpy inner and leathery outer layers, in which the air-passages and stomata are few, and the cells either small or their walls thickened by secondary deposits of cellulose, as shown in Mesembryanthemum, Sedum, Cotyledon, and Sempervivum; 2nd, the stem condensed into a single, central, unbranched, barrel-shaped or top-shaped mass, which is either leafless, and armed only with spines, as in Mammillaria, Echinocactus, and various Euphorbias, or without spines, and bearing fleshy or rigid leaves, as in Cycads, Welwitschia, and Vitis Bainesii and V. macropus; 3rd, branching, fleshy, or hard stem-types, without proper leaves, but in which the main stems or petioles put on a leafy appearance, as in Opuntia, Phyllocactus, Colletia, and the phyllodineous Acacias; 4th, much-branching shrubs, with copious whip-like branches without either leaves or prickles, as Retama, Ephedra, Rhipsalis, Cassytha, and Euphorbia Tirucalli; 5th, much-branched wiry herbs or shrubs, with an excessive development of prickles, as Fagonia, Alhagi, Gum Acacias, and Acanthosicyos; 6th, shrubs with small, hard, rigid leaves, as Fabiana, Proteaceæ, Larrea, Epacris, Bruniaceæ; 7th, leaves, and often also branches, gland-dotted, as Myrtaceæ, Rutaceæ, and Psoralea, or yielding gummy exudations, like myrrh and frankincense; 8th, flowers protected by an excessive development of scariose bracts, as in Helichrysum, Gomphrena, and Barleria; 9th, dense hairiness or scurfiness on the leaf, bract, and other foliar organs, as shown in Kochia, Eriocephalus, Aerua, and Dalea; 10th, in the development of a tuberous root, large out of all ordinary proportion in comparison with the stems and leaves that come from it, as shown in Hoarea, Seymouria, Diposis, Oxalis, and Brachystelma.

In Monocotyledons we have the Xerophilous type represented in two very characteristic forms: the large, thick, fleshy-leaved type, as illustrated by Aloe, Gasteria, Haworthia, Fourcroya, Agave, and Bulbine; and the familiar bulb type, to which so many of our most beautiful open-air garden-flowers belong,—Lilies, Tulips, Hyacinths, Daffodils, Crocuses, Colchicums, Ixias,—plants which mostly inhabit, not the heart of the rainless tract, but its borders, where rain comes but seldom and sparingly, and which push up into leaf and the flower in the brief season of fertility, and spend the rest of the year in the form of an under-ground mass of dry or fleshy leaf-scales, in the axils of some of which new plants are formed by a process of vegetative reproduction which enables them to hold their ground even if no seed be ripened.

One of the most remarkable points about these Xerophilous plants is the extraordinary way in which many familiar groups of plants, which are distributed through different climates, are modified in form in the Xerophilous belts. We have an excellent instance of this in Euphorbia, which is a genus of 700 species, spread over all parts of the world, all the members of which coincide in the extremely peculiar structure of the flower. About 600 of the species are annual or perennial herbs, several of them widely-spread garden and cornfield weeds, with slender, unarmed stems, and a copious development of scattered, entirely sessile, simple leaves. About a hundred species inhabit the specially Xerophilous region, and these, whilst retaining absolutely their floral structure, become so extremely modified in habit that they are usually taken for Cactuses by inexperienced visitors to our living collections. I can only indicate roughly the general appearance of two or three, taken at random. Euphorbia canariensis is a shrub 20 feet high, with a general shape like a chandelier, throwing out from the main stem copious firm, fleshy, ascending branches, a couple of inches thick, without any leaves, each branch furrowed so as to have five angles, and each angle armed with a row of pairs of hard, pungent prickles, which spread from the ridge at an angle of 45°. Euphorbia Tirucalli is a tall bush, with copious, slender, round, rod-like branches, $\frac{1}{8}$ to $\frac{1}{4}$ inch thick, without any leaves, furrows, or prickles. The Cape Euphorbia polygona has simple, fleshy, cylindrical stems about a foot high, like those of a Cereus in habit, grooved vertically into a dozen deep furrows, each sharp ridge between the furrows armed with a row of close, large, simple, horizontal prickles. The Cape E. meloformis is a top-shaped, leathery, tuberous mass, 3 or 4 inches high and thick, without either leaves or prickles, with eight ridges and eight grooves radiating from a central umbilicus, and carried down the sides.

The large floras of decidedly Xerophilous type are five in number; two in the Northern, and three in the Southern hemisphere, and are as follows:—

1st. The Desert flora, extending from the Canaries, through the Sahara, and through Egypt and Arabia to the Indus delta. This is not so rich in large groups and large genera of decidedly Xerophilous type as some of the others, but it is the largest arid tract in the world, and has a great many endemic genera and species. In the Canaries, in striking Xerophilous types, we have Æonium, Greenovia, Monanthes, Kleinia, Ceropegia, and the Euphorbia canariensis just described. In the continental portion of its area occur several Cactus-like Euphorbias, a few Stapelias and Mesembryanthemums, Aloe socotrina, Retama, Boswellia, Balsamodendron, Nitraria, Seltzenia, Miltianthus, Reaumuria, Anastatica, many erect shrubby Convolvuluses and prickly Acacias, Prosopis, Mærua, Sphærocoma, Fagonia, Balanites, Francœuria, Peganum, Crotalaria arenaria and thebaica; and amongst bulbs, Ornithogalums, Scillas, Urgineas, Xiphions, Trichonema, Erythrostictus, and Dipcadi serotinum. This passes at its eastern end into the little-known flora of the Tibetan plateau and heart of Asia, the great home of Astragalus, Allium, Artemisia, Calligonum, Halimodendron, Galatella, and Cousinia; but it is completely broken up and dissipated in the eastern half of Asia, near the tropic, by the Himalayas.

2nd. The flora of Southern California, New Mexico, Texas, and North Mexico, running out northward to Utah and Kansas, but stopped in a southern direction by the

Mexican Andes. This is the exclusive home of Agave and its allies Fourcroya and Beschorneria, and of the rigid-leaved tree Liliaceæ, Yucca, Hesperaloe, Dasylirion, and Beaucarnea, and it is the great centre of the Cactuses. Of other marked Xerophilous types, it possesses Dion, Echeveria, Claytonia, Spraguea, Talinum, Lewisia, Larrea, Eriogonum, many spiny Mimoseæ, many fleshy-leaved Portulaceæ and Chenopodiaceæ; and in bulbs, Calochortus, Milla, Androstephium, Tigridia, Rigidella, Ferraria, and several Alliums.

Turning now to the Southern hemisphere, we have—

3rd. The flora of Southern Angola, stretching down the coast to the mouth of the Orange River, and across the Kalihari Desert and Cape Karroo to Kaffirland. This is the great home of Aloe (of which one huge arborescent species is said to reach 150 feet in the spread of its branches), Gasteria, Haworthia, Stapelia, Mesembryanthemum (of which latter genus alone there are said to be not less than 400 species of extremely varied habit), and of the Cactus-like Euphorbias. This is the richest Xerophilous flora in the world; and, besides the types already mentioned, possesses Kalanchoe, Cotyledon, Portulacaria, Rhipsalis, Bulbine, a great variety of Crassulas, Welwitschia, Acanthosicyos, Encephalartos, Prionium, Augea, Sisyndite, Sarcocaulon, a great number of Helichrysa, Vitis macropus and V. Bainesii, Anacampseros, many tuberous-rooted Pelargonia, Oxalises and Asclepiads, Kleinia, Othonna, Adenium, Pachypodium, Testudinaria; in rigid and dotted-leaved shrubs, crowds of Proteaceæ, Diosmeæ, Cliffortia, Cluytia, and the Karroo genera of

Compositæ; and in bulbs, Massonia, Lachenalia, Drimia, Ixia, Gladiolus, Babiana, Tritonia, Moræa, Androcymbium, and the very curious climber Bowiea.

4th. The flora of Central Australia, including the Swan River territory, and reaching on the north to the tropic, and on the south to the Victorian Alps. Here there are no Cactuses, Stapelias, Agaves, nor Aloes, and Crassulaceæ is only represented by Bryophyllum. The fleshy-leaved dicotyledons are represented by Zygophyllum, Calandrinia, two or three species of Mesembryanthemum, and several Chenopodiaceæ; and the fleshy endogens by Bulbine. Of the phyllodineous Leguminosæ there are Brachysema, Jacksonia, and not less than 270 species of Acacia. In petaloid monocotyledons there are Stypandra, Patersonia, Cæsia, Thysanotus, Tricoryne, and other Anthericeæ. In Cycads there are Cycas and Macrozamia, and a very peculiar endemic monocotyledonous type of similar habit in Kingia and Xanthorrhœa. The dicotyledons, with large scariose bracts, are represented copiously by Helichrysum and Gomphrena, and there is a similar endemic monocotyledonous type in Borya and Laxmannia. The most abundant type of all is that of bushes with rigid and gland-dotted leaves, very abundantly represented here in Boronieæ, Leguminosæ, Myrtaceæ, Epacridaceæ, and Proteaceæ.

5th. The flora of the Chilian province of Atacama, which extends on the west side of the Andes from the borders of Bolivia to 28° or 30° south latitude, and in the heart of the continent of Catamarca, Tucuman, Cordova, Mendoza, and other provinces of the Argentine Confederation. Here there are no Agaves, Aloes, nor Stapelias, and scarcely any Crassulaceæ, but a great many Cactuses and the Cactus-like Euphorbias are represented by one, and Mesembryanthemums by two or three species. Amongst its characteristic Xerophilous types are Calycereæ, an order confined to this tract; Loasaceæ, which pass up the Andes to the Rocky Mountains; Larrea, Diostea, Fabiana, Pintoa, Plectrocarpa, Bulnesia, Calandrinia, Tetragonia, Colletia, Discaria, the phyllodineous species of Baccharis, Diposis, Grahamia, Silvæa; and in bulbs, Leucocoryne, Milla, Rotherbe, Placea, Stephanolirion, and the very peculiar tribe, Gilliesieæ. Northwards this passes into the dry tract of Central Brazil, the home of Barbacenia, Vellozia, Lychnophoreæ, Microlicieæ, the Cassias of the Chamæcrista group, and a crowd of Cactuses, Mimoseæ, and erect Convolvuli.

The concomitants in plant form of the Hygrophilous type of constitution are luxuriant growth, erectness, and great size of the timber-trees; the presence in the tropical zone of abundant climbers and epiphytes; the absence of prickles, whether adventitious or stipular, or formed by indurated branchlets, leaf-borders, or calyx-teeth; the absence of hair or matting from the leaves, bracts, and other foliar surfaces; the abundance of flowers with large delicate corollas; and the organisation of the leaves, which are planned by air-channels, stomata, and the arrangement and structure of the cell-layers, so as to favour copious evaporation. Within the 20,000,000 square miles that make up the tropical zone, it is the absence and presence of plants of these two opposed types of constitution that give their characteristic tone to the different floras, except so far as this depends on purely geographical conditions. As I have already indicated which are the luxuriant characteristically Hygrophilous floras of the tropical zone, I need not repeat them now. Amongst the most characteristically Hygrophilous plant-types of the tropics are the woody climbers (Lianas), Peppers, Gingers, Dracænas, filmy Ferns, Cyatheas, Laurels, Marattiaceæ, and Anonaceæ.

The distribution of Ferns in general illustrates extremely well how the presence or absence of plants of these two types affects the general character of the tropical floras. Taking Ferns as they stand, as regards species limitation, in the first edition of our 'Synopsis Filicum,' out of 2228 known species, 1901, or 85 per cent., occur in the tropical zone, and 1437 species, or 65 per cent. of the order, are confined to it; but of the genera there are at any rate three—Cheilanthes, Pellæa, and Nothochlæna, including together 125 species—which cannot be considered Hygrophilous. But neglecting these as not materially affecting the result, because many of them are also not tropical, we find practically that the number of Ferns in any tropical or sub-tropical flora furnishes an excellent test of the moisture or dryness of the climate of the country. To take first the continents: there are 944 species in tropical America, 863 in tropical Asia, and 346 in tropical Africa. To take next countries with an insular climate: there are 320 in the Himalayas, 118 in Japan, 153 at the Cape, 113 in New Zealand, 160 in Australia, 213 in the Mascaren Isles, about 200 in Ceylon, 100 in Formosa, 400 in the

Polynesian, and 650 in the Malayan Islands. Contrast these with the number of species in continental climates: Asia Minor, 25; Algeria, 24; Spain, 39; Banda, 7; the Punjaub, apart from the hills, 11; Italy, 40; Arabia Felix, 19. In Egypt the only known Fern is Adiantum Capillus-Veneris. In Nubia there are five; the same Adiantum, Nothochlæna vellea, Onychium melanopus, Actiniopteris radiata, and Ophioglossum vulgatum. In the neighbourhood of Pekin there are five: Adiantum Edgeworthii, A. Capillus-Junonis, Cheilanthus argentea, Asplenium japonicum, and A. pekinense.

In Brazil we have the two kinds of flora displayed side by side under the same latitude: the Hygrophilous type in the Regio Dryadum of Martius, which belts the coast from the province of Santa Catherina, through Rio Janeiro and Bahia, to Pernambuco; and the Xerophilous type in his Regio Oreadum, which occupies a large tract in the interior of the empire in the provinces of Goyaz, Minas Geraes, and St. Paulo. A great many species and genera are restricted to one of the two districts, but there are also a great many other groups and genera, which are represented by a large number of species in both, as, for instance, in orders Malpighiaceæ, Convolvulaceæ, and Bignoniaceæ; and in genera Eupatorium, Vernonia, Mikania, Vitis, and Echites and its allies. The species of these are mostly distinct in the two tracts, and put on so different a type in their vegetative organs, that though, of course, where there is generic identity there is no sensible difference in flower-structure, yet, in nineteen cases out of twenty, it is easy to see from which tract the plant comes by a mere glance at its texture and general aspect, the rigidity of the leaves or their hairy coating, the shortened petioles, the diminished flowers, the congested inflorescence of all, the erect stems of the Malpighiaceæ and Bignoniaceæ, the vanished tendrils of the Vines, the greater quantity and rigidity of the pappus-bristles of the Compositæ, marking the Oreads from the Dryads.

Even within the compass of Britain we have the two types contrasted to a certain extent. Out of the 606 species, which in Britain are gradually lost in passing from the south to the north of the island, Mr. Watson has separated seventy which belong by preference to the west side of the island, and constitute what he calls the "Atlantic type of distribution;" and 127 species which belong by preference to the east side of the island, and constitute what he names the "Germanic type of distribution." In Britain, as we have already explained, the west side is more insular, and the east side is more continental in its climate; and difference in atmospheric climate is in this case intensified in its relation to plant-stations by the nature of the subjacent rocks, the chalk and other dry rocks of calcareous nature being mainly concentrated in the eastern half of England, between Hampshire, Sussex, and the Tyne. There can be little doubt that a principal cause of one set of these plants affecting the east, and the other the west, side of the island is the more Xerophilous constitution of the Germanic, and the more Hygrophilous constitution of the Atlantic group; the two types here, as elsewhere in extra-tropical latitudes, corresponding in the main to the groups which, in their relation to temperature, I have called the warm-lovers and cold-fearers.

In the North of England, and especially in my native Yorkshire, we have masses of these dry rocks of calcareous constitution, with great belts interspersed between them of strata of other kinds. There are a certain number of plants which follow the dry rock from area to area, and avoid the intermediate belts. In the North Riding of Yorkshire I found that sixty-seven species, or one in thirteen of the indigenous plants, did this more or less decidedly. As instances of such plants, I may mention the common Columbine, the Lily of the Valley, the Fly Orchis, Bee Orchis, Helianthemum vulgare, Geranium sanguineum, Sesleria cærulea, Actæa spicata, and Brachypodium pinnatum.

In the heart of the continent there are two great hill-masses of different lithological constitution,—the granitic Vosges and calcareous Jura. The late M. Thurmann, who investigated the subject very carefully, has given an account of the species which are peculiar to each range; and we find that many species (such as Betula alba, Sarothamnus scoparius, Galium saxatile, Hypericum pulchrum, and Stellaria Holostea), which in Britain are the common product of strata of all kinds, and grow freely upon these same limestone hills to which the insect Orchises and wild Columbine are restricted, upon the continent are absent from the calcareous Jura, and restricted to the granitic Vosges. It would seem that under the more insular climate that these plants could grow freely on soils which they avoid under the continental climate, and that in this way the moisture of the air in its relation to plants is modified by the character of the soils in which they grow, and the nature of the great masses of rock beneath the immediate surface.

CHAPTER XI.

On the Influence of Man on the Distribution of Plants.

THE influence of man in modifying the distribution of plants has been very great, and the denser a population becomes the greater is the change produced. According to their relation to man we may class plants under seven groups, as follows:—1st. The wild plants which are soon destroyed in a tract of country which man occupies fully. 2nd. The wild plants which hold their ground under similar circumstances. 3rd. The plants which man cultivates for clothing, medicine, and for his own food and that of the animals he has domesticated. 4th. The plants which man involuntarily introduces along with those which he cultivates on a grand scale, or what Mr. Watson calls "Colonists." 5th. Garden plants grown for ornament, and trees introduced for the sake of their timber or fruit, and bushes introduced for fencing. 6th. Plants of this last class which spread beyond the places where they are planted, and make themselves at home in their new country, propagating themselves from generation to generation, like its original inhabitants: these Mr. Watson calls "Denizens," and to this group M. de Candolle would restrict the use of the term "naturalised," which is often used with greater looseness of application. 7th. Plants introduced with foreign ballast or in similar ways, or which stray from garden-cultivation, but are not able to take any permanent hold upon the soil in their new country: these Mr. Watson calls "Aliens" or "Casuals." I will say a few words about each of these groups, illustrating them principally in reference to the flora of our own country.

The plants which are specially liable to be destroyed from a tract of country fully occupied by man are those that grow in woods and upon heaths and swamps. In Britain a large proportion of the whole surface is converted into arable land, and there are whole counties in which neither a natural wood nor a patch of heatherland remains. In the North-temperate zone, where the range of species is very wide, and the wood- and heath-plants grow together in great numbers, it is very unlikely that a species should get entirely destroyed. Our knowledge of the Botany of Britain, in considerable detail, now goes back for a couple of centuries; and there are very few plants, which we know with certainty as having ever grown really wild in the island, that are not forthcoming at the present time, though some, like Cypripedium Calceolus, Phyllodoce taxifolia, and Lobelia urens, are either quite extinct or upon the very edge of extinction. But if we take a limited tract, like a county, the known loss in species is often considerable. The gradual way in which plants have been exterminated as London has grown is fully illustrated in Trimen & Dyer's 'Flora of Middlesex.' Out of 859 plants which have been clearly known as inhabiting the county, they estimate that 58 species have been destroyed. A list of these will be found at page 345 of the 'Middlesex Flora,' and it includes 17 swamp plants, 4 shrubs, 6 Orchids, and 2 Ferns.

In other regions of the world, where the plan of plant-distribution is different, the change produced by the intervention of man has often been far greater. In the tropics shade is an essential condition of life for a large proportion of the species, and when the woods are cut down these are killed. In the Warm-temperate zone, as a rule, the species are usually much more limited in range than in our latitudes. I give an account of what has occurred in South Africa and St. Helena almost in the words of Dr. Shaw and Dr. Hooker, who have studied upon the spot the Botany of the two colonies.

At the Cape the great grazing district is what is called the Midlands, a tract which extends from the high Snewbergen mountains north-eastward in the direction of Natal, and includes the provinces of Colesberg, Cradock, and Albert. At the time of the travels of Burchell it was covered with luxuriant greensward, with few trees upon the plains, mainly Acacia horrida and brushwood of a few species, whilst its low hilly ranges were covered with bushes and trees, and along its watercourses various kinds of Willow and Acacia luxuriated. This has been the great wool-producing territory of the Cape, and is now being completely changed in the character of its vegetation by overstocking. When first introduced the sheep fed mainly on the grass, but in a country with only periodical rains and a subtropical sun this family soon began to give way. Shrubs could alone stand against the sheep and climate combined. At first and as long as the grass was prominent the shrubs enjoyed immunity from the sheep. But the grass vanished very rapidly, and the bush and scrub came to be the main resource of the flocks, and the ground was left to them and obnoxious and poisonous herbs, Gomphocarpi, Tripteres and Melicæ. The climate necessarily became affected. The rain came down less certainly. Side by side with the attacks of the sheep the more subtle and insidious agency of a changing climate came into power. The hardy plants of the great desert Karroo, on the south-west, commenced to travel northwards, and added their energies to the extirpating of the indigenous flora of the region. Species of Chrysocoma, Pentzia, and other Karroo Compositæ came in. Sweet-bush, such as Lyciums, vanished before them. Chrysocoma truncifolia has been the prevailing plant of late years. It belongs originally to the south-west of the colony. At first it was eschewed by the sheep, but now they have to fall back upon it from necessity. It is a hardy plant, and presents a green appearance when everything else is blackened and scorched. In the southern part of the Midlands it is now so solely the resource of the sheep that the mutton, from the beginning of the year to the end, tastes and smells of it. In short, the district is now fast becoming an extension of dreary, scrubby, half-desert Karroo.

In St. Helena we owe to goats the almost entire destruction of one of the most peculiar floras in the world. The island lies in 16° south latitude, is 1200 miles from Africa, 1800 from America, and 600 miles from the little Island of Ascension, which is the nearest land. It is only ten miles long by seven broad, and rears itself out of the ocean, a black pyramidal volcanic mass, girdled by beetling sea-cliffs, cleft by steep narrow ravines. When discovered, 360 years ago, it was entirely covered with forests, the trees drooping over the tremendous precipices that overhang the sea. Now all is changed: fully five-sixths of the island are utterly barren, and by far the greater part of the vegetation which exists is made up of introduced European, Cape, and American plants. The indigenous flora is almost confined to a few patches on the slope of Diana's Peak, the central ridge of the island, 2700 feet above sea-level. The destruction in this case has been caused by goats. They were introduced in 1513, and increased so rapidly that Captain Cavendish states that in 1588 they existed in thousands. In 1709 trees still abounded, and one, the endemic native Ebony, in such quantities that it was used to burn lime with. At this time the governor of the island reported to the Court of Directors of the East India Company that the timber was rapidly disappearing, and that the goats ought to be destroyed for the sake of the preservation of the Ebony wood, and because the island suffered from drought for want of forests. He received the laconic reply, "The goats are not to be destroyed, being more valuable than Ebony." Another century elapsed, and in 1810 another governor reports the total destruction of the great forests by the goats, and that fuel was so scarce that the Government had to pay for coal (in a tropical island) £2729 a year. Still, even then, so rich was the soil and so great the amount of seed annually shed, and so rapid was the growth of the native plants, that the governor goes on to say that he believed that if the goats were killed and the island left to itself it would become covered again with wood in twenty years. About this time the goats *were* killed; but another enemy to the indigenous vegetation was at the same time introduced, which has now made it impossible that the native plants should ever resume their places. Major-General Beatson, the then governor, proposed and carried out the planting of the island with trees and shrubs introduced from other countries; and these have grown up and spread with such rapidity that the native plants have not been able to compete with them, and the island is now overrun with English Willows, Brooms and Brambles, and Australian Casuarinas, Acacias and Eucalypti, and a host of introduced weeds and grasses. Unfortunately no botanical observations were made in the island till the ruin of the forests was effected. What we have been able to recover from the wreck has been forty-five kinds of flowering plant, forty of which are absolutely peculiar to the island, and seventeen so distinct that they have been regarded as forming endemic genera; and twenty-three species of Fern, thirteen of which are endemic.

The second list, the wild plants that hold their ground well in a fully-settled country, are those that grow in grassy places, by stream-sides, in open exposed ground and moderate shade. The first take refuge in the meadows and pastures, and the last upon the hedge-banks, whilst the scope for the others is not materially lessened.

Respecting the plants cultivated on a grand scale for the use of man it is not necessary for me to enter into details, as the part they play is sufficiently obvious. If, following the generally accepted plan, we divide the long period of man's history which passed over before we have any knowledge derived from historic records, into a Stone period, a Bronze period, and an Iron period, according as the implements used are derived from these materials, we find that in Central Europe man began to domesticate plants and animals early in the first, long before he learnt the use of the metals. We have the record, in the Danish Kjokken-Moddings, of a period when man lived on fish and wild fruits, and all domesticated plants and animals were unknown. In the earlier Swiss-lake dwellings, such as those at Wangen on the Lake of Constance, we have, mixed with nothing but stone implements, remains of a kind of cloth made of plaited Flax, lumps of carbonised Wheat (Triticum vulgare), grains of Triticum dicoceum and two-ranked Barley (Hordeum distichum); and at Robbenhausen and elsewhere, under similar conditions, Hordeum hexastichon, in fine ear (the same kind of Barley which is associated with Egyptian mummies), carbonised Apples and Pears of small size, such as still grow wild in the Swiss woods, stones of the wild Plum, mixed with seeds of the Bramble and Raspberry, and nuts of the Beech and Hazel. At this era the dog, sheep, and goat were already domesticated, but the use of metals was quite unknown.

One of the most noteworthy points about the common plants of cultivation is that many of the commonest and best-known so-called specific types, as the Sugar-cane Wheat, Oat, Tomato, Artichoke, Tobacco, Gossypium herbaceum and barbadense, are totally unknown anywhere in a wild state. But of all these, what are considered distinct species of the same genus are known, and it can scarcely be doubted, judging from the amount of variation which we see in types of which the origin is known, such as the Cabbage, Apple, Pear, and Cherry, that the original types of these others are not really lost, as was commonly supposed till lately, but that an amount of change equivalent to that of an ordinary species has been wrought by domestication. Heer has lately traced the common cultivated Linseed of the present day down into Linum angustifolium at the date of the Swiss-lake dwellings. This last is a plant, widely spread through Europe in a wild state, which has been universally admitted as a distinct species, and I give therefore the characters in which the two types differ :—

Usitatissimum.	*Angustifolium.*
An erect annual, with a single stem from a root.	A perennial, with many stems spreading from the top of the same root.
Leaves lanceolate, the largest 1½ inch long, 1½ to 2 lines broad.	Leaves linear, the largest ½ to 1 inch long, 1 line broad.
Sepals oblong-lanceolate, ¼ inch long.	Sepals oblong-cuspidate, about 2 lines long.
Expanded flower 1 inch across.	Expanded flower ¾ inch across.
Ripe capsule globose, ½ inch thick.	Ripe capsule globose, ¼ inch thick.
Seeds oblanceolate-oblong, 2½ lines long.	Seeds oblong, under ⅛ inch long.

According to Mr. Watson's estimate, the Colonists of Britain number sixty-four species, or about five per cent. of its total flora. In this group we have such plants as the Poppies, Fumitories, Ranunculus arvensis, Chrysanthemum segetum, and Lychnis Githago. These are all annuals, and we have no ground for supposing that, common as they are at the present day, they may not have been introduced into Britain from the South of Europe, along with Wheat, Barley, and Oats. If we extend the group so as to include in it all what are commonly called "Weeds," that is, plants that habitually grow in prepared arable soil, we shall have to count for Britain about 100 species.

The most remarkable point about these annual weeds is the wonderful quantity of seed some of them are capable of producing. An average plant of Papaver dubium or Rhœas will yield 20 flowers, with 300 seeds to a flower, 6000 seeds to a root. An average plant of Shepherd's Purse will yield 800 flowers with 20 seeds each, 16,000 seeds to a root. An average plant of Chickweed or Spergula will yield 300 flowers with 10 seeds each, 3000 seeds to a root. Twenty thousand one-seeded flowers is not an extravagant estimate for a plant of Chenopodium album. This explains the great rapidity with which they will sometimes spread under favouring circumstances. But if a piece of ground be left to itself they do not hold it long. The first year they fill a piece of neglected waste soil almost totally; the second year the quantity is smaller; and by the third year we find they have almost disappeared, and their place is filled by such biennials and perennials as Nettles, Docks, Thistles, Millfoil, Brambles, and coarse grasses, such as Triticum and Dactylis.

It is very curious to see how some of our English weeds that have been introduced in the United States have made themselves at home there, and others have not. Some of our commonest and most prolific kinds have failed to spread; and, on the other hand, plants which do not, from anything that we can see, seem to have any special advantage to help them in the struggle for life, have become widely diffused. To cite a few instances:—Corn-cockle spreads, but Poppies do not; Groundsel is unknown, Chickweed spreads everywhere; Anthemis Cotula is very common, whilst Pyrethrum inodorum is unknown; Lamium amplexicaule spreads faster and becomes more plentiful than Lamium purpureum; Viper's Bugloss is in some parts a great nuisance; weed-Speedwells are very rare; Couch-grass and Carduus arvensis spread; Coltsfoot is very rare, and Scabiosa (Knautia) arvensis unknown.

Respecting the sixth group, Garden plants, I need not say anything. Of the Denizens or naturalized plants, Mr. Watson's estimate for Britain is about fifty species, or four per cent. of its present flora. As instances, may be cited Pyrethrum Parthenium, Artemisia Absinthium, Myrrhis odorata, Populus alba, Prunus Cerasus, and Ulmus suberosa.. These are usually either old long-established garden plants, or trees and bushes, of which, in a country in which the woods have been so much interfered with as in ours, the nativity is uncertain. In

Mauritius these Denizens form a third or a quarter of the flora, and some of them are now the commonest plants in the island. Here they are frequently shrubs that have been introduced for the sake of their fruit or for fencing, like Rubus rosæfolius, Zizyphus vulgaris, and various Cassias and Cæsalpinias, or trees that have been planted, like Casuarina and Hæmatoxylon, to fill the place of the wild forests that have been destroyed.

In a country like ours, with so many trade relations with other parts of the world, the number of the plants that annually get introduced, so that they spring up once beyond the bounds of gardens, is considerable. These Aliens stray from gardens, or are introduced with foreign ballast or clover or corn-seed, or are brought in with cotton and wool imported from other countries. A great many such spring up year by year, especially annuals, and either never perfect good seed or it fails to get a place to grow in. My experience of the Botany of Britain now goes back for a quarter of a century, and during that time, out of the many hundred plants that have been introduced, I can only count up three Aliens that have fully established themselves—Veronica Buxbaumii, a weed of cultivated ground, first seen in Britain in 1829, which may now be fairly reckoned a Colonist in many counties; Galinsoga parviflora, a composite plant allied to the Groundsel, a native of Chili, which got astray from Kew Gardens, about the year 1850, into the Asparagus beds of the neighbourhood, and is now a plentiful weed in the market-gardens of the western suburbs of London; and Anacharis canadensis or Alsinastrum, an

American water-weed, first recorded as British in 1847, which shows no particular tendency to increase in its native country, but which, brought into ours, has become diffused in our ponds and canals in a short time in a wonderful manner, although we have had one sex only, and consequently no seed has ever been produced, but it has had to multiply by mere vegetative reproduction.

CHAPTER XII.

On the Influence of the Distribution of Climate and Sea and Land, in past times, on Plant Geography.

We see that to a very large extent plants are influenced in their distribution by the conditions of Heat and Moisture which prevail in the world at the present time. If we look at the flora of a limited tract of country, like Britain, the effect of these influences seems very striking. The differences between the floras of Sussex and Argyleshire appear to be accounted for, to a large extent, by the present difference between the climates of the two counties. But, if we make the comparison between two tracts of country far apart, say between Yorkshire and one of the New England States, or between Mauritius and Juan Fernandez, we find that there are often very slight differences between their climates, and very great differences between their floras. It seems quite clear that types that have the same climatic constitution have originated in different parts of the world, and that thus the wild flora of any given tract depends largely upon its geographical position.

Specific Centres.—It is commonly taken for granted that each species has originated from a single centre. The principal reason for our thinking this is that we do not find plants scattered about indiscriminately, but that each, as a rule, occupies a definite geographical area within the limits of its climatic capabilities. If we know that a certain species grows both in Britain and the Himalayas, we confidently expect to find it spread through the intervening countries; and this is so continually the case in actual fact that the apparent exceptions cannot be regarded as invalidating the general rule; and the conclusion that each species has originated from a single centre is therefore universally accepted. The same plan of distribution often holds good in respect of genera, tribes and natural orders; and this is one of the strongest arguments in favour of the idea that these have descended from one common ancestor.

Representative Types.—When two types that possess close structural affinity grow in different climates or different geographical areas, we speak of them as *representing* one another. It often happens that two plants of different climates resemble one another so closely that one school of botanists calls them varieties of a single species, and another school calls them distinct but closely-allied species. We have a good instance in our common wild English evergreen shrubs. Ilex Aquifolium, the Holly of Central Europe, is represented in the Mediterranean region by Ilex balearica; Hedera Helix by Hedera canariensis; Buxus sempervirens, the common Box of gardens, by Buxus balearica; and the Box and Ivy, again, in the Himalayas, each by a third "sub-species," as these forms of debateable rank are now often called. Or, to take similar instances from our common Ferns, Polypodium vulgare of Britain is represented in the Canary Islands by Polypodium australe; Ceterach officinarum by Ceterach aureum; and Asplenium Trichomanes by Asplenium anceps. These are all mesotherm types on the one hand, and meiotherm types on the other; and most botanists would now account for the differences between them by supposing that they originated from a common ancestor, and diverged gradually through living under different climatic conditions. In the same way Armeria alpina and Plantago subulata of the hill-peaks of the Arctic-alpine zone represent the common Armeria maritima and Plantago maritima of our Cool-temperate shores.

There is another kind of "representative species," where one plant answers to another extremely near it in characters, placed in a substantially similar climate, but in a different geographical area. The three Raspberries, Rubus idæus, biflorus and strigosus, in this way represent one another in Europe, the Himalayas, and North America. Prunus Padus in Europe answers to Prunus virginiana and serotina in North America; in the same areas Platanus orientalis answers to Platanus occidentalis, Pyrus Aucuparia to Pyrus americana; Cercis Siliquastrum, chinensis, and canadensis represent each other in South Europe, China, and the United States; and Apium graveolens and Lomaria Spicant of the northern hemisphere answer to Apium australe and Lomaria alpina of the South-temperate zone. It would be easy to give instances of both these kinds of representation, allied forms in structure placed under different climates, and in different geographical areas, in tribes, genera and orders, as well as in species; and they furnish another strong argument in favour of the theory of evolution.

Insular Floras.—When we study the flora of Britain, and compare the plants of our island and their distribution with those of the continent, the conclusion appears irresistible that the plants of Britain were spread abroad over its surface whilst island and continent were still joined together. The only wild species out of the 1300 that grow in Britain proper, which are not also continental, are Eriocaulon septangulare, a plant of Ireland and North America, and a few critical types, such as Rosa hibernica, Rubus pyramidalis and Lindleianus, and Hieracium Gibsoni, which cannot safely be relied upon. For Ireland, also, the same conclusion may confidently be stated, because not only are the plants the same, but their distribution in detail lends entire support to the same idea. The species that have a northern tendency with us have the same northern tendency on the continent, the characteristic Arctic-alpines of our hill-summits grow, the same species upon the continent in the same way, and our cold-fearing hygrophilous types of the south-west creep up to us from West France and the Spanish Peninsula. This entire absence of peculiar, or, as they are called, "endemic" types, in non-critical genera, is the most remarkable feature of the British flora, and the study of the details of its distribution is calculated to impress forcibly on the mind the conclusion that the present distribution of species in these latitudes was a fully-accomplished fact before sea and land acquired their present relations; and considering how many thousands of years Britain has been separated from the continent by the German Ocean, this entire absence of endemic types from its flora is a strong argument against the idea of a rapid spontaneous differentiation of specific types in the vegetable kingdom.

We do not find that this entire absence of endemic types holds good for other islands; but we find that their Botany lends strong support to the idea that the plants were settled down before the islands were insulated. Mr. Watson has lately summed up the flora of the Azores, and, out of the 480 plants that form the whole flora of the group, finds that only 40 are endemic, that about 400 are European, 320 North African, and that 340 occur in Madeira and the Canaries taken together; so that the flora of all these islands substantially forms part of that of the Mediterranean basin. Out of 128 Thalamifloræ that grow in Mauritius and the Seychelles, I find that 30 are endemic species. One of the most distinct insular floras in the world is that of New Zealand, where out of 935 flowering plants 677 species are endemic, 222 Australian, and 111 American. St. Helena, with 53 endemic species out of 68, is an extreme case in the direction of individuality.

Geological Evidence.—If we consult geological evidence we find that the greater proportion of the Paleozoic fossils are arborescent Acrogens, including various types of giant Lycopodiaceæ and Equisetaceæ, lost long ago. The fossils of the earlier strata of the secondary series are almost exclusively Cycads and Coniferæ; but it seems now a conclusion safely established that a great many of the present generic types were formed before the close of the cretaceous epoch. Amongst the fossils of the chalk Heer enumerates genera of all the main groups at present in existence, such as Trichomanes, Asplenium, Gleichenia, Sequoia, Pinus, Torreya, Salisburia, Sparganium, Populus, Ficus, Myrica, Sassafras, Andromeda, Diospyros, Panax, Rhus, Sapindus, and Magnolia. Since then the whole tertiary period has intervened, leaving deposits spread over the lower levels of all the great continents. In the Chilian Andes the tertiary beds reach up to 1500 feet, in the South of Europe to 2000 feet, and in the Niti pass, in Tibet, they have been noted at an elevation of no less than 17,000 feet above the present sea-level. In Britain the tertiary series is represented very imperfectly; but we have beds of the eocene alone 600 to 700 feet thick in the London clay, and 1200 to 1300 feet thick in the Bagshot sands. During the earlier tertiaries it seems as if for a long time a torrid climate had prevailed in Europe, as the predominant fossils of our latitudes, both vegetable and animal, are macrotherm types—Palms, Pandani, Bamboos, Lauraceæ, Mimoseæ, Dalbergia, Cassia, Cæsalpinia, Combretaceæ, Tree-ferns, Cinnamons, Figs; Elephants, Hippopotami and Rhinoceroses. In our own latitudes there is every reason to believe that late in the tertiary period the sea reached up to a height of 1500 feet in the North of England, and the present hills existed only as peaks and ridges with an Arctic climate; and that there was a period of cold when such plants as Salix polaris and Betula nana came down to the present sea-level, and that at a comparatively late date the sea was not high enough to separate Great Britain and Ireland from the continent and each other. It would, I believe, be generally accepted as probable, by those best qualified to judge, that all these changes of climate and level have occurred since a large proportion of the genera as we have them now have been in existence. But without endeavouring to trace all these changes in detail, I will only attempt to indicate, in a very cursory way, to what extent the botanical types are now restricted to particular geographical areas within the compass of the restriction which they have through climatic limitation.

Geographical Range of the Macrotherms.—The equatorial zone is more consolidated geographically than any of the other three, as it consists mainly of three continuous areas. The number of characteristic macrotherm species of the higher orders, common to the three continents, is not less than 300 or 400, and the geographical range of many of them is thoroughly cosmopolitan, as the following examples will indicate.

Waltheria americana, Linn. (*indica*, L.).—A Malvaceous undershrub. Tropical America; from Cuba, Florida and the Bahamas to Rio Janeiro and Peru, ascending to 3000 feet in the Andes; Fernando Noronha, Sandwich Islands, Viti, Isle of Pines, and other groups in Polynesia, North Australia, Malay Isles, South China, Philippines, India from Ceylon to the Himalayas, ascending to 4000 feet in Kumaon, Madagascar, Bourbon, Mauritius, Comoros, Africa from Natal to Kaffraria, Angola, and Senegal.

Ximenia americana, L. (*X. elliptica*, Forst.).—A spiny shore shrub, 15 to 20 feet high, with fruit like a plum. Florida and West Indes to Buenos Ayres, Columbia and Peru; Society and Fiji Isles, Samoa, New Caledonia and North Australia; Timor, Malay Isles, Penang, Tavoy, Ceylon and Peninsular India; Seychelles, Nubia to Zambesi Land, Senegal, Guinea, Angola.

Tephrosia purpurea, Pers. (*T. piscatoria*, Pers.; *T. leptostachya*, D.C.).—A perennial, pea-like herb. North Mexico and West Indies to South Brazil, ascending to 6000 to 7000 feet in the Andes; common in Polynesia and through North Australia to New South Wales, Formosa, Philippines, Pescadores, Timor, South China, Malay Isles, Ceylon and through India, ascending to 5000 feet in Central Himalayas, Seychelles, Mauritius, Madagascar, Kaffraria, Natal, Orange free state to Nubia, Angola and Senegal.

Trichomanes rigidum.—A filmy Fern. Cuba and Mexico, up to 5000 feet, to Peru and Rio Janeiro, ascending to 7000 to 8000 feet in the Andes, Samoa, New Hebrides, Viti and other Polynesian isles, Queensland, New Zealand, Philippines, Borneo, Java, South Japan, Malay peninsula, Tavoy, Neilgherries, Ceylon, Seychelles, Madagascar, Mauritius, Bourbon, Natal, Grahamstown, Comoros, Angola, Guinea, Fernando Po.

Lycopodium cernuum.—West Indies and Mexico to South Brazil and Peru, ascending to 5000 to 6000 feet in the Andes, Galapagos, Fiji, Tahiti and other Polynesian isles, St. Paul's Island (near hot springs), New Zealand, Australia, Malay Isles, Formosa, Philippines, South China, Nagasaki, Ceylon to East Himalayas, Seychelles, Mauritius, Comoros, Cape Colony, Guinea, Angola, Azores, St. Helena, Ascension.

Many of these cosmopolitan macrotherms, for want of proper comparison, have been described in local floras under a great number of specific names; Tephrosia purpurea has not less than thirty, and the Trichomanes twenty. The orders principally represented amongst them are Malvaceæ, Leguminosæ, Convolvulaceæ, Cyperaceæ, Gramineæ and Ferns. Of Ferns alone there are sixty-four cosmopolitan macrotherm species. There are a great many species common to Asia and Africa that do not reach America, and a few, such as Sparganophorus Vaillantii, Paullinia pinnata, Ecastaphyllum Brownei and monetaria, Hydrocotyle canariensis, Davallia concinna, Adiantum tetraphyllum and Hymenophyllum lineare, that are American and African, but not Asian.

Of genera there are a very large number that extend into all the three continents, and out of the large number of macrotherm orders very few that are not common to all three. The only large natural orders restricted to the New and Old World respectively are Bromeliaceæ and Gesneraceæ to America and Dipterocarpeæ to the Old World. Of small groups the following are endemic:—Vochysiaceæ, Humiriaceæ, Mayacaceæ and Lacistemaceæ in America, and Balsaminaceæ, Chlœnaceæ, Apostasiaceæ, Aquilariaceæ, Nepenthaceæ and Taccaceæ in the Old World. Of the large orders, Malpighiaceæ, Melastomaceæ and Passifloraceæ only occur in the Old World to a small extent.

Geographical Range of the Mesotherms.—This is the zone which is most broken up in its main geographical areas, and in which there is the greatest amount of geographical localisation of types of all grades. There are very few characteristic species that extend to all or nearly all the seven geographical areas; Lythrum hyssopifolium and Parietaria debilis fulfil this condition, the following being the countries in which they occur:—

Lythrum hyssopifolium. — Mississippi States, Mexico, Chili, Juan Fernandez, South Brazil, Monte Video, Sandwich Isles, New Zealand, Van Diemen's Land, Temperate Australia, Cape Colony, North China, Affghanistan, Orient, South Europe to Central Russia, Belgium, Alsace, England, Barbary States, Canaries, Azores.

Parietaria debilis.—Southern United States and Mexico, Andes of New Granada, Bolivia and Peru, Chili, Uraguay, Mendoza, Buenos Ayres, Norfolk Island, New Zealand, Tasmania, Temperate Australia, Comoros, Mountains of Fernando Po, Guinea and Abyssinia, Madeira and Canaries to Asia Minor, Central Siberia and Afghanistan and East Himalayas, ascending to 12,000 to 14,000 feet.

There are a great many types of different grades that connect together the south hemisphere floras of this zone, distant though Cape Colony, Australia and Extratropical South America now are from one another. Of this kind in species are Apium australe, Triglochin triandrum, Adiantum æthiopicum, Lomaria attenuata and Aspidium coriaceum, all of which are abundant in all the three areas; in genera, Acæna, Gunnera, Scœvola and Uncinia; and in orders, Restiaceæ and Proteaceæ, which are two considerable orders almost restricted to these three south temperate floras, the latter containing forty genera and upwards of six hundred species, all bushes and trees of very peculiar and characteristic habit. Over and above this the alliance of the Cape flora with Extratropical South America and Australia is but trifling; but the links between Extratropical South America on the one hand, and on the other Australia and New Zealand, are considerable. No less than 118 species are common to New Zealand and America, of which 77 are also Australian. Of well-known characteristic South-American generic types that reappear in New Zealand we have instances in Fuchsia, Passiflora, Calceolaria, Ourisia and Pernettya, and of species Oxalis magellanica, Nertera depressa, Lomaria alpina and Polypodium australe.

There are several characteristic mesotherm genera divided between North and South America, as Œnothera, Gilia, Collomia, Mentzelia and Gayophytum, and in the same way between the Mediterranean basin and Cape. Of such some are most plentiful at the Cape, like Erica, Wahlenbergia, Kleinia, Stapelia and Mesembryanthemum, and some, like Dianthus, Matthiola, Ballota and Echium, in the northern area.

There are several curious cases in which large groups are represented in the different geographical areas of this zone by different genera and subgenera. In Cotyledon we have Cotyledon proper at the Cape, Umbilicus in South Europe and Asia, and Echeveria in America; in Rutaceæ, the tribe Ruteæ, with 6 genera and 49 species in the northern hemisphere; the tribe Diosmeæ, with 11 genera and 180 species at the Cape, and the tribe Boronieæ, with 18 genera and 173 species in Australia; in the tribe Podalyrieæ of Leguminosæ we have 5 genera with 80 species in the northern hemisphere, 2 genera with 26 species at the Cape, 19 genera with 365 species in Australia.

In the characteristic orders of the zone the following are the principal that are nearly or quite endemic; in South America Nolanaceæ, Gilliesiaceæ, Francoaceæ, Philesiaceæ, Calycereæ and Tropæolaceæ, all small; in America generally, Hydrophyllaceæ, Loasaceæ and Sarraceniaceæ; in North America and East Asia, taken together, Magnoliaceæ, Calyacanthaceæ, Polemoniaceæ and Hydrangeæ; in the Mediterranean basin, Cistaceæ and Resedaceæ; in Australia, Tremandraceæ, Stackhouseaceæ, Epacridaceæ, Stylidiaceæ, Goodeniaceæ, Casuarinaceæ and Desvauxiaceæ; and at the Cape, Bruniaceæ, Stilbaceæ, Penæaceæ and Selaginaceæ.

Geographical Range of the Meiotherms.—In the cool-temperate zone types of all the three grades are very widely diffused geographically. Out of the 1425 British species none are endemic, only 316 restricted to Europe, about 250 reach the Himalayas, 450 reach America, and nearly 100 the southern hemisphere. According to Dr. Asa Gray's summary of the geography of the flowering plants of the Northern United States, out of 2091 only 71 are endemic, 416 extend westward to the Pacific coast or near it, 308 are Asiatic, and 321 European. The following will give an idea of the entire range of some of these widespread meiotherm species:—

Taraxacum officinale (the Common Dandelion).—All through Europe and Siberia from arctic latitudes, ascending into all the six zones in Britain, to Algeria and Sikkim,—where it grows at from 11,000 to 18,000 feet,—Formosa, Hong Kong and Japan, North America, from Greenland down to New Mexico and the Andes of Southern Mexico, Canaries, Azores, Temperate Australia, New Zealand, Chatham Island, Straits of Magellan, Andes of Chili and Mendoza.

Lycopodium clavatum.—All through the north temperate zone from Lapland and Archangel and Britain to Canada and the United States; Natal, Cape Colony, all through the Himalayas, hills of Java, Moulmein, Neilgherries, Ceylon, Andes of Mexico, Columbia and Peru, ascending to 11,000 feet; Organ Mountains and hills of West Indies and Central Brazil, Fuegia, Staten Land, Kerguelen's Land, Tristan d'Acunha, Falkland Isles, Sandwich Isles, Auckland and Campbell Isles, New Zealand, Van Diemen's Land, common at 4000 feet and upwards.

Asplenium Trichomanes.—Temperate regions of Old World from Britain, the Azores and Madeira to Japan and the Himalayas, where it ascends to 8000 feet; Algeria, Cape Colony, Temperate Australia, Van Diemen's Land, New Zealand, Sandwich Isles, Temperate North America, Andes of Mexico, New Granada and Peru, Organ Mountains.

Cerastium triviale.—Universal in north temperate hemisphere from Lapland, Iceland and Britain, to Greenland and United States, Azores, Canaries, Barbary, St. Helena, Cape Colony, Camaroons, Abyssinia, through the Himalayas, ascending to 12,000 feet in Sikkim, Neilgherries, Sandwich Islands, Australia, New Zealand, Andes of Mexico, Uraguay, Chili, Patagonia, Falklands, Tristan d'Acunha.

Lythrum Salicaria.—Through Europe from Britain to Siberia and Japan, Barbary, West Himalayas, Afghanistan, Australia, Van Diemen's Land, New Zealand, United States.

Montea fontana.—All through Europe from Britain and Lapland to Greece, Spain and Corsica, Algeria, West Himalayas, Russian America, Greenland, California, Rocky Mountains (not Eastern States), Andes of Mexico, Bolivia and Peru, Chili, Uraguay, Kerguelen's Land, Falkland Isles (9000 to 12,000 feet), Cape Horn, Auckland Isles, Campbell Isles, New Zealand, Van Diemen's Land.

To illustrate the way in which these meiotherm species reach the proper zones of isolated mountains that rise from the zones of former latitudes, I give a list of twenty-one British plants which were gathered by Mann upon the Cameroons, an isolated range in the Gulf of Guinea very near the equator, at a height of 7000 to 12,000 feet:—Cardamine hirsuta, Cerastium triviale, Radiola Millegrana, Oxalis corniculata, Cotyledon Umbilicus, Sanicula europæa, Galium Aparine, Scabiosa succisa, Limosella aquatica, Sibthorpia europæa, Solanum nigrum, Trichonema Bulbocodium, Juncus capitatus, Luzula campestris, Aira cæspitosa and caryophyllea, Poa nemoralis, Kœleria cristata, Festuca bromoides, F. gigantea and Brachypodium sylvaticum.

How close the alliance often is between the herbaceous plants of Europe and North America is well shown in the natural order Ranunculaceæ, in which the geography of the thirty-one genera, or large subgenera of the north temperate zone, is as follows:—

Represented by the same Species in Europe and North America.—Euanemone, Hepatica, Batrachium, Ranunculus, Coptis, Myosurus, Caltha, Actæa.

Represented by different Species in Europe and North America.—Atragene, Clematis, Pulsatilla, Thalictrum, Trollius, Pæonia, Isopyrum, Aquilegia, Delphinium, Aconitum, Cimicifuga.

Confined to the Old World.—Adonis, Callianthemum, Oxygraphis, Calathodes, Glaucidium, Helleborus, Eranthis, Nigella, Anemonopsis.

Asian and American, not European.—Trautvetteria.

American alone.—Hydrastis, Xanthorhiza.

The following is a list of the arborescent and fruticose genera, the most restricted in their distribution of all, represented by identical and by distinct species in Europe and the United States:—

By the same Species.—Viburnum, Loiseleuria, Empetrum, Ribes, Humulus, Castanea, Myrica, Betula, Alnus, Salix, Sedum, Phyllodoce, Juniperus, Taxus, Spiræa, Rubus, Vaccinium, Arctostaphyllos, Andromeda, Cassiope, Cassandra.

Genus the same, but Species distinct.—Tilia, Rhus, Rhamnus, Euonymus, Acer, Rosa, Cratægus, Cercis, Prunus, Pyrus, Amelanchier, Sambucus, Rhododendron, Ilex, Ulmus, Planera, Celtis, Morus, Platanus, Juglans, Quercus, Fagus, Corylus, Carpinus, Populus, Pinus, Berberis, Vitis, Celastrus, Staphylea.

Geographical Range of the Microtherms.—Probably not less than 500 species are scattered over the mountain ridges and peaks of the arctic-alpine zone in the northern hemisphere, in a way which the following instances will show:—

Thalictrum alpinum.—Arctic zone of New and Old World, Iceland, Faroe, Norway, Sweden, England, Scotland, Ireland, Wales, Alps, Pyrenees, Carpathians, Tyrol, Transylvania, Caucasus, Altai, Baikal, Songaria, East and West Himalayas (in Sikkim at 11,000 to 15,000 feet), Behring's Straits, Newfoundland, Rocky Mountains.

Silene acaulis.—Arctic America, Greenland, Lapland, Spitzbergen, Iceland, Faroe, Shetland, Scotland, England, Wales, Norway, Sweden, Alps, Pyrenees, Apennines, Tyrol, Bavaria, Carinthia, Rocky Mountains.

Lychnis alpina.—Greenland, Lapland, Dovrefeld, Braemar, Cumberland, Iceland, Swiss Alps, Dauphiné, Pyrenees, Tyrol, Bosnia, Ural, Davuria, Labrador, Rocky Mountains.

Dryas octopetala.—Common all round the arctic zone, Dovrefeld, Iceland, Faroe, Scotland, Teesdale, Ireland, Swiss Alps, Jura, Pyrenees, Apennines, Dauphiné, Tyrol, Bavaria, Carinthia, Scardus, Altai, Davuria, Rocky Mountains (in latitude 49°, at 7000 to 8000 feet).

We cannot explain the present wide-spread distribution over distant peaks and ridges of these in any other way than by supposing that at some former period of cold they have been spread over what is now the cool-temperate zone through the northern hemisphere, and that when a warmer climate has come they have retreated to the heights, and there maintained their ground. Very few of these arctic-alpines of the northern hemisphere extend to the tropics or the southern hemisphere.

The most widely-spread characteristic plants of this zone are the following, all of which extend from the arctic zone by latitude to the mountains of the south temperate zone, mainly in America by way of the Andes, which are the only range of high hills that bridge over the zone tropical by latitude from north to south:—Vesicaria arctica, Draba incana, Lychnis apetala, Sagina Linnæi, Epilobium alpinum, Saxifraga cæspitosa, Erigeron alpinus, Empetrum nigrum, Carex magellanica (irrigua), Alopecurus alpinus, Phleum alpinum, Trisetum subspicatum, Lycopodium Selago.

Upon review of the whole series of facts that relate to the geographical, as subordinate to the climatic, distribution of plants at the present time, the most striking point to notice seems to be how independent species often are, and genera more frequently, and orders more frequently still, of present geographical limitations; and if the origin of species from a single centre be admitted, this is a strong proof of the ancientness of specific types as compared with the present arrangement of sea and land, and their durability through a long series of changing circumstances.

Summary.—The following, therefore, are the principal conclusions with regard to the influence exercised upon plant-distribution by causes over and above present climate, which known facts seem to support:—

1. That each species has originated from a single centre.

2. That species have originated in different parts of the world, and that the flora of any given tract depends largely on its geographical position.

3. That a large portion of the present genera (or types which agree in structure down to minute detail) were in existence before the end of the secondary period, and have passed through the very great changes in climate and the relative positions of sea and land that have occurred during the tertiary period.

4. That species (or types which accord, not in structure only, but in vegetative characters,—such as shape of leaves and arrangement of flowers) were dispersed in broad outline as at present, before present islands were insulated, and the present general dispersion of sea and land worked out.

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