ALFRED RUSSEL WALLACE

ISLAND LIFE; OR, THE PHENOMENA AND CAUSES OF INSULAR FAUNAS AND FLORAS

Alfred Wallace

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Island Life; Or, The Phenomena and Causes of Insular Faunas and Floras:

Содержание

PREFACE TO THE SECOND EDITION 6
PREFACE TO THE FIRST EDITION 9
PART I 12
CHAPTER I 12
CHAPTER II 25
CHAPTER III 52
CHAPTER IV 84
CHAPTER V 107
CHAPTER VI 122
CHAPTER VII 153
CHAPTER VIII 178
Конец ознакомительного фрагмента. 199

Alfred Russel Wallace Island Life; Or, The Phenomena and Causes of Insular Faunas and Floras

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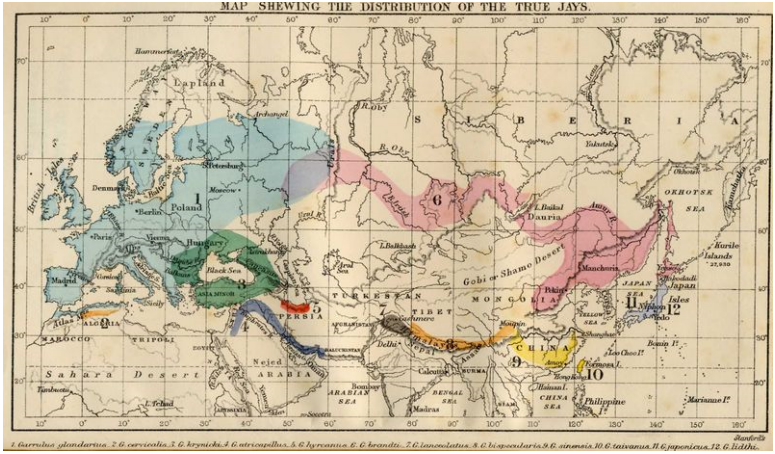

TO

SIR JOSEPH DALTON HOOKER,

K.C.S.I., C.B., F.R.S., ETC., ETC

WHO, MORE THAN ANY OTHER WRITER,

HAS ADVANCED OUR KNOWLEDGE OF THE GEOGRAPHICAL

DISTRIBUTION OF PLANTS, AND ESPECIALLY

OF INSULAR FLORAS,

I Dedicate this Volume;

PREFACE TO THE SECOND EDITION

This edition has been carefully revised throughout, and owing to the great increase to our knowledge of the Natural History of some of the islands during the last twelve years considerable additions or alterations have been required. The more important of these changes are the following:—

Chapter VII. The account of the migrations of animals and plants during and since the Glacial Epoch, has been modified to accord with newer information.

Chapters VIII and IX. The discussion of the causes of Glacial Epochs and Mild Arctic Climates has been somewhat modified in view of the late Dr. Croll's remarks, and the argument rendered clearer.

Chapter XIII. Several additions to the Fauna of the Galapagos have been noted.

Chapter XV. Considerable additions have been made to this chapter embodying the recent discoveries of birds and insects new to the Sandwich Islands, while a much fuller account has been given of its highly peculiar and very interesting flora.

Chapter XVI. Important additions and corrections have been made in the lists of peculiar British animals and plants embodying the most recent information.

Chapter XVII. Very large additions have been made to the mammalia and birds of Borneo, and full lists of the peculiar species are given.

Chapter XVIII. A more accurate account is given of the birds of Japan.

Chapter XIX. The recent additions to the mammals and birds of Madagascar are embodied in this chapter, and a fuller sketch is given of the rich and peculiar flora of the island.

Chapter XXI. and XXII. Some important additions have been made to these chapters owing to more accurate information as to the depth of the sea around New Zealand, and to the discovery of abundant remains of fossil plants of the tertiary and cretaceous periods both in New Zealand and Australia.

In the body of the work I have in each case acknowledged the valuable information given me by naturalists of eminence in their various departments, and I return my best thanks to all who have so kindly assisted me. I am however indebted in a special manner to one gentleman—Mr. Theo. D. A. Cockerell, now Curator of the Museum of the Jamaica Institute—who supplied me with a large amount of information by searching the most recent works in the scientific libraries, by personal inquiries among naturalists, and also by giving me the benefit of his own copious notes and observations. Without his assistance it would have been difficult for me to have made the present edition so full and complete as I hope it now is. In a work of such wide range, and dealing with so large a body of facts some errors will doubtless be detected,

though, I trust few of importance.

Parkstone, Dorset, *December, 1891*.

PREFACE TO THE FIRST EDITION

The present volume is the result of four years' additional thought and research on the lines laid down in my *Geographical Distribution of Animals*, and may be considered as a popular supplement to and completion of that work.

It is, however, at the same time a complete work in itself: and, from the mode of treatment adopted, it will, I hope, be well calculated to bring before the intelligent reader the wide scope and varied interest of this branch of natural history. Although some of the earlier chapters deal with the same questions as my former volumes, they are here treated from a different point of view; and as the discussion of them is more elementary and at the same time tolerably full, it is hoped that they will prove both instructive and interesting. The plan of my larger work required that *genera* only should be taken account of; in the present volume I often discuss the distribution of *species*, and this will help to render the work more intelligible to the unscientific reader.

The full statement of the scope and object of the present essay given in the "Introductory" chapter, together with the "Summary" of the whole work and the general view of the more important arguments given in the "Conclusion," render it unnecessary for me to offer any further remarks on these points. I may, however, state generally that, so far as I am able

to judge, a real advance has here been made in the mode of treating problems in Geographical Distribution, owing to the firm establishment of a number of preliminary doctrines or "principles," which in many cases lead to a far simpler and yet more complete solution of such problems than have been hitherto possible. The most important of these doctrines are those which establish and define—(1) The former wide extension of all groups now discontinuous, as being a necessary result of "evolution"; (2) The permanence of the great features of the distribution of land and water on the earth's surface; and, (3) The nature and frequency of climatal changes throughout geological time.

I have now only to thank the many friends and correspondents who have given me information or advice. Besides those whose assistance is acknowledged in the body of the work, I am especially indebted to four gentlemen who have been kind enough to read over the proofs of chapters dealing with questions on which they have special knowledge, giving me the benefit of valuable emendations and suggestions. Mr. Edward R. Alston has looked over those parts of the earlier chapters which relate to the mammals of Europe and the North Temperate zone; Mr. S. B. J. Skertchley, of the Geological Survey, has read the chapters which discuss the glacial epoch and other geological questions; Professor A. Newton has looked over the passages referring to the birds of the Madagascar group; while Sir Joseph D. Hooker has given me the invaluable benefit of his remarks on

my two chapters dealing with the New Zealand flora.

Croydon, *August, 1880*.

PART I
THE DISPERSAL OF ORGANISMS ITS PHENOMENA, LAWS, AND CAUSES

CHAPTER I
INTRODUCTORY

Remarkable Contrasts in distribution of Animals—Britain and Japan—Australia and New Zealand—Bali and Lombok—Florida and Bahama Islands—Brazil and Africa—Borneo, Madagascar, and Celebes—Problems in distribution to be found in every country—Can be solved only by the combination of many distinct lines of inquiry, biological and physical—Islands offer the best subjects for the study of distribution—Outline of the subjects to be discussed in the present volume.

When an Englishman travels by the nearest sea-route from Great Britain to Northern Japan he passes by countries very unlike his own, both in aspect and natural productions. The sunny isles of the Mediterranean, the sands and date-palms of Egypt, the arid rocks of Aden, the cocoa groves of Ceylon, the tiger-

haunted jungles of Malacca and Singapore, the fertile plains and volcanic peaks of Luzon, the forest-clad mountains of Formosa, and the bare hills of China, pass successively in review; till after a circuitous voyage of thirteen thousand miles he finds himself at Hakodadi in Japan. He is now separated from his starting-point by the whole width of Europe and Northern Asia, by an almost endless succession of plains and mountains, arid deserts or icy plateaux, yet when he visits the interior of the country he sees so many familiar natural objects that he can hardly help fancying he is close to his home. He finds the woods and fields tenanted by tits, hedge-sparrows, wrens, wagtails, larks, redbreasts, thrushes, buntings, and house-sparrows, some absolutely identical with our own feathered friends, others so closely resembling them that it requires a practised ornithologist to tell the difference. If he is fond of insects he notices many butterflies and a host of beetles which, though on close examination they are found to be distinct from ours, are yet of the same general aspect, and seem just what might be expected in any part of Europe. There are also of course many birds and insects which are quite new and peculiar, but these are by no means so numerous or conspicuous as to remove the general impression of a wonderful resemblance between the productions of such remote islands as Britain and Yesso.

Now let an inhabitant of Australia sail to New Zealand, a distance of less than thirteen hundred miles, and he will find himself in a country whose productions are totally unlike those of his own. Kangaroos and wombats there are none, the birds

are almost all entirely new, insects are very scarce and quite unlike the handsome or strange Australian forms, while even the vegetation is all changed, and no gum-tree, or wattle, or grass-tree meets the traveller's eye.

But there are some more striking cases even than this, of the diversity of the productions of countries not far apart. In the Malay Archipelago there are two islands, named Bali and Lombok, each about as large as Corsica, and separated by a strait only fifteen miles wide at its narrowest part. Yet these islands differ far more from each other in their birds and quadrupeds than do England and Japan. The birds of the one are extremely *unlike* those of the other, the difference being such as to strike even the most ordinary observer. Bali has red and green woodpeckers, barbets, weaver-birds, and black-and-white magpie-robins, none of which are found in Lombok, where, however, we find screaming cockatoos and friar-birds, and the strange mound-building megapodes, which are all equally unknown in Bali. Many of the kingfishers, crow-shrikes, and other birds, though of the same general form, are of very distinct species; and though a considerable number of birds are the same in both islands the difference is none the less remarkable—as proving that mere distance is one of the least important of the causes which have determined the likeness or unlikeness in the animals of different countries.

In the western hemisphere we find equally striking examples. The Eastern United States possess very peculiar and interesting

plants and animals, the vegetation becoming more luxuriant as we go south but not altering in essential character, so that when we reach Alabama or Florida we still find ourselves in the midst of pines, oaks, sumachs, magnolias, vines, and other characteristic forms of the temperate flora; while the birds, insects, and land-shells are of the same general character with those found further north.[1] But if we now cross over the narrow strait, about fifty miles wide, which separates Florida from the Bahama Islands, we find ourselves in a totally different country, surrounded by a vegetation which is essentially tropical and generally identical with that of Cuba. The change is most striking, because there is little difference of climate, of soil, or apparently of position, to account for it; and when we find that the birds, the insects, and especially the land-shells of the Bahamas are almost all West Indian, while the North American types of plants and animals have almost all completely disappeared, we shall be convinced that such differences and resemblances cannot be due to existing conditions, but must depend upon laws and causes to which mere proximity of position offers no clue.

Hardly less uncertain and irregular are the effects of climate. Hot countries usually differ widely from cold ones in all their organic forms; but the difference is by no means constant, nor does it bear any proportion to difference of temperature.

[1] A small number of species belonging to the West Indies are found in the extreme southern portion of the Florida Peninsula.

Between frigid Canada and sub-tropical Florida there are less marked differences in the animal productions than between Florida and Cuba or Yucatan, so much more alike in climate and so much nearer together. So the differences between the birds and quadrupeds of temperate Tasmania and tropical North Australia are slight and unimportant as compared with the enormous differences we find when we pass from the latter country to equally tropical Java. If we compare corresponding portions of different continents, we find no indication that the almost perfect similarity of climate and general conditions has any tendency to produce similarity in the animal world. The equatorial parts of Brazil and of the West Coast of Africa are almost identical in climate and in luxuriance of vegetation, but their animal life is totally diverse. In the former we have tapirs, sloths, and prehensile-tailed monkeys; in the latter elephants, antelopes, and man-like apes; while among birds, the toucans, chatterers, and humming-birds of Brazil are replaced by the plantain-eaters, bee-eaters, and sun-birds of Africa. Parts of South-temperate America, South Africa, and South Australia, correspond closely in climate; yet the birds and quadrupeds of these three districts are as completely unlike each other as those of any parts of the world that can be named.

If we visit the great islands of the globe, we find that they present similar anomalies in their animal productions, for while some exactly resemble the nearest continents others are widely different. Thus the quadrupeds, birds and insects of

Borneo correspond very closely to those of the Asiatic continent, while those of Madagascar are extremely unlike African forms, although the distance from the continent is less in the latter case than in the former. And if we compare the three great islands Sumatra, Borneo, and Celebes—lying as it were side by side in the same ocean—we find that the two former, although furthest apart, have almost identical productions, while the two latter, though closer together, are more unlike than Britain and Japan situated in different oceans and separated by the largest of the great continents.

These examples will illustrate the kind of questions it is the object of the present work to deal with. Every continent, every country, and every island on the globe, offers similar problems of greater or less complexity and interest, and the time has now arrived when their solution can be attempted with some prospect of success. Many years study of this class of subjects has convinced me that there is no short and easy method of dealing with them; because they are, in their very nature, the visible outcome and residual product of the whole past history of the earth. If we take the organic productions of a small island, or of any very limited tract of country, such as a moderate-sized country parish, we have, in their relations and affinities—in the fact that they are *there* and others are *not* there, a problem which involves all the migrations of these species and their ancestral forms—all the vicissitudes of climate and all the changes of sea and land which have affected those migrations—the whole series

of actions and reactions which have determined the preservation of some forms and the extinction of others,—in fact the whole history of the earth, inorganic and organic, throughout a large portion of geological time.

We shall perhaps better exhibit the scope and complexity of the subject, and show that any intelligent study of it was almost impossible till quite recently, if we concisely enumerate the great mass of facts and the number of scientific theories or principles which are necessary for its elucidation.

We require then in the first place an adequate knowledge of the fauna and flora of the whole world, and even a detailed knowledge of many parts of it, including the islands of more special interest and their adjacent continents. This kind of knowledge is of very slow growth, and is still very imperfect;[2]

[2] I cannot avoid here referring to the enormous waste of labour and money with comparatively scanty and unimportant results to natural history of most of the great scientific voyages of the various civilized governments during the present century. All these expeditions combined have done far less than private collectors in making known the products of remote lands and islands. They have brought home fragmentary collections, made in widely scattered localities, and these have been usually described in huge folios or quartos, whose value is often in inverse proportion to their bulk and cost. The same species have been collected again and again, often described several times over under new names, and not unfrequently stated to be from places they never inhabited. The result of this wretched system is that the productions of some of the most frequently visited and most interesting islands on the globe are still very imperfectly known, while their native plants and animals are being yearly exterminated, and this is the case even with countries under the rule or protection of European governments. Such are the Sandwich Islands, Tahiti, the Marquesas, the Philippine Islands, and a host of smaller ones; while Bourbon and Mauritius, St. Helena, and several others, have only been adequately explored after an

and in many cases it can never now be obtained owing to the reckless destruction of forests and with them of countless species of plants and animals. In the next place we require a true and natural classification of animals and plants, so that we may know their real affinities; and it is only now that this is being generally arrived at. We further have to make use of the theory of "descent with modification" as the only possible key to the interpretation of the facts of distribution, and this theory has only been generally accepted within the last twenty years. It is evident that, so long as the belief in "special creations" of each species prevailed, no explanation of the complex facts of distribution *could* be arrived at or even conceived; for if each species was created where it is now found no further inquiry can take us beyond that fact, and there is an end of the whole matter. Another important factor in our interpretation of the phenomena of distribution, is a knowledge of the extinct forms that have inhabited each country during the tertiary and secondary periods of geology. New facts of this kind are daily coming to light, but except as regards Europe, North America, and parts of India, they are extremely scanty; and even in the best-known countries the record itself is often very defective and fragmentary. Yet we have already obtained remarkable evidence of the migrations

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important portion of their productions has been destroyed by cultivation or the reckless introduction of goats and pigs. The employment in each of our possessions, and those of other European powers, of a resident naturalist at a very small annual expense, would have done more for the advancement of knowledge in this direction than all the expensive expeditions that have again and again circumnavigated the globe.

of many animals and plants in past ages, throwing an often unexpected light on the actual distribution of many groups.[3] By this means alone can we obtain positive evidence of the past migrations of organisms; and when, as too frequently is the case, this is altogether wanting, we have to trust to collateral evidence and more or less probable hypothetical explanations. Hardly less valuable is the evidence of stratigraphical geology; for this often shows us what parts of a country have been submerged at certain epochs, and thus enables us to prove that certain areas have been long isolated and the fauna and flora allowed time for special development. Here, too, our knowledge is exceedingly imperfect, though the blanks upon the geological map of the world are yearly diminishing in extent. Lastly, as a most valuable supplement to geology, we require to know approximately, the depth and contour of the ocean-bed, since this affords an important clue to the former existence of now-submerged lands, uniting islands to continents, or affording intermediate stations which have aided the migrations of many organisms. This kind of information has only been partially obtained during the last few years; and it will be seen in the latter part of this volume, that some of the most recent deep-sea soundings have afforded a basis for an explanation of one of the most difficult and interesting questions in geographical biology—the origin of the fauna and

[3] The general facts of Palæontology, as bearing on the migrations of animal groups, are summarised in my *Geographical Distribution of Animals*, Vol. I. Chapters VI., VII., and VIII.

flora of New Zealand.

Such are the various classes of evidence that bear directly on the question of the distribution of organisms; but there are others of even a more fundamental character, and the importance of which is only now beginning to be recognised by students of nature. These are, firstly, the wonderful alterations of climate which have occurred in the temperate and polar zones, as proved by the evidences of glaciation in the one and of luxuriant vegetation in the other; and, secondly, the theory of the permanence of existing continents and oceans. If glacial epochs in temperate lands and mild climates near the poles have, as now believed by men of eminence, occurred several times over in the past history of the earth, the effects of such great and repeated changes, both on the migration, modification, and extinction, of species, must have been of overwhelming importance—of more importance perhaps than even the geological changes of sea and land. It is therefore necessary to consider the evidence for these climatal changes; and then, by a critical examination of their possible causes, to ascertain whether they were isolated phenomena, were due to recurrent cosmical actions, or were the result of a great system of terrestrial development. The latter is the conclusion we arrive at; and this conclusion brings with it the conviction, that in the theory which accounts for both glacial epochs and warm polar climates, we have the key to explain and harmonize many of the most anomalous biological and geological phenomena, and one which is especially valuable

for the light it throws on the dispersal and existing distribution of organisms. The other important theory, or rather corollary from the preceding theory—that of the permanence of oceans and the general stability of continents throughout all geological time, is as yet very imperfectly understood, and seems, in fact, to many persons in the nature of a paradox. The evidence for it, however, appears to me to be conclusive; and it is certainly the most fundamental question in regard to the subject we have to deal with: since, if we once admit that continents and oceans may have changed places over and over again (as many writers maintain), we lose all power of reasoning on the migrations of ancestral forms of life, and are at the mercy of every wild theorist who chooses to imagine the former existence of a now-submerged continent to explain the existing distribution of a group of frogs or a genus of beetles.

As already shown by the illustrative examples adduced in this chapter, some of the most remarkable and interesting facts in the distribution and affinities of organic forms are presented by islands in relation to each other and to the surrounding continents. The study of the productions of the Galapagos—so peculiar, and yet so decidedly related to the American continent—appears to have had a powerful influence in determining the direction of Mr. Darwin's researches into the origin of species; and every naturalist who studies them has always been struck by the unexpected relations or singular anomalies which are so often found to characterize the fauna and flora of islands. Yet their full

importance in connection with the history of the earth and its inhabitants has hardly yet been recognised; and it is in order to direct the attention of naturalists to this most promising field of research, that I restrict myself in this volume to an elucidation of some of the problems they present to us. By far the larger part of the islands of the globe are but portions of continents undergoing some of the various changes to which they are ever subject; and the correlative proposition, that every portion of our continents has again and again passed through insular conditions, has not been sufficiently considered, but is, I believe, the statement of a great and most suggestive truth, and one which lies at the foundation of all accurate conception of the physical and organic changes which have resulted in the present state of the earth.

The indications now given of the scope and purpose of the present volume renders it evident that, before we can proceed to the discussion of the remarkable phenomena presented by insular faunas and floras, and the complex causes which have produced them, we must go through a series of preliminary studies, adapted to give us a command of the more important facts and principles on which the solution of such problems depends. The succeeding eight chapters will therefore be devoted to the explanation of the mode of distribution, variation, modification, and dispersal, of species and groups, illustrated by facts and examples; of the true nature of geological change as affecting continents and islands; of changes of climate, their nature, causes, and effects; of the duration of geological time and the

rate of organic development.

CHAPTER II
THE ELEMENTARY FACTS OF DISTRIBUTION

Importance of Locality as an essential character of Species—Areas of Distribution—Extent and Limitations of Specific Areas—Specific range of Birds—Generic Areas—Separate and overlapping areas—The species of Tits as illustrating Areas of Distribution—The distribution of the species of Jays—Discontinuous generic areas—Peculiarities of generic and family distribution—General features of overlapping and discontinuous areas—Restricted areas of Families—The distribution of Orders.

So long as it was believed that the several species of animals and plants were "special creations," and had been formed expressly to inhabit the countries in which they are now found, their habitat was an ultimate fact which required no explanation. It was assumed that every animal was *exactly* adapted to the climate and surroundings amid which it lived, and that the only, or, at all events, the chief reason why it did not inhabit another country was, that the climate or general conditions of that country were not suitable to it, but in what the unsuitability consisted we could rarely hope to discover. Hence the exact locality of any species was not thought of much importance from

a scientific point of view, and the idea that anything could be learnt by a comparative study of different floras and faunas never entered the minds of the older naturalists.

But so soon as the theory of evolution came to be generally adopted, and it was seen that each animal could only have come into existence in some area where ancestral forms closely allied to it already lived, a real and important relation was established between an animal and its native country, and a new set of problems at once sprang into existence. From the old point of view the *diversities* of animal life in the separate continents, even where physical conditions were almost identical, was the fact that excited astonishment; but seen by the light of the evolution theory, it is the *resemblances* rather than the diversities in these distant continents and islands that are most difficult to explain. It thus comes to be admitted that a knowledge of the exact area occupied by a species or a group is a real portion of its natural history, of as much importance as its habits, its structure, or its affinities; and that we can never arrive at any trustworthy conclusions as to how the present state of the organic world was brought about, until we have ascertained with some accuracy the general laws of the distribution of living things over the earth's surface.

Areas of Distribution.—Every species of animal has a certain area of distribution to which, as a rule, it is permanently confined, although, no doubt, the limits of its range fluctuate somewhat from year to year, and in some exceptional cases may

be considerably altered in a few years or centuries. Each species is moreover usually limited to one continuous area, over the whole of which it is more or less frequently to be met with, but there are many apparent and some real exceptions to this rule. Some animals are so adapted to certain kinds of country—as to forests or marshes, mountains or deserts—that they cannot, permanently, live elsewhere. These may be found scattered over a wide area in suitable spots only, but can hardly on that account be said to have several distinct areas of distribution. As an example we may name the chamois, which lives only on high mountains, but is found in the Pyrenees, the Alps, the Carpathians, in some of the Greek mountains and the Caucasus. The variable hare is another and more remarkable case, being found all over Northern Europe and Asia beyond lat. 55°, and also in Scotland and Ireland. In central Europe it is unknown till we come to the Alps, the Pyrenees, and the Caucasus, where it again appears. This is one of the best cases known of the discontinuous distribution of a *species*, there being a gap of about a thousand miles between its southern limits in Russia, and its reappearance in the Alps. There are of course numerous instances in which species occur in two or more islands, or in an island and continent, and are thus rendered discontinuous by the sea, but these involve questions of changes in sea and land which we shall have to consider further on. Other cases are believed to exist of still wider separation of a species, as with the marsh titmice and the reed buntings of Europe and Japan, where similar forms are found in the

extreme localities, while distinct varieties or sub-species, inhabit the intervening districts.

Extent and Limitations of Specific Areas.—Leaving for the present these cases of want of continuity in a species, we find the most wide difference between the extent of country occupied, varying in fact from a few square miles to almost the entire land surface of the globe. Among the mammalia, however, the same species seldom inhabits both the old and new worlds, unless they are strictly arctic animals, as the reindeer, the elk, the arctic fox, the glutton, the ermine, and some others. The common wolf of Europe and Northern Asia is thought by many naturalists to be identical with the variously coloured wolves of North America extending from the Arctic Ocean to Mexico, in which case this will have perhaps the widest range of any species of mammal. Little doubt exists as to the identity of the brown bears and the beavers of Europe and North America; but all these species range up to the arctic circle, and there is no example of a mammal universally admitted to be identical yet confined to the temperate zones of the two hemispheres. Among the undisputed species of mammalia the leopard has an enormous range, extending all over Africa and South Asia to Borneo and the east of China, and thus having probably the widest range of any known mammal. The winged mammalia have not usually very wide ranges, there being only one bat common to the Old and New Worlds. This is a British species, *Vesperugo serotinus*, which is found over the larger part of North America, Europe and Asia, as far as Pekin,

and even extends into tropical Africa, thus rivalling the leopard and the wolf in the extent of country it occupies.

Of very restricted ranges there are many examples, but some of these are subject to doubts as to the distinctness of the species or as to its geographical limits being really known. In Europe we have a distinct species of ibex (*Capra Pyrenaica*) confined to the Pyrenean mountains, while the true marmot is restricted to the Alpine range. More remarkable is the Pyrenean water-mole (*Mygale Pyrenaica*), a curious small insectivorous animal found only in a few places in the northern valleys of the Pyrenees. In islands there are many cases of undoubted restriction of species to a small area, but these involve a different question from the range of species on continents where there is no *apparent* obstacle to their wider extension.

Specific range of Birds.—Among birds we find instances of much wider range of species, which is only what might be expected considering their powers of flight; but, what is very curious, we also find more striking (though perhaps not more frequent) examples of extreme limitation of range among birds than among mammals. Of the former phenomenon perhaps the most remarkable case is that afforded by the osprey or fishing-hawk, which ranges over the greater portion of all the continents, as far as Brazil, South Africa, the Malay Islands, and Tasmania. The barn owl (*Strix flammea*) has nearly as wide a range, but in this case there is more diversity of opinion as to the specific difference of many of the forms inhabiting remote

countries, some of which seem undoubtedly to be distinct. Among passerine birds the raven has probably the widest range, extending from the arctic regions to Texas and New Mexico in America, and to North India and Lake Baikal in Asia; while the little northern willow-wren (*Phylloscopus borealis*) ranges from arctic Norway across Asia to Alaska, and southward to Ceylon, China, Borneo, and Timor.

Of very restricted continental ranges the best examples in Europe are, the little blue magpie (*Cyanopica cooki*) confined to the central portions of the Spanish peninsula; and the Italian sparrow found only in Italy and Corsica. In Asia, Palestine affords some examples of birds of very restricted range—a beautiful sun-bird (*Nectarinea osea*) a peculiar starling (*Amydrus tristramii*) and some others, being almost or quite confined to the warmer portions of the valley of the Jordan. In the Himalayas there are numbers of birds which have very restricted ranges, but those of the Neilgherries are perhaps better known, several species of laughing thrushes and some other birds being found only on the summits of these mountains. The most wonderfully restricted ranges are, however, to be found among the humming-birds of tropical America. The great volcanic peaks of Chimborazo and Pichincha have each a peculiar species of humming-bird confined to a belt just below the limits of perpetual snow, while the extinct volcano of Chiriqui in Veragua has a species confined to its wooded crater. One of the most strange and beautiful of the humming-birds (*Loddigesia*

mirabilis) was obtained once only, more than forty years ago, near Chachapoyas in the Andes of northern Peru; and though Mr. Gould sent many drawings of the bird to people visiting the district and for many years offered a high reward for a specimen, no other has ever been seen![4]

The above details will sufficiently explain what is meant by the "specific area" or range of a species. The very wide and very narrow ranges are exceptional, the great majority of species both of mammals and birds ranging over moderately wide areas, which present no striking contrasts in climate and physical conditions. Thus a large proportion of European birds range over the whole continent in an east and west direction, but considerable numbers are restricted either to the northern or the southern half. In Africa some species range over all the continent south of the desert, while large numbers are restricted to the equatorial forests, or to the upland plains. In North America, if we exclude the tropical and the arctic portions, a considerable number of species range over all the temperate parts of the continent, while still more are restricted to the east, the centre, or the west, respectively.

Generic Areas.—Having thus obtained a tolerably clear idea of the main facts as to the distribution of isolated species, let us now consider those collections of closely-allied species termed genera. What a genus is will be sufficiently understood by a

[4] Since these lines were written, a fine series of specimens of this rare humming-bird has been obtained from the same locality. (See *Proc. Zool. Soc.* 1881, pp. 827-834.)

few illustrations. All the different kinds of dogs, jackals, and wolves belong to the dog genus, Canis; the tiger, lion, leopard, jaguar, and the wild cats, to the cat genus, Felis; the blackbird, song-thrush, missel-thrush, fieldfare, and many others to the thrush genus, Turdus; the crow, rook, raven, and jackdaw, to the crow genus, Corvus; but the magpie belongs to another, though closely-allied genus, Pica, distinguished by the different form and proportions of its wings and tail from all the species of the crow genus. The number of species in a genus varies greatly, from one up to several hundreds. The giraffe, the glutton, the walrus, the bearded reedling, the secretary-bird, and many others, have no close allies, and each forms a genus by itself. The beaver genus, Castor, and the camel genus, Camelus, each consist of two species. On the other hand, the deer genus, Cervus has forty species; the mouse and rat genus, Mus more than a hundred species; and there is about the same number of the thrush genus; while among the lower classes of animals genera are often very extensive, the fine genus Papilio, or swallow-tailed butterflies, containing more than four hundred species; and Cicindela, which includes our native tiger beetles, has about the same number. Many genera of shells are very extensive, and one of them—the genus Helix, including the commonest snails, and ranging all over the world—is probably the most extensive in the animal kingdom, numbering about two thousand described species.[5]

[5] Many of these large genera are now subdivided, the divisions being sometimes termed genera, sometimes sub-genera.

Separate and Overlapping Areas.—The species of a genus are distributed in two ways. Either they occupy distinct areas which do not touch each other and are sometimes widely separated, or they touch and occasionally overlap each other, each species occupying an area of its own which rarely coincides exactly with that of any other species of the same genus. In some cases, when a river, a mountain-chain, or a change of conditions as from pasture to desert or forest, determines the range of species, the areas of two species of the same genus may just meet, one beginning where the other ends; but this is comparatively rare. It occurs, however, in the Amazon valley, where several species of monkeys, birds, and insects come up to the south bank of the river but do not pass it, while allied species come to the north bank, which in like manner forms their boundary. As examples we may mention that one of the Saki monkeys (*Pithecia monachus?*) comes up to the south bank of the Upper Amazon, while immediately we cross over to the north bank we find another species (*Pithecia rufibarbata?*). Among birds we have the green jacamar (*Galbula viridis*), abundant on the north bank of the Lower Amazon, while on the south bank we have two allied species (*Galbula rufoviridis* and *G. cyaneicollis*); and among insects we have at Santarem on the south bank of the Amazon, the beautiful blue butterfly, *Callithea sapphira*, while almost opposite to it, at Monte-alegre, an allied species, *Callithea Leprieuri* is alone found. Perhaps the most interesting and best known case of a series of allied species, whose ranges

are separate but conterminous, is that of the beautiful South American wading birds, called trumpeters, and forming the genus Psophia. There are five species, all found in the Amazon valley, but each limited to a well-marked district bounded by great rivers. On the north bank of the Amazon there are two species, one in its lower valley extending up to the Rio Negro; and the other in the central part of the valley beyond that river; while to the south of the Amazon there are three, one above the Madeira, one below it, and a third near Para, probably separated from the last by the Tocantins river.

Overlapping areas among the species of a genus is a more common phenomenon, and is almost universal where these species are numerous in the same continent. It is, however, exceedingly irregular, so that we often find one species extending over a considerable portion of the area occupied by the genus and including the entire areas of some of the other species. So little has been done to work out accurately the limits of species that it is very difficult to give examples. One of the best is to be found in the genus *Dendræca*, a group of American wood-warblers. These little birds all migrate in the winter into the tropical regions, but in the summer they come north, each having its particular range. Thus, *D. dominica* comes as far as the middle Eastern States, *D. cærulea* keeps west of the Alleghanies, *D. discolor* comes to Michigan and New England; four other species go farther north in Canada, while several extend to the borders of the Arctic zone.

The Species of Tits as Illustrating Areas of Distribution.—In

our own hemisphere the overlapping of allied species may be well illustrated by the various kinds of titmice, constituting the genus Parus, several of which are among our best known English birds. The great titmouse (*Parus major*) has the widest range of all, extending from the Arctic circle to Algeria, Palestine, and Persia, and from Ireland right across Siberia to the Ochotsk sea, probably following the great northern forest belt. It does not extend into China and Japan, where distinct species are found. Next in extent of range is the coal tit (*Parus ater*) which inhabits all Europe from the Mediterranean to about 64° N. latitude, in Asia Minor to the Lebanon and Caucasus, and across Siberia to Amoorland and Japan. The marsh tit (*Parus palustris*) inhabits temperate and south Europe from 61° N. latitude in Norway to Poland and South-west Russia, and in the south from Spain to Asia Minor. Closely allied to this—of which it is probably only a variety or sub-species—is the northern marsh tit (*Parus borealis*), which overlaps the last in Norway and Sweden, and also in South Russia and the Alps, but extends further north into Lapland and North Russia, and thence probably in a south-easterly direction across Central Asia to North China. Yet another closely-allied species (*Parus camtschatkensis*) ranges from North-eastern Russia across Northern Siberia to Lake Baikal and to Hakodadi in Japan, thus overlapping *Parus borealis* in the western portion of its area. Our little favourite, the blue tit (*Parus cæruleus*) ranges over all Europe from the Arctic circle to the Mediterranean, and on to Asia Minor and Persia, but does not

seem to pass beyond the Ural mountains. Its lovely eastern ally the azure tit (*Parus cyaneus*) overlaps the range of *P. cæruleus* in Western Europe as far as St. Petersburg and Austria, rarely straggling to Denmark, while it stretches all across Central Asia between the latitudes 35° and 56° N. as far as the Amoor valley. Besides these wide-ranging species there are several others which are more restricted. *Parus teneriffæ*, a beautiful dark blue form of our blue tit, inhabits North-west Africa and the Canaries; *Parus ledouci*, closely allied to our coal tit, is found only in Algeria; *Parus lugubris*, allied to the marsh tit, is confined to South-east Europe and Asia Minor, from Hungary and South Russia to Palestine; and *Parus cinctus*, another allied form, is confined to the extreme north in Lapland, Finland, and perhaps Northern Russia and Siberia. Another beautiful little bird, the crested titmouse (*Parus cristatus*) is sometimes placed in a separate genus. It inhabits nearly all Central and South Europe, wherever there are pine forests, from 64° N. latitude to Austria and North Italy, and in the west to Spain and Gibraltar, while in the east it does not pass the Urals and the Caucasus range. Its nearest allies are in the high Himalayas.

These are all the European tits, but there are many others inhabiting Asia, Africa, and North America; so that the genus Parus has a very wide range, in Asia to Ceylon and the Malay Islands, in Africa to the Cape, and in North America to the highlands of Mexico.

The Distribution of the Species of Jays.—Owing to the

very wide range of several of the tits, the uncertainty of the specific distinction of others, and the difficulty in many cases of ascertaining their actual distribution, it has not been found practicable to illustrate this genus by means of a map. For this purpose we have chosen the genus Garrulus or the jays, in which the species are less numerous, the specific areas less extensive, and the species generally better defined; while being large and handsome birds they are sure to have been collected, or at least noticed, wherever they occur. There are, so far as yet known, twelve species of true jays, occupying an area extending from Western Europe to Eastern Asia and Japan, and nowhere passing the Arctic circle to the north, or the tropic of Cancer to the south, so that they constitute one of the most typical of the Palæarctic[6] genera. The following are the species, beginning with the most westerly and proceeding towards the east. The numbers prefixed to each species correspond to those on the coloured map which forms the frontispiece to this volume.

1. *Garrulus glandarius.*—The common jay, inhabits the British Isles and all Europe except the extreme north, extending also into North Africa, where it has been observed in many parts of Algeria. It occurs near Constantinople, but apparently not in Asia Minor; and in Russia, up to, but not beyond, the Urals. The jays being woodland birds are not found in open plains or barren uplands, and their distribution is hence by no means uniform

[6] The Palæarctic region includes temperate Asia and Europe, as will be explained in the next chapter.

within the area they actually occupy.

2. *Garrulus cervicalis.*—The Algerian jay, is a very distinct species inhabiting a limited area in North Africa, and found in some places along with the common species.

3. *Garrulus krynicki.*—The black-headed jay, is closely allied to the common species, but quite distinct, inhabiting a comparatively small area in South-eastern Europe, and Western Asia.

4. *Garrulus atricapillus.*—The Syrian jay, is very closely allied to the last, and inhabits an adjoining area in Syria, Palestine, and Southern Persia.

5. *Garrulus hyrcanus.*—The Persian jay, is a small species allied to our jay and only known from the Elburz Mountains in the north of Persia.

6. *Garrulus brandti.*—Brandt's jay, is a very distinct species, having an extensive range across Asia from the Ural Mountains to North China, Mandchuria, and the northern island of Japan, and also crossing the Urals into Russia where it has been found as far west as Kazan in districts where the common jay also occurs.

7. *Garrulus lanceolatus.*—The black-throated jay, is a very distinct form known only from the North-western Himalayas and Nepal, common about Simla, and extending into Cashmere beyond the range of the next species.

8. *Garrulus bispecularis.*—The Himalayan jay is also very distinct, having the head coloured like the back, and not striped as in all the western species. It inhabits the Himalayas east of

Cashmere, but is more abundant in the western than the eastern division, though according to the Abbé David it reaches Moupin in East Thibet.

9. *Garrulus sinensis.*—The Chinese jay, is very closely allied to the Himalayan, of which it is sometimes classed as a sub-species. It seems to be found in all the southern mountains of China, from Foochow on the east to Sze-chuen and East Thibet on the west, as it is recorded from Moupin by the Abbé David as well as the Himalayan bird—a tolerable proof that it is a distinct form.

10. *Garrulus taivanus.*—The Formosan jay is a very close ally of the preceding, confined to the island of Formosa.

11. *Garrulus japonicus.*—The Japanese jay is nearly allied to our common British species, being somewhat smaller and less brightly coloured, and with black orbits; yet these are the most widely separated species of the genus. According to Mr. Seebohm this species is equally allied to the Chinese and Siberian jays.

In the accompanying map (see frontispiece) we have laid down the distribution of each species so far as it can be ascertained from the works of Sharpe and Dresser for Europe, Jerdon for India, Swinhoe for China, and Mr. Seebohm's recent work for Japan. There is, however, much uncertainty in many places, and gaps have to be filled up conjecturally, while such a large part of Asia is still very imperfectly explored, that considerable modifications may have to be made when the

country becomes more accurately known. But though details may be modified we can hardly suppose that the great features of the several specific areas, or their relations to each other will be much affected; and these are what we have chiefly to consider as bearing on the questions here discussed.

The first thing that strikes us on looking at the map, is, the small amount of overlapping of the several areas, and the isolation of many of the species; while the next most striking feature is the manner in which the Asiatic species almost surround a vast area in which no jays are found. The only species with large areas, are the European *G. glandarius* and the Asiatic *G. Brandti*. The former has three species overlapping it—in Algeria, in South-eastern and North-eastern Europe respectively. The Syrian jay (No. 4), is not known to occur anywhere with the black-headed jay (No. 3), and perhaps the two areas do not meet. The Persian jay (No. 5), is quite isolated. The Himalayan and Chinese jays (Nos. 7, 8, and 9) form a group which are isolated from the rest of the genus; while the Japanese jay (No. 11), is also completely isolated as regards the European jays to which it is nearly allied. These peculiarities of distribution are no doubt in part dependent on the habits of the jays, which live only in well-wooded districts, among deciduous trees, and are essentially non-migratory in their habits, though sometimes moving southwards in winter. This will explain their absence from the vast desert area of Central Asia, but it will not account for the gap between the North and South Chinese species, nor for the absence of jays

from the wooded hills of Turkestan, where Mr. N. A. Severtzoff collected assiduously, obtaining 384 species of birds but no jay. These peculiarities, and the fact that jays are never very abundant anywhere, seem to indicate that the genus is now a decaying one, and that it has at no very distant epoch occupied a larger and more continuous area, such as that of the genus Parus at the present day.

Discontinuous generic Areas.—It is not very easy to find good examples of genera whose species occupy two or more quite disconnected areas, for though such cases may not be rare, we are seldom in a position to mark out the limits of the several species with sufficient accuracy. The best and most remarkable case among European birds is that of the blue magpies, forming the genus Cyanopica. One species (*C. cooki*) is confined (as already stated) to the wooded and mountainous districts of Spain and Portugal, while the only other species of the genus (*C. cyanus*) is found far away in North-eastern Asia and Japan, so that the two species are separated by about 5,000 miles of continuous land. Another case is that of the curious little water-moles forming the genus Mygale, one species *M. muscovitica*, being found only on the banks of the Volga and Don in South-eastern Russia, while the other, *M. pyrenaica*, is confined to streams on the northern side of the Pyrenees. In tropical America there are four different kinds of bell-birds belonging to the genus Chasmorhynchus, each of which appears to inhabit a restricted area completely separated from the others. The most northerly is *C. tricarunculatus* of Costa

Rica and Veragua, a brown bird with a white head and three long caruncles growing upwards at the base of the beak. Next comes *C. variegatus*, in Venezuela, a white bird with a brown head and numerous caruncles on the throat, perhaps conterminous with the last; in Guiana, extending to near the mouth of the Rio Negro, we have *C. niveus*, the bell-bird described by Waterton, which is pure white, with a single long fleshy caruncle at the base of the beak; the last species, *C. nudicollis*, inhabits South-east Brazil, and is also white, but with black stripes over the eyes, and with a naked throat. These birds are about the size of thrushes, and are all remarkable for their loud, ringing notes, like a bell or a blow on an anvil, as well as for their peculiar colours. They are therefore known to the native Indians wherever they exist, and we may be the more sure that they do not spread over the intervening areas where they have never been found, and where the natives know nothing of them.

A good example of isolated species of a group nearer home, is afforded by the snow-partridges of the genus Tetraogallus. One species inhabits the Caucasus range and nowhere else, keeping to the higher slopes from 6,000 to 11,000 feet above the sea, and accompanying the ibex in its wanderings, as both feed on the same plants. Another has a wider range in Asia Minor and Persia, from the Taurus mountains to the South-east corner of the Caspian Sea; a third species inhabits the Western Himalayas, between the forests and perpetual snow, extending eastwards to Nepal; while a fourth is found on the north side of the mountains

in Thibet, and the ranges of these two perhaps overlap; the last species inhabit the Altai mountains, and like the two first appears to be completely separated from all its allies.

There are some few still more extraordinary cases in which the species of one genus are separated in remote continents or islands. The most striking of these is that of the tapirs, forming the genus Tapirus, of which there are two or three species in South America, and one very distinct species in Malacca and Borneo, separated by nearly half the circumference of the globe. Another example among quadrupeds is a peculiar genus of moles named Urotrichus, of which one species inhabits Japan and the other British Columbia. The cuckoo-like honey-guides, forming the genus Indicator, are tolerably abundant in tropical Africa, but there are two outlying species, one in the Eastern Himalaya mountains, the other in Borneo, both very rare, and recently an allied species has been found in the Malay peninsula. The beautiful blue and green thrush-tits forming the genus Cochoa, have two species in the Eastern Himalayas and Eastern China, while the third is confined to Java; the curious genus Eupetes, supposed to be allied to the dippers, has one species in Sumatra and Malacca, while four other species are found two thousand miles distant in New Guinea; lastly, the lovely ground-thrushes of the genus Pitta, range from Hindostan to Australia, while a single species, far removed from all its near allies, inhabits West Africa.

Peculiarities of Generic, and Family Distribution.—The

examples now given sufficiently illustrate the mode in which the several species of a genus are distributed. We have next to consider genera as the component parts of families, and families of orders, from the same point of view.

All the phenomena presented by the species of a genus are reproduced by the genera of a family, and often in a more marked degree. Owing, however, to the extreme restriction of genera by modern naturalists, there are not many among the higher animals that have a world-wide distribution. Among the mammalia there is no such thing as a truly cosmopolitan genus. This is owing to the absence of all the higher orders except the mice from Australia, while the genus Mus, which occurs there, is represented by a distinct group, Hesperomys, in America. If, however, we consider the Australian dingo as a native animal we might class the genus Canis as cosmopolite, but the wild dogs of South America are now formed into separate genera by some naturalists. Many genera, however, range over three or more continents, as Felis (the cat genus) absent only from Australia; Ursus (the bear genus) absent from Australia and tropical Africa; Cervus (the deer genus) with nearly the same range; and Sciurus (the squirrel genus) found in all the continents but Australia. Among birds Turdus, the thrush, and Hirundo, the swallow genus, are the only perching birds which are truly cosmopolites; but there are many genera of hawks, owls, wading and swimming birds, which have a world-wide range.

As a great many genera consist of single species there is no

lack of cases of great restriction, such as the curious lemur called the "potto," which is found only at Sierra Leone, and forms the genus Perodicticus; the true chinchillas found only in the Andes of Peru and Chili south of 9° S. lat. and between 8,000 and 12,000 feet elevation; several genera of finches each confined to limited portions of the higher Himalayas, the blood-pheasants (Ithaginis) found only above 10,000 feet from Nepal to East Thibet; the bald-headed starling of the Philippine islands, the lyre-birds of East Australia, and a host of others.

It is among the different genera of the same family that we meet with the most striking examples of discontinuity, although these genera are often as unmistakably allied as are the species of a genus; and it is these cases that furnish the most interesting problems to the student of distribution. We must therefore consider them somewhat more fully.

Among mammalia the most remarkable of these divided families is that of the camels, of which one genus Camelus, the true camels, comprising the camel and dromedary, is confined to Asia, while the other Auchenia, comprising the llamas and alpacas, is found only in the high Andes and in the plains of temperate South America. Not only are these two genera separated by the Atlantic and by the greater part of the land of two continents, but one is confined to the Northern and the other to the Southern hemisphere. The next case, though not so well known, is equally remarkable; it is that of the Centetidæ, a family of small insectivorous animals, which are wholly confined

to Madagascar and the large West Indian islands Cuba and Hayti, the former containing five genera and the latter a single genus with a species in each island. Here again we have the whole continent of Africa as well as the Atlantic ocean separating allied genera. Two families (or subfamilies) of rat-like animals, Octodontidæ and Echimyidæ, are also divided by the Atlantic. Both are mainly South American, but the former has two genera in North and East Africa, and the latter also two in South and West Africa. Two other families of mammalia, though confined to the Eastern hemisphere, are yet markedly discontinuous. The Tragulidæ are small deer-like animals, known as chevrotains or mouse-deer, abundant in India and the larger Malay islands and forming the genus Tragulus; while another genus, Hyomoschus, is confined to West Africa. The other family is the Simiidæ or anthropoid apes, in which we have the gorilla and chimpanzee confined to West and Central Africa, while the allied orangs are found only in the islands of Sumatra and Borneo, the two groups being separated by a greater space than the Echimyidæ and other rodents of Africa and South America.

Among birds and reptiles we have several families, which, from being found only within the tropics of Asia, Africa, and America, have been termed tropicopolitan groups. The Megalæmidæ or barbets are gaily coloured fruit-eating birds, almost equally abundant in tropical Asia and Africa, but less plentiful in America, where they probably suffer from the competition of the larger sized toucans. The genera of each

country are distinct, but all are closely allied, the family being a very natural one. The trogons form a family of very gorgeously coloured and remarkable insect-eating birds very abundant in tropical America, less so in Asia, and with a single genus of two species in Africa.

Among reptiles we have two families of snakes—the Dendrophidæ or tree-snakes, and the Dryiophidæ or green whip-snakes—which are also found in the three tropical regions of Asia, Africa, and America, but in these cases even some of the genera are common to Asia and Africa, or to Africa and America. The lizards forming the family Amphisbænidæ are divided between tropical Africa and America, a few species only occurring in the southern portion of the adjacent temperate regions; while even the peculiarly American family of the iguanas is represented by two genera in Madagascar, and one in the Fiji and Friendly Islands. Passing on to the Amphibians the worm-like Cæciliadæ are tropicopolitan, as are also the toads of the family Engystomatidæ. Insects also furnish some analogous cases, three genera of Cicindelidæ, (Pogonostoma, Ctenostoma, and Peridexia) showing a decided connection between this family in South America and Madagascar; while the beautiful family of diurnal moths, Uraniidæ, is confined to the same two countries. A somewhat similar but better known illustration is afforded by the two genera of ostriches, one confined to Africa and Arabia, the other to the plains of temperate South America.

General features of Overlapping and Discontinuous Areas.—

These numerous examples of discontinuous genera and families form an important section of the facts of animal dispersal which any true theory must satisfactorily account for. In greater or less prominence they are to be found all over the world, and in every group of animals, and they grade imperceptibly into those cases of conterminous and overlapping areas which we have seen to prevail in most extensive groups of species, and which are perhaps even more common in those large families which consist of many closely allied genera. A sufficient proof of the overlapping of generic areas is the occurrence of a number of genera of the same family together. Thus in France or Italy about twenty genera of warblers (Sylviadæ) are found, and as each of the thirty-three genera of this family inhabiting temperate Europe and Asia has a different area, a great number must here overlap. So, in most parts of Africa, at least ten or twelve genera of antelopes may be found, and in South America a large proportion of the genera of monkeys of the family Cebidæ occur in many districts; and still more is this the case with the larger bird families, such as the tanagers, the tyrant shrikes, or the tree-creepers, so that there is in all these extensive families no genus whose area does not overlap that of many others. Then among the moderately extensive families we find a few instances of one or two genera isolated from the rest, as the spectacled bear, Tremarctos, found only in Chili, while the remainder of the family extends from Europe and Asia over North America to the Mountains of Mexico, but no further south; the Bovidæ,

or hollow-horned ruminants, which have a few isolated genera in the Rocky Mountains and the islands of Sumatra and Celebes; and from these we pass on to the cases of wide separation already given.

Restricted Areas of Families.—As families sometimes consist of single genera and even single species, they often present examples of very restricted range; but what is perhaps more interesting are those cases in which a family contains numerous species and sometimes even several genera, and yet is confined to a narrow area. Such are the golden moles (Chrysochloridæ) consisting of two genera and three species, confined to extratropical South Africa; the hill-tits (Liotrichidæ), a family of numerous genera and species mainly confined to the Himalayas, but with a few straggling species in the Malay countries and the mountains of China; the Pteroptochidæ, large wren-like birds, consisting of eight genera and nineteen species, almost entirely confined to temperate South America and the Andes; and the birds-of-paradise, consisting of nineteen or twenty genera and about thirty-five species, almost all inhabitants of New Guinea and the immediately surrounding islands, while a few, doubtfully belonging to the family, extend to East Australia. Among reptiles the most striking case of restriction is that of the rough-tailed burrowing snakes (Uropeltidæ), the five genera and eighteen species being strictly confined to Ceylon and the southern parts of the Indian Peninsula.

The Distribution of Orders.—When we pass to the larger

groups, termed orders, comprising several families, we find comparatively few cases of restriction and many of worldwide distribution; and the families of which they are composed are strictly comparable to the genera of which families are composed, inasmuch as they present examples of overlapping, or conterminous, or isolated areas, though the latter are comparatively rare. Among mammalia the Insectivora offer the best example of an order, several of whose families inhabit areas more or less isolated from the rest; while the Marsupialia have six families in Australia, and one, the opossums, far off in America.

Perhaps, more important is the limitation of some entire orders to certain well-defined portions of the globe. Thus the Proboscidea, comprising the single family and genus of the elephants, and the Hyracoidea, that of the Hyrax or Syrian coney, are confined to parts of Africa and Asia; the Marsupials to Australia and America; and the Monotremata, the lowest of all mammals—comprising the duck-billed Platypus and the spiny Echidna, to Australia and New Guinea. Among birds the Struthiones or ostrich tribe are almost confined to the three Southern continents, South America, Africa and Australia; and among Amphibia the tailed Batrachia—the newts and salamanders—are similarly restricted to the northern hemisphere.

These various facts will receive their explanation in a future chapter.

MAP SHEWING THE ZOOLOGICAL REGIONS.

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CHAPTER III
CLASSIFICATION OF THE FACTS OF DISTRIBUTION. —ZOOLOGICAL REGIONS

The Geographical Divisions of the Globe do not correspond to Zoological divisions—The range of British Mammals as indicating a Zoological Region—Range of East Asian and North African Mammals—The Range of British Birds—Range of East Asian Birds—The limits of the Palæarctic Region—Characteristic features of the Palæarctic Region—Definition and characteristic groups of the Ethiopian Region—Of the Oriental Region—Of the Australian Region—Of the Nearctic Region—Of the Neotropical Region—Comparison of Zoological Regions with the Geographical Divisions of the Globe.

Having now obtained some notion of how animals are dispersed over the earth's surface, whether as single species or as collected in those groups termed genera, families, and orders, it will be well, before proceeding further, to understand something of the classification of the facts we have been considering, and some of the simpler conclusions these facts lead to.

We have hitherto described the distribution of species and groups of animals by means of the great geographical divisions

of the globe in common use; but it will have been observed that in hardly any case do these define the limits of anything beyond species, and very seldom, or perhaps never, even those accurately. Thus the term "Europe" will not give, with any approach to accuracy, the range of any one genus of mammals or birds, and perhaps not that of half-a-dozen species. Either they range into Siberia, or Asia Minor, or Palestine, or North Africa; and this seems to be always the case when their area of distribution occupies a large portion of Europe. There are, indeed, a few species limited to Central or Western or Southern Europe, and these are almost the only cases in which we can use the word for zoological purposes without having to add to it some portion of another continent. Still less useful is the term Asia for this purpose, since there is probably no single animal or group confined to Asia which is not also more or less nearly confined to the tropical or the temperate portion of it. The only exception is perhaps the tiger, which may really be called an Asiatic animal, as it occupies nearly two-thirds of the continent; but this is an unique example, while the cases in which Asiatic animals and groups are strictly limited to a portion of Asia, or extend also into Europe or into Africa or to the Malay Islands, are exceedingly numerous. So, in Africa, very few groups of animals range over the whole of it without going beyond either into Europe or Asia Minor or Arabia, while those which are purely African are generally confined to the portion south of the tropic of Cancer. Australia and America are terms which better serve the

purpose of the zoologist. The former defines the limit of many important groups of animals; and the same may be said of the latter, but the division into North and South America introduces difficulties, for almost all the groups especially characteristic of South America are found also beyond the isthmus of Panama, in what is geographically part of the northern continent.

It being thus clear that the old and popular divisions of the globe are very inconvenient when used to describe the range of animals, we are naturally led to ask whether any other division can be made which will be more useful, and will serve to group together a considerable number of the facts we have to deal with. Such a division was made by Mr. P. L. Sclater more than twenty years ago, and it has, with some slight modifications, come into pretty general use in this country, and to some extent also abroad; we shall therefore proceed to explain its nature and the principles on which it is established, as it will have to be often referred to in future chapters of this work, and will take the place of the old geographical divisions whose inconvenience has already been pointed out. The primary zoological divisions of the globe are called "regions," and we will begin by ascertaining the limits of the region of which our own country forms a part.

The Range of British Mammals as indicating a Zoological Region.—We will first take our commonest wild mammalia and see how far they extend, and especially whether they are confined to Europe or range over parts of other continents:

1. Wild Cat	Europe	N. Africa	Siberia, Afghanistan.
2. Fox	Europe	N. Africa	Central Asia to Amoor.
3. Weasel	Europe	N. Africa	Central Asia to Amoor.
4. Otter	Europe	N. Africa	Siberia.
5. Badger	Europe	N. Africa	Central Asia to Amoor.
6. Stag	Europe	N. Africa	Central Asia to Amoor.
7. Hedgehog	Europe	—	Central Asia to Amoor.
8. Mole	Europe	—	Central Asia.
9. Squirrel	Europe	—	Central Asia to Amoor.
10. Dormouse	Europe	—	—
11. Water-rat	Europe	—	Central Asia to Amoor.
12. Hare	Europe	—	W. Siberia, Persia.
13. Rabbit	Europe	N. Africa	—

We thus see that out of thirteen of our commonest quadrupeds only one is confined to Europe, while seven are found also in Northern Africa, and eleven range into Siberia, most of them stretching quite across Asia to the valley of the Amoor on the extreme eastern side of that continent. Two of the above-named British species, the fox and weasel, are also inhabitants of the New World, being as common in the northern parts of North America as they are with us; but with these exceptions the entire range of our commoner species is given, and they clearly show that all Northern Asia and Northern Africa must be added to Europe in order to form the region which they collectively inhabit. If now we go into Central Europe and take, for example, the quadrupeds of Germany, we shall find that these too, although much more numerous, are confined to the same

limits, except that some of the more arctic kinds, as already stated, extend into the colder regions of North America.

Range of East Asian and North African Mammals.—Let us now pass to the other side of the great northern continent, and examine the list of the quadrupeds of Amoorland, in the same latitude as Germany. We find that there are forty-four terrestrial species (omitting the bats, the seals, and other marine animals), and of these no less than twenty-six are identical with European species, and twelve or thirteen more are closely allied representatives, leaving only five or six which are peculiarly Asiatic. We can hardly have a more convincing proof of the essential oneness of the mammalia of Europe and Northern Asia.

In Northern Africa we do not find so many European species (though even here they are very numerous) because a considerable number of West Asiatic and desert forms occur. Having, however, shown that Europe and Western Asia have almost identical animals, we may treat all these as really European, and we shall then be able to compare the quadrupeds of North Africa with those of Europe and West Asia. Taking those of Algeria as the best known, we find that there are thirty-three species identical with those of Europe and West Asia, while twenty-four more, though distinct, are closely allied, belonging to the same genera; thus making a total of fifty-seven of European type. On the other hand, we have seven species which are either identical with species of tropical Africa or allied to them, and six more which are especially characteristic of the African and

Asiatic deserts which form a kind of neutral zone between the temperate and tropical regions. If now we consider that Algeria and the adjacent countries bordering the Mediterranean form part of Africa, while they are separated from Europe by a wide sea and are only connected with Asia by a narrow isthmus, we cannot but feel surprised at the wonderful preponderance of the European and West Asiatic elements in the mammalia which inhabit the district.

The Range of British Birds.—As it is very important that no doubt should exist as to the limits of the zoological region of which Europe forms a part, we will now examine the birds, in order to see how far they agree in their distribution with the mammalia. Of late years great attention has been paid to the distribution of European and Asiatic birds, many ornithologists having travelled in North Africa, in Palestine, in Asia Minor, in Persia, in Siberia, in Mongolia, and in China; so that we are now able to determine the exact ranges of many species in a manner that would have been impossible a few years ago. These ranges are given for all British species in the new edition of Yarrell's *History of British Birds* edited by Professor Newton, while those of all European birds are given in still more detail in Mr. Dresser's beautiful work on the birds of Europe. In order to confine our examination within reasonable limits, and at the same time give it the interest attaching to familiar objects, we will take the whole series of British Passeres or perching birds given in Professor Newton's work (118 in number) and arrange them

in series according to the extent of their range. These include not only the permanent residents and regular migrants to our country, but also those which occasionally straggle here, so that it really comprises a large proportion of all European birds.

I. British Birds which extend to North Africa and Central or North-east Asia.	
1. *Lanius collurio*	Red backed Shrike (also all Africa).
2. *Oriolus Galbula*	Golden Oriole (also all Africa).
3. *Turdus musicus*	Song-Thrush.
4. ,, *iliacus*	Red-wing.
5. ,, *pilaris*	Fieldfare.
6. *Monticola saxatilis*	Blue rock Thrush.
7. *Ruticilla suecica*	Bluethroat (also India in winter).
8. *Saxicola rubicola*	Stonechat (also India in winter).
9. ,, *œnanthe*	Wheatear (also N. America).
10. *Acrocephalus arundinaceus*	Great Reed-Warbler.
11. *Sylvia curruca*	Lesser Whitethroat.
12. *Parus major*	Great Titmouse.
13. *Motacilla sulphurea*	Grey Wagtail (also China and Malaya).
14. ,, *raii*	Yellow Wagtail.
15. *Anthus trivialis*	Tree Pipit.
16. ,, *spiloletta*	Water Pipit.
17. ,, *campestris*	Tawny Pipit.
18. *Alauda arvensis*	Skylark.
19. ,, *cristata*	Crested Lark.
20. *Emberiza schœniclus*	Reed Bunting.
21. ,, *citrinella*	Yellow-hammer.
22. *Fringilla montifringilla*	Brambling.
23. *Passer montanus*	Tree Sparrow (also S. Asia).
24. ,, *domesticus*	House Sparrow.
25. *Coccothraustes vulgaris*	Hawfinch.
26. *Carduelis spinus*	Siskin (also China).
27. *Loxia curvirostra*	Crossbill.
28. *Sturnus vulgaris*	Starling.
29. *Pyrrhocorax graculus*	Chough.
30. *Corvus corone*	Crow.
31. *Hirundo rustica*	Swallow (all Africa and Asia).
32. *Cotyle riparia*	Sand Martin (also India and N. America).
II. British Birds which range to Central or North-east Asia.	

We find, that out of a total of 118 British Passeres there are:

32 species which range to North Africa and Central or East Asia.

25 species which range to Central or East Asia, but not to North Africa.

43 species which range to North Africa and Western Asia.

6 species which range to North Africa, but not at all into Asia.

7 species which range to West Asia, but not to North Africa.

5 species which do not range out of Europe.

These figures agree essentially with those furnished by the mammalia, and complete the demonstration that all the temperate portions of Asia and North Africa must be added to Europe to form a natural zoological division of the earth. We must also note how comparatively few of these overpass the limits thus indicated; only seven species extending their range occasionally into tropical or South Africa, eight into some parts of tropical Asia, and six into arctic or temperate North America.

Range of East Asian Birds.—To complete the evidence we only require to know that the East Asiatic birds are as much like those of Europe, as we have already shown to be the case when we take the point of departure from our end of the continent. This does not follow necessarily, because it is possible that a totally distinct North Asiatic fauna might there prevail; and, although our birds go eastward to the remotest parts of Asia, their birds might not come westward to Europe. The birds of Eastern Siberia

have been carefully studied by Russian naturalists and afford us the means of making the required comparison. There are 151 species belonging to the orders Passeres and Picariæ (the perching and climbing birds), and of these no less than 77, or more than half, are absolutely identical with European species; 63 are peculiar to North Asia, but all except five or six of these are allied to European forms; the remaining 11 species are migrants from South-eastern Asia. The resemblance is therefore equally close whichever extremity of the Euro-Asiatic continent we take as our starting point, and is equally remarkable in birds as in mammalia. We have now only to determine the limits of this, our first zoological region, which has been termed the "Palæarctic" by Mr. Sclater, meaning the "northern old-world" region—a name now well known to naturalists.

The Limits of the Palæarctic Region.—The boundaries of this region, as nearly as they can be ascertained, are shown on our general map at the beginning of this chapter, but it will be evident on consideration, that, except in a few places, its limits can only be approximately defined. On the north, east, and west it extends to the ocean, and includes a number of islands whose peculiarities will be pointed out in a subsequent chapter; so that the southern boundary alone remains, but as this runs across the entire continent from the Atlantic to the Pacific ocean, often traversing little-known regions, we may perhaps never be able to determine it accurately, even if it admits of such determination. In drawing the boundary line across Africa we meet with our

first difficulty. The Euro-Asiatic animals undoubtedly extend to the northern borders of the Sahara, while those of tropical Africa come up to its southern margin, the desert itself forming a kind of sandy ocean between them. Some of the species on either side penetrate and even cross the desert, but it is impossible to balance these with any accuracy, and it has therefore been thought best, as a mere matter of convenience, to consider the geographical line of the tropic of Cancer to form the boundary. We are thus enabled to define the Palæarctic region as including all north temperate Africa; and, a similar intermingling of animal types occurring in Arabia, the same boundary line is continued to the southern shore of the Persian Gulf. Persia and Afghanistan undoubtedly belong to the Palæarctic region, and Baluchistan should probably go with these. The boundary in the north-western part of India is again difficult to determine, but it cannot be far one way or the other from the river Indus as far up as Attock, opposite the mouth of the Cabool river. Here it will bend to the south-east, passing a little south of Cashmeer, and along the southern slopes of the Himalayas into East Thibet and China, at heights varying from 9,000 to 11,000 feet according to soil, aspect, and shelter. It may, perhaps, be defined as extending to the upper belt of forests as far as coniferous trees prevail; but the temperate and tropical faunas are here so intermingled that to draw any exact parting line is impossible. The two faunas are, however, very distinct. In and above the pine woods there are abundance of warblers of northern genera, with wrens, numerous

titmice, and a great variety of buntings, grosbeaks, bullfinches and rosefinches, all more or less nearly allied to the birds of Europe and Northern Asia; while a little lower down we meet with a host of peculiar birds allied to those of tropical Asia and the Malay Islands, but often of distinct genera. There can be no doubt, therefore, of the existence here of a pretty sharp line of demarkation between the temperate and tropical faunas, though this line will be so irregular, owing to the complex system of valleys and ridges, that in our present ignorance of much of the country it cannot be marked in detail on any map.

Further east in China it is still more difficult to determine the limits of the region, owing to the great intermixture of migrating birds; tropical forms passing northwards in summer as far as the Amoor river, while the northern forms visit every part of China in winter. From what we know, however, of the distribution of some of the more typical northern and southern species, we are able to fix the limits of the Palæarctic region a little south of Shanghai on the east coast. Several tropical genera come as far north as Ningpo or even Shanghai, but rarely beyond; while in Formosa and Amoy tropical forms predominate. Such decidedly northern forms as bullfinches and hawfinches are found at Shanghai; hence we may commence the boundary line on the coast between Shanghai and Ningpo, but inland it probably bends a little southward, and then northward to the mountains and valleys of West China and East Thibet in about 32° N. latitude; where, at Moupin, a French missionary, Père David,

made extensive collections showing this district to be at the junction of the tropical and temperate faunas. Japan, as a whole, is decidedly Palæarctic, although its extreme southern portion, owing to its mild insular climate and evergreen vegetation, gives shelter to a number of tropical forms.

Characteristic Features of the Palæarctic Region.—Having thus demonstrated the unity of the Palæarctic region by tracing out the distribution of a large proportion of its mammalia and birds, it only remains to show how far it is characterised by peculiar groups such as genera and families, and to say a few words on the lower forms of life which prevail in it.

Taking first the mammalia, we find this region distinguished by possessing two peculiar genera of Talpidæ or moles, the family being confined to the Palæarctic and Nearctic regions. The true hedgehogs (Erinaceus) are also characteristic, being only found elsewhere in South Africa and in the northern part of the Oriental region. Among Carnivora, the racoon-dog (Nyctereutes) of North-eastern Asia, and the true badgers of the genus Meles are peculiar, most other parts of the world possessing distinct genera of badgers. It has six peculiar genera, or subgenera, of deer; seven peculiar genera of Bovidæ, chiefly antelopes; while the entire group of goats and sheep, comprising twenty-two species, is almost confined to it, one species only occurring in the Rocky mountains of North America and another in the Nilgiris of Southern India. Among the rodents there are nine genera with twenty-seven species wholly confined to it,

while several others, as the hamsters, the dormice, and the pikas, have only a few species elsewhere.

In birds there are a large number of peculiar genera of which we need mention only a few of the more important, as the grasshopper warblers (Locustella) with seven species, the Accentors with twelve species, and about a dozen other genera of warblers, including the robins; the bearded titmouse and several allied genera; the long-tailed titmice forming the genus Acredula; the magpies, choughs, and nut-crackers; a host of finches, among which the bullfinches (Pyrrhula) and the buntings (Emberiza) are the most important. The true pheasants (Phasianus) are wholly Palæarctic, except one species in Formosa, as are several genera of wading birds. Though the reptiles of cold countries are few as compared with those of the tropics, the Palæarctic region in its warmer portions has a considerable number, and among these are many which are peculiar to it. Such are four genera of snakes, seven of lizards, five of frogs and toads, and twelve of newts and salamanders; while of fresh-water fishes there are about twenty peculiar genera.[7] Among insects we may mention the elegant Apollo butterflies of the Alps as forming a peculiar genus (Parnassius), only found elsewhere in the Rocky Mountains of North America, while the beautiful genus Thais of the south of Europe and Sericinus of North China are equally remarkable. Among other insects we can only now refer to the

[7] The following list of the genera of reptiles and amphibia peculiar to the Palæarctic Region has been furnished me by Mr. G. A. Boulenger, of the British Museum:—

great family of Carabidæ, or predaceous ground-beetles, which are immensely numerous in this region, there being about fifty peculiar genera; while the large and handsome genus Carabus, with its allies Procerus and Procrustes, containing nearly 300 species, is almost wholly confined to this region, and would alone serve to distinguish it zoologically from all other parts of the globe.

Having given so full an exposition of the facts which determine the extent and boundaries of the Palæarctic region, there is less need of entering into much detail as regards the other regions of the Eastern Hemisphere; their boundaries being easily defined, while their forms of animal life are well marked and strongly contrasted.

Definition and Characteristic Groups of the Ethiopian Region.—The Ethiopian region consists of all tropical and south Africa, to which are appended the large island of Madagascar and the Mascarene Islands to the east and north of it, though these differ materially from the continent, and will have to be discussed in a separate chapter. For the present, then, we will take Africa south of the tropic of Cancer, and consider how far its animals are distinct from those of the Palæarctic region.

Taking first the mammalia, we find the following remarkable animals at once separating it from the Palæarctic and every other region. The gorilla and chimpanzee, the baboons, numerous lemurs, the spotted hyæna, the aard-wolf and hyæna-dog, zebras, the hippopotamus, giraffe, and more than seventy

peculiar antelopes. Here we have a wonderful collection of large and peculiar quadrupeds, but the Ethiopian region is also characterised by the absence of others which are not only abundant in the Palæarctic region but in many tropical regions as well. The most remarkable of these deficiencies are the bears the deer and the wild oxen, all of which abound in the tropical parts of Asia while bears and deer extend into both North and South America. Besides the large and conspicuous animals mentioned above, Africa possesses a number of completely isolated groups; such are the potamogale, a curious otter-like water-shrew, discovered by Du Chaillu in West Africa, so distinct as to constitute a new family, Potamogalidæ; the goldenmoles, also forming a peculiar family, Chrysochloridæ; as do the elephant-shrews, Macroscelididæ; the singular aard-varks, or earth-pigs, forming a peculiar family of Edentata called Orycteropodidæ; while there are numerous peculiar genera of monkeys, swine, civets, and rodents.

Among birds the most conspicuous and remarkable are, the great-billed vulture-crows (Corvultur), the long-tailed whydah finches (Vidua), the curious ox-peckers (Buphaga), the splendid metallic starlings (Lamprocolius), the handsome plantain-eaters (Musophaga), the ground-hornbills (Bucorvus), the numerous guinea-fowls belonging to four distinct genera, the serpent-eating secretary-bird (Serpentarius), the huge boat-billed heron (Balæniceps), and the true ostriches. There are also three quite peculiar African families, the Musophagidæ or plantain-eaters,

including the elegant crested touracos; the curious little finch-like colies (Coliidæ), and the Irrisoridæ, insect-eating birds allied to the hoopoes but with glossy metallic plumage and arboreal habits.

In reptiles, fishes, insects, and land-shells, Africa is very rich, and possesses an immense number of peculiar forms. These are not sufficiently familiar to require notice in a work of this character, but we may mention a few as mere illustrations: the puff-adders, the most hideous of poisonous snakes; the chameleons, the most remarkable of lizards; the goliath-beetles, the largest and handsomest of the Cetoniidæ; and some of the Achatinæ, which are the largest of all known land-shells.

Definition and Characteristic Groups of the Oriental Region.—The Oriental region comprises all Asia south of the Palæarctic limits, and along with this the Malay Islands as far as the Philippines, Borneo, and Java. It was called the Indian region by Mr. Sclater, but this term has been objected to because the Indo-Chinese and Malayan districts are the richest and most characteristic, while the peninsula of India is the poorest portion of it. The name "Oriental" has therefore been adopted in my work on *The Geographical Distribution of Animals* as preferable to either Malayan or Indo-Australian, both of which have been proposed, but are objectionable, as being already in use in a different sense.

The great features of the mammals of the Oriental region are, the long-armed apes, the orang-utans, the tiger, the sun-

bears and honey-bears, the tapir, the chevrotains or mouse-deer, and the Indian elephant. Its most conspicuous birds are the immense number and variety of babbling-thrushes (Timaliidæ), its beautiful little hill-tits (Liotrichidæ), its green bulbuls (Phyllornithidæ), its many varieties of the crow-family, its beautiful gapers and pittas adorned with the most delicate colours, its great variety of hornbills, and its magnificent Phasianidæ, comprising the peacocks, argus-pheasants, fire-backed pheasants, and jungle-fowl. Many of these are, it is true, absent from the peninsula of Hindostan, but sufficient remain there to ally it with the other parts of the region.

Among the remarkable but less conspicuous forms of mammalia which are peculiar to this region are, monkeys of the genus Presbyter, extending to every part of it; lemurs of three peculiar genera—Nycticebus and Loris (slow lemurs) and Tarsius (spectre lemurs); the flying lemur (Galeopithecus), now classed as a peculiar family of Insectivora and found only in the Malay Islands; the family of the Tupaias, or squirrel-shrews, curious little arboreal Insectivora somewhat resembling squirrels; no less than twelve peculiar genera of the civet family, three peculiar antelopes, five species of rhinoceros, and the round-tailed flying squirrels forming the genus Pteromys.

Of the peculiar groups of birds we can only mention a few. The curious little tailor-birds of the genus Orthotomus are found over the whole region and almost alone serve to characterise it, as do the fine laughing-thrushes, forming the genus Garrulax;

while the beautiful grass-green fruit-thrushes (Phyllornis), and the brilliant little minivets (Pericrocotus), are almost equally universal. Woodpeckers are abundant, belonging to a dozen peculiar genera; while gaudy barbets and strange forms of cuckoos and hornbills are also to be met with everywhere. Among game birds, the only genus that is universally distributed, and which may be said to characterise the region, is Gallus, comprising the true jungle-fowl, one of which, Gallus bankiva, is found from the Himalayas and Central India to Malacca, Java, and even eastward to Timor, and is the undoubted origin of almost all our domestic poultry. Southern India and Ceylon each possesses distinct species of jungle-fowl, and a third very handsome green bird (Gallus æneus inhabits Java.)

Reptiles are as abundant as in Africa, but they present no well-known groups which can be considered as specially characteristic. Among insects we may notice the magnificent golden and green Papilionidæ of various genera as being unequalled in the world; while the great Atlas moth is probably the most gigantic of Lepidoptera, being sometimes ten inches across the wings, which are also very broad. Among the beetles the strange flat-bodied Malayan mormolyce is the largest of all the Carabidæ, while the catoxantha is equally a giant among the Buprestidæ. On the whole, the insects of this region probably surpass those of any other part of the world, except South America, in size, variety, and beauty.

Definition and Characteristic Groups of the Australian

Region.—The Australian region is so well marked off from the Oriental, as well as from all other parts of the world, by zoological peculiarities, that we need not take up much time in describing it, especially as some of its component islands will come under review at a subsequent stage of our work. Its most important portions are Australia and New Guinea, but it also includes all the Malayan and Pacific Islands to the east of Borneo, Java, and Bali, the Oriental region terminating with the submarine bank on which those islands are situated. The island of Celebes is included in this region from a balance of considerations, but it almost equally well belongs to the Oriental, and must be left out of the account in our general sketch of the zoological features of the Australian region.

The great feature of the Australian region is the almost total absence of all the forms of terrestrial mammalia which abound in the rest of the world, their place being supplied by a great variety of Marsupials. In Australia and New Guinea there are no Insectivora, Carnivora, nor Ungulata, while even the rodents are only represented by a few small rats and mice. In the remoter Pacific Islands mammals are altogether absent (except perhaps in New Zealand), but in the Moluccas and other islands bordering on the Oriental region the higher mammals are represented by a few deer, civets, and pigs, though it is doubtful whether the two former may not have been introduced by man, as was almost certainly the case with the semi-domesticated dingo of

Australia.[8] These peculiarities in the mammalia are so great that every naturalist agrees that Australia must be made a separate region, the only difference of opinion being as to its extent, some thinking that New Zealand should form another separate region; but this question need not now delay us.

In birds Australia is by no means so isolated from the rest of the world, as it contains great numbers of warblers, thrushes, flycatchers, shrikes, crows, and other familiar types of the Eastern Hemisphere; yet a considerable number of the most characteristic Oriental families are absent. Thus there are no vultures, woodpeckers, pheasants, bulbuls, or barbets in the

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[8] Remains of the dingo have been found fossil in Pleistocene deposits but the antiquity of man in Australia is not known. It is not, however, improbable that it may be as great as in Europe. My friend A. C. Swinton, Esq., while working in the then almost unknown gold-field of Maryborough, Victoria, in January, 1855, found a fragment of a well-formed stone axe resting on the metamorphic schistose bed-rock about five feet beneath the surface. It was overlain by the compact gravel drift called by the miners "cement," and by an included layer of hard iron-stained sandstone. The fragment is about an inch and three-eighths wide and the same length, and is of very hard fine-grained black basalt. One side is ground to a very smooth and regular surface, terminating in a well-formed cutting edge more than an inch long, the return face of the cutting part being about a quarter of an inch wide. The other side is a broken surface. The weapon appears to have been an axe or tomahawk closely resembling that figured at p. 335 of Lumholtz's *Among Cannibals*, from Central Queensland. The fragment was discovered by Mr. Swinton and the late Mr. Mackworth Shore, one of the discoverers of the gold-field, before any rush to it had taken place, and it seems impossible to avoid the conclusion that it was formed prior to the deposit of the gravel drift and iron-stained sandstone under which it lay. This would indicate a great antiquity of man in Australia, and would enable us to account for the fossilised remains of the dingo in Pleistocene deposits as those of an animal introduced by man.

Australian region; and the absence of these is almost as marked a feature as that of cats, deer, or monkeys, among mammalia. The most conspicuous and characteristic birds of the Australian region are, the piping crows; the honey-suckers (Meliphagidæ), a family quite peculiar to the region; the lyre-birds; the great terrestrial kingfishers (Dacelo); the great goat-suckers called more-porks in Australia and forming the genus Podargus; the wonderful abundance of parrots, including such remarkable forms as the white and black cockatoos, and the gorgeously coloured brush-tongued lories; the almost equal abundance of fine pigeons more gaily coloured than any others on the globe; the strange brush-turkeys and mound-builders, the only birds that never sit upon their eggs, but allow them to be hatched, reptile-like, by the heat of the sand or of fermenting vegetable matter; and lastly, the emus and cassowaries, in which the wings are far more rudimentary than in the ostriches of Africa and South America. New Guinea and the surrounding islands are remarkable for their tree-kangaroos, their birds-of-paradise, their raquet-tailed kingfishers, their great crown-pigeons, their crimson lories, and many other remarkable birds. This brief outline being sufficient to show the distinctness and isolation of the Australian region, we will now pass to the consideration of the Western Hemisphere.

Definition and Characteristic Groups of the Nearctic Region.—The Nearctic region comprises all temperate and arctic North America, including Greenland, the only doubt being as to its

southern boundary, many northern types penetrating into the tropical zone by means of the highlands and volcanic peaks of Mexico and Guatemala, while a few which are characteristic of the tropics extend northward into Texas and California. There is, however, considerable evidence showing that on the east coast the Rio Grande del Norte, and on the west a point nearly opposite Cape St. Lucas, form the most natural boundary; but instead of being drawn straight across, the line bends to the south-east as soon as it rises on the flanks of the table-land, forming a deep loop which extends some distance beyond the city of Mexico, and perhaps ought to be continued along the higher ridges of Guatemala.

The Nearctic region is so similar to the Palæarctic in position and climate, and the two so closely approach each other at Behring Straits, that we cannot wonder at there being a certain amount of similarity between them—a similarity which some naturalists have so far over-estimated as to think that the two regions ought to be united. Let us therefore carefully examine the special zoological features of this region, and see how far it resembles, and how far differs from, the Palæarctic.

At first sight the mammalia of North America do not seem to differ much from those of Europe or Northern Asia. There are cats, lynxes, wolves and foxes, weasels, bears, elk and deer, voles, beavers, squirrels, marmots, and hares, all very similar to those of the Eastern Hemisphere, and several hardly distinguishable. Even the bison or "buffalo" of the prairies, once so abundant

and characteristic, is a close ally of the now almost extinct "aurochs" of Lithuania. Here, then, we undoubtedly find a very close resemblance between the two regions, and if this were all, we should have great difficulty in separating them. But along with these, we find another set of mammals, not quite so conspicuous but nevertheless very important. We have first, three peculiar genera of moles, one of which, the star-nosed mole, is a most extraordinary creature, quite unlike anything else. Then there are three genera of the weasel family, including the well-known skunk (Mephitis), all quite different from Eastern forms. Then we come to a peculiar family of carnivora, the racoons, very distinct from anything in Europe or Asia; and in the Rocky Mountains we find the prong-horn antelope (Antilocapra) and the mountain goat of the trappers (Aplocerus), both peculiar genera. Coming to the rodents we find that the mice of America differ in some dental peculiarities from those of the rest of the world, and thus form several distinct genera; the jumping mouse (Xapus) is a peculiar form of the jerboa family, and then we come to the pouched rats (Geomyidæ), a very curious family consisting of four genera and nineteen species, peculiar to North America, though not confined to the Nearctic region. The prairie dogs (Cynomys), the tree porcupine (Erethizon), the curious sewellel (Haploodon), and the opossum (Didelphys) complete the list of peculiar mammalia which distinguish the northern region of the new world from that of the old. We must add to these peculiarities some remarkable deficiencies. The Nearctic

region has no hedgehogs, nor wild pigs, nor dormice, and only one wild sheep in the Rocky Mountains as against twenty species of sheep and goats in the Palæarctic region.

In birds also the similarities to our own familiar songsters first strike us, though the differences are perhaps really greater than in the quadrupeds. We see thrushes and wrens, tits and finches, and what seem to be warblers and flycatchers and starlings in abundance; but a closer examination shows the ornithologist that what he took for the latter are really quite distinct, and that there is not a single true flycatcher of the family Muscicapidæ, or a single starling of the family Sturnidæ in the whole continent, while there are very few true warblers (Sylviidæ), their place being taken by the quite distinct families Mniotiltidæ or wood-warblers, and Vireonidæ or greenlets. In like manner the flycatchers of America belong to the totally distinct family of tyrant-birds, Tyrannidæ, and those that look like starlings to the hang-nests, Icteridæ; and these four peculiar families comprise about a hundred and twenty species, and give a special character to the ornithology of the country. Add to these such peculiar birds as the mocking thrushes (Mimus), the blue jays (Cyanocitta), the tanagers, the peculiar genera of cuckoos (Coccygus and Crotophaga), the humming-birds, the wild turkeys (Meleagris), and the turkey-buzzards (Cathartes), and we see that if there is any doubt as to the mammals of North America being sufficiently distinct to justify the creation of a separate region, the evidence of the birds would alone settle the

question.

The reptiles, and some others of the lower animals, add still more to this weight of evidence. The true rattlesnakes are highly characteristic, and among the lizards are several genera of the peculiar American family, the Iguanidæ. Nowhere in the world are the tailed batrachians so largely developed as in this region, the Sirens and the Amphiumidæ forming two peculiar families, while there are nine peculiar genera of salamanders, and two others allied respectively to the Proteus of Europe and the Sieboldia or giant salamander of Japan. There are seven peculiar families and about thirty peculiar genera of fresh-water fishes; while the fresh-water molluscs are more numerous than in any other region, more than thirteen hundred species and varieties having been described.

Combining the evidence derived from all these classes of animals, we find the Nearctic region to be exceedingly well characterised, and to be amply distinct from the Palæarctic. The few species that are common to the two are almost all arctic, or, at least, northern types, and may be compared with those desert forms which occupy the debatable ground between the Palæarctic, Ethiopian, and Oriental regions. If, however, we compare the number of species, which are common to the Nearctic and Palæarctic regions with the number common to the western and eastern extremities of the latter region, we shall find a wonderful difference between the two cases; and if we further call to mind the number of important groups characteristic of

the one region but absent from the other, we shall be obliged to admit that the relation that undoubtedly exists between the faunas of North America and Europe is of a very distinct nature from that which connects together Western Europe and North-eastern Asia in the bonds of zoological unity.

Definition and Characteristic Groups of the Neotropical Region.—The Neotropical region requires very little definition, since it comprises the whole of America south of the Nearctic region, with the addition of the Antilles or West Indian Islands. Its zoological peculiarities are almost as marked as those of Australia, which, however, it far exceeds in the extreme richness and variety of all its forms of life. To show how distinct it is from all the other regions of the globe, we need only enumerate some of the best known and more conspicuous of the animal forms which are peculiar to it. Such are, among mammalia—the prehensile-tailed monkeys and the marmosets, the blood-sucking bats, the coati-mundis, the peccaries, the llamas and alpacas, the chinchillas, the agoutis, the sloths, the armadillos, and the ant-eaters; a series of types more varied, and more distinct from those of the rest of the world than any other continent can boast of. Among birds we have the charming sugar-birds, forming the family Cœrebidæ; the immense and wonderfully varied group of tanagers; the exquisite little manakins, and the gorgeously-coloured chatterers; the host of tree-creepers of the family Dendrocolaptidæ; the wonderful toucans; the puff-birds, jacamars, todies and motmots; the marvellous assemblage of

four hundred distinct kinds of humming-birds; the gorgeous macaws; the curassows, the trumpeters, and the sun-bitterns. Here again there is no other continent or region that can produce such an assemblage of remarkable and perfectly distinct groups of birds; and no less wonderful is its richness in species, since these fully equal, if they do not surpass, those of the two great tropical regions of the Eastern Hemisphere (the Ethiopian and the Oriental) combined.

As an additional indication of the distinctness and isolation of the Neotropical region from all others, and especially from the whole Eastern Hemisphere, we must say something of the otherwise widely distributed groups which are absent. Among mammalia we have first the order Insectivora, entirely absent from South America, though a few species are found in Central America and the West Indies; the Viverridæ or civet family is wholly wanting, as are every form of sheep, oxen, or antelopes; while the swine, the elephants, and the rhinoceroses of the old world are represented by the diminutive peccaries and tapirs.

Among birds we have to notice the absence of tits, true flycatchers, shrikes, sunbirds, starlings, larks (except a solitary species in the Andes), rollers, bee-eaters, and pheasants, while warblers are very scarce, and the almost cosmopolitan wagtails are represented by a single species of pipit.

We must also notice the preponderance of low or archaic types among the animals of South America. Edentates, marsupials, and rodents form the majority of the terrestrial mammalia; while

such higher groups as the carnivora and hoofed animals are exceedingly deficient. Among birds a low type of Passeres, characterised by the absence of the singing muscles, is excessively prevalent, the enormous groups of the ant-thrushes, tyrants, tree-creepers, manakins, and chatterers belonging to it. The Picariæ (a lower group) also prevail to a far greater extent than in any other regions, both in variety of forms and number of species; and the chief representatives of the gallinaceous birds—the curassows and tinamous, are believed to be allied, the former to the brush-turkeys of Australia, the latter (very remotely) to the ostriches, two of the least developed types of birds.

Whether, therefore, we consider its richness in peculiar forms of animal life, its enormous variety of species, its numerous deficiencies as compared with other parts of the world, or the prevalence of a low type of organisation among its higher animals, the Neotropical region stands out as undoubtedly the most remarkable of the great zoological divisions of the earth.

In reptiles, amphibia, fresh-water fishes, and insects, this region is equally peculiar, but we need not refer to these here, our only object now being to establish by a sufficient number of well-known and easily remembered examples, the distinctness of each region from all others, and its unity as a whole. The former has now been sufficiently demonstrated, but it may be well to say a few words as to the latter point.

The only outlying portions of the region about which there can be any doubt are—Central America, or that part of the region

north of the Isthmus of Panama, the Antilles or West Indian Islands, and the temperate portion of South America including Chili and Patagonia.

In Central America, and especially in Mexico, we have an intermixture of South American and North American animals, but the former undoubtedly predominate, and a large proportion of the peculiar Neotropical groups extend as far as Costa Rica. Even in Guatemala and Mexico we have howling and spider-monkeys, coati-mundis, tapirs, and armadillos; while chatterers, manakins, ant-thrushes, and other peculiarly Neotropical groups of birds are abundant. There is therefore no doubt as to Mexico forming part of this region, although it is comparatively poor, and exhibits the intermingling of temperate and tropical forms.

The West Indies are less clearly Neotropical, their poverty in mammals as well as in most other groups being extreme, while great numbers of North American birds migrate there in winter. The resident birds, however, comprise trogons, sugar-birds, chatterers, with many humming-birds and parrots, representing eighteen peculiar Neotropical genera; a fact which decides the region to which the islands belong.

South temperate America is also very poor as compared with the tropical parts of the region, and its insects contain a considerable proportion of north temperate forms. But it contains armadillos, cavies and opossums; and its birds all belong to American groups, though, owing to the inferior climate and deficiency of forests, a number of the families of birds peculiar

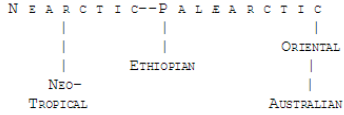
to tropical America are wanting. Thus there are no manakins, chatterers, toucans, trogons, or motmots; but there are abundance of hang-nests, tyrant-birds, ant-thrushes, tree-creepers, and a fair proportion of humming-birds, tanagers and parrots. The zoology is therefore thoroughly Neotropical, although somewhat poor; and it has a number of peculiar forms of strictly Neotropical types—as the chinchillas, alpacas, &c., which are not found in the tropical regions except in the high Andes.

Comparison of Zoological Regions with the Geographical Divisions of the Globe.—Having now completed our survey of the great zoological regions of the globe, we find that they do not differ so much from the old geographical divisions as our first example might have led us to suppose. Europe, Asia, Africa, Australia, North America, and South America, really correspond, each to a zoological region, but their boundaries require to be modified more or less considerably; and if we remember this, and keep their extensions or limitations always in our mind, we may use the terms "South American" or "North American," as being equivalent to Neotropical and Nearctic, without much inconvenience, while "African" and "Australian" equally well serve to express the zoological type of the Ethiopian and Australian regions. Europe and Asia require more important modifications. The European fauna does indeed well represent the Palæarctic in all its main features, and if instead of Asia we say tropical Asia we have the Oriental region very fairly defined; so that the relation of the geographical with the zoological

primary divisions of the earth is sufficiently clear. In order to make these relations visible to the eye and more easily remembered, we will put them into a tabular form:

Regions.	Geographical Equivalent.
Palæarctic	EUROPE, with north temperate Africa and Asia.
Ethiopian	AFRICA (south of the Sahara) with Madagascar.
Oriental	TROPICAL ASIA, to Philippines and Java.
Australian	AUSTRALIA, with Pacific Islands, Moluccas, &c.
Nearctic	NORTH AMERICA, to North Mexico.
Neotropical	SOUTH AMERICA, with tropical N. America and W. Indies.

The following arrangement of the regions will indicate their geographical position, and to a considerable extent their relation to each other.



CHAPTER IV
EVOLUTION THE KEY TO DISTRIBUTION

Importance of the Doctrine of Evolution—The Origin of New Species—Variation in Animals—The Amount of Variation in North American Birds—How New Species arise from a Variable Species—Definition and Origin of Genera—Cause of the Extinction of Species—The Rise and Decay of Species and Genera—Discontinuous Specific Areas, why Rare—Discontinuity of the Area of Parus Palustris—Discontinuity of Emberiza Schœniclus—The European and Japanese Jays—Supposed Examples of Discontinuity among North American Birds—Distribution and Antiquity of Families—Discontinuity a proof of Antiquity—Concluding Remarks.

In the preceding chapters we have explained the general nature of the phenomena presented by the distribution of animals, and have illustrated and defined the new geographical division of the earth which is found best to agree with them. Before we go further into the details of our subject, and especially before we attempt to trace the causes which have brought about the existing biological relations of the islands of the globe, it is absolutely necessary to have a clear comprehension of the collateral facts and general principles to which we shall

most frequently have occasion to refer. These may be briefly defined as, the powers of dispersal of animals and plants under different conditions, such as geological and climatal changes, and the origin and development of species and groups by natural selection. This last is of the most fundamental importance, and its bearing on the dispersal of animals has been much neglected. We therefore devote the present chapter to its consideration.

As we have already shown in our first chapter that the distribution of species, of genera, and of families, present almost exactly the same general phenomena in varying degrees of complexity, and that almost all the interesting problems we have to deal with depend upon the mode of dispersal of one or other of these; and as, further, our knowledge of most of these groups, in the higher animals at least, is confined to the tertiary period of geology, it is therefore unnecessary for us to enter into any questions involving the origin of more comprehensive groups, such as classes or orders. This enables us to avoid most of the disputed questions as to the development of animals, and to confine ourselves to those general principles regulating the origin and development of species and genera which were first laid down by Mr. Darwin thirty years ago, and have now come to be adopted by naturalists as established propositions in the theory of evolution.

The Origin of New Species.—How, then, do new species arise, supposing the world to have been, physically, much as we now see it; and what becomes of them after they have arisen? In

the first place we must remember that new species can only be formed when and where there is room for them. If a continent is fully stocked with animals, each species being so well adapted for its mode of life that it can overcome all the dangers to which it is exposed, and maintain on the average a tolerably uniform population, then, so long as no change takes place, no new species will arise. For every place or station is supposed to be filled by creatures in all respects adapted to surrounding conditions, able to defend themselves from all enemies, and to obtain food notwithstanding the rivalry of many competitors. But such a perfect balance of organisms nowhere exists upon the earth, and probably never has existed. The well-known fact that some species are very common, while others are very rare, is an almost certain proof that the one is better adapted to its position than the other; and this belief is strengthened when we find the individuals of one species ranging into different climates, subsisting on different food, and competing with different sets of animals, while the individuals of another species will be limited to a small area beyond which they seem unable to extend. When a change occurs, either of climate or geography, some of the small and ill-adapted species will probably die out altogether, and thus leave room for others to increase, or for new forms to occupy their places.

But the change will most likely affect even flourishing species in different ways, some beneficially, others injuriously. Or, again, it may affect a great many injuriously, to such an extent as

to require some change in their structure or habits to enable them to get on as well as before. Now "variation" and the "struggle for existence" come into play. All the weaker and less perfectly organised individuals die out, while those which vary in such a way as to bring them into more harmony with the new conditions constantly survive. If the change of conditions has been considerable, then, after a few centuries, or perhaps even a few generations, one or more *new species* will be almost sure to be formed.

Variation in Animals.—To make this more intelligible to those who have not considered the subject, and to obviate the difficulty many feel about "favourable variations occurring at the right time," it will be well to discuss this matter a little more fully. Few persons consider how largely and universally all animals are varying. We know, however, that in every generation, if we could examine all the individuals of any common species, we should find considerable differences, not only in size and colour, but in the form and proportions of all the parts and organs of the body. In our domesticated animals we know this to be the case, and it is by means of the continual selection of such slight varieties to breed from that all our extremely different domestic breeds have been produced. Think of the difference in every limb, and every bone and muscle, and probably in every part, internal and external of the whole body, between a greyhound and a bull-dog! Yet, if we had the complete series of ancestors of these two breeds before us, we should probably find that in no one

generation was there a greater difference than now occurs in the same breed, or sometimes even the same litter. It is often thought, however, that wild species do not vary sufficiently to bring about any such change as this in the same time; and though naturalists are well aware that this is a mistake, it is only recently that they have been able to adduce positive proof of their opinion.

The Amount of Variation in North American Birds.—An American naturalist, Mr. J. A. Allen, has made elaborate observations and measurements of the birds of the United States, and he finds a wonderful and altogether unsuspected amount of variation between individuals of the same species. They differ in the general tint, and in the markings and distribution of the colours; in size and proportions; in the length of the wings, tail, bill, and feet; in the length of particular feathers, altering the shape of the wing or tail; in the length of the tarsi and of the separate toes, and in the length, width, thickness, and curvature of the bill. These variations are very considerable, often reaching to one-sixth or one-seventh of the average dimensions, and sometimes more. Thus *Turdus fuscescens* (Wilson's thrush) varied in length of wing from 3.58 to 4.16 inches, and in the tail from 3.55 to 4.00 inches; and in twelve specimens, all taken in the same locality, the wing varied in length from 14.5 to 21 per cent., and the tail from 14 to 22.5 per cent. In *Sialia sialis* (the blue bird) the middle toe varied from .77 to .91 inch, and the hind toe from .58 to .72 inch, or more than 21.5 per cent. on the mean, while the bill varied from .45 to .56 inch in length,

and from .30 to .38 inch in width, or about 20 per cent. in both cases. In *Dendræca coronata* (the yellow-crowned warbler) the quills vary in proportionate length, so that the 1st, the 2nd, the 3rd, or the 4th, is sometimes longest; and a similar variation of the wing involving a change of proportion between two or more of the feathers is recorded in eleven species of birds. Colour and marking vary to an equal extent; the dark streaks on the under surface of *Melospiza melodia* (the American song-sparrow) being sometimes reduced to narrow lines. while in other specimens they are so enlarged as to cover the greater part of the breast and sides of the body, sometimes uniting on the middle of the breast into a nearly continuous patch. In one of the small spotted wood-thrushes, *Turdus fuscescens*, the colours are sometimes very pale, and the markings on the breast reduced to indistinct narrow lines, while in other specimens the general colour is much darker, and the breast markings dark, broad, and triangular. All the variations here mentioned occur between adult males, so that there is no question of differences of age or sex, and the pair last referred to were taken at the same place and on the same day.[9]

These interesting facts entirely support the belief in the variability of all animals in all their parts and organs, to an extent amply sufficient for natural selection to work with. We may, indeed, admit that these are extreme cases, and that the

[9] These facts are taken from a memoir on *The Mammals and Winter Birds of Florida*, by J. A. Allen; forming Vol. II., No. 3, of the Bulletin of the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

majority of species do not vary half or a quarter so much as shown in the examples quoted, and we shall still have ample variation for all purposes of specific modification. Instead of an extreme variation in the dimensions and proportions of the various organs of from 10 to 25 per cent. as is here proved to occur, we may assume from 3 to 6 per cent. as generally occurring in the majority of species; and if we further remember that the above excessive variations were found by comparing a number of specimens of each species, varying from 50 to 150 only, we may be sure that the smaller variations we require must occur in considerable numbers among the thousands or millions of individuals of which all but the very rare species consist. If, therefore, we were to divide the population of any species into three groups of equal extent, with regard to any particular character—as length of wing, or of toes, or thickness or curvature of bill, or strength of markings—we should have one group in which the mean or average character prevailed with little variation, one in which the character was greatly, and one in which it was little, developed. If we formed our groups, not by equal numbers, but by equal amount of variation, we should probably find, in accordance with the law of averages, that the central group in which the mean characteristics prevailed was much more numerous than the extremes, perhaps twice, or even three times, as great as either of them, and forming such a series as the following—10 maximum, 30 mean, 10 minimum development. In ordinary cases we have no reason to believe

that the mean characters or the amount of variation of a species changes materially from year to year or from century to century, and we may therefore look upon the central group as the type of the species which is best adapted to the conditions in which it has actually to exist. This type will therefore always form the majority, because the struggle for existence will lead to the continual suppression of the less perfectly adapted extremes. But sometimes a species has a wide range into countries which differ in physical conditions, and then it often happens that one or other of the extremes will predominate in a portion of its range. These form local varieties, but as they occur mixed with the other forms, they are not considered to be distinct species, although they may differ from the other extreme form quite as much as species often do from each other.[10]

How New Species arise from a Variable Species.—It is now very easy to understand how, from such a variable species, one or more new species may arise. The peculiar physical or organic conditions that render one part of the area better adapted to an extreme form may become intensified, and the most extreme variations thus having the advantage, they will multiply at the expense of the rest. If the change of conditions spreads over the whole area occupied by the species, this one extreme form will replace the others; while if the area should be cut in two by subsidence or elevation, the conditions of the two parts may

[10] The great variation in wild animals is more fully discussed and illustrated in the author's *Darwinism* (Chapter III.).

be modified in opposite directions, so as to be each adapted to one extreme form; in which case the original type will become extinct, being replaced by two species, each formed by a combination of certain extreme characters which had before existed in some of its varieties.

The changes of conditions which lead to such selection of varieties are very diverse in nature, and new species may thus be formed, diverging in many ways from the original stock. The climate may change from moist to dry, or the reverse, or the temperature may increase or diminish for long periods, in either case requiring a corresponding change of constitution, of covering, of vegetable or of insect food, to be met by the selection of variations of colour or of swiftness, of length of bill or of strength of claws. Again, competitors or enemies may arrive from other regions, giving the advantage to such varieties as can change their food, or by swifter flight or greater wariness can escape their new foes. We may thus easily understand how a series of changes may occur at distant intervals, each leading to the selection and preservation of a special set of variations, and thus what was a single species may become transformed into a group of allied species differing from each other in a variety of ways, just as we find them in nature.

Among these species, however, there will be some which will have become adapted to very local or special conditions, and will therefore be comparatively few in number and confined to a limited area; while others, retaining the more general

characters of the parent form, but with some important change of structure, will be better adapted to succeed in the struggle for existence with other animals, will spread over a wider area, and increase so as to become common species. Sometimes these will acquire such a perfection of organisation by successive favourable modifications that they will be able to spread greatly beyond the range of the parent form. They then become what are termed dominant species, maintaining themselves in vigour and abundance over very wide areas, displacing other species with which they come into competition, and, under still further changes of conditions, becoming the parents of a new set of diverging species.

Definition and Origin of Genera.—As some of the most important and interesting phenomena of distribution relate to genera rather than to single species, it will be well here to explain what is meant by a genus, and how genera are supposed to arise.

A genus is a group of allied species which differs from all other groups in some well marked characters, usually of a structural rather than a superficial nature. Species of one genus usually differ from each other in size, in colour or marking, in the proportions of the limbs or other organs, and in the form and size of such superficial appendages as horns, crests, manes, &c.; but they generally agree in the form and structure of important organs, as the teeth, the bill, the feet, and the wings. When two groups of species differ from each other constantly in one or more of these latter particulars they are said to belong to different

genera. We have already seen that species vary in these more important as well as in the more superficial characters. If, then, in any part of the area occupied by a species some change of habits becomes useful to it, all such structural variations as facilitate the change will be accumulated by natural selection, and when they have become fixed in the proportions most beneficial to the animal, we shall have the first species of a new genus.

A creature which has been thus modified in important characters will be a new type, specially adapted to fill a new place in the economy of nature. It will almost certainly have arisen from an extensive or dominant species, because only such are sufficiently rich in individuals to afford an ample supply of the necessary variations, and it will inherit the vigour of constitution and adaptability to a wide range of conditions which gave success to its ancestors. It will therefore have every chance in its favour in the struggle for existence; it may spread widely and displace many of its nearest allies, and in doing so will itself become modified superficially and become the parent of a number of subordinate species. It will now have become a dominant *genus*, occupying an entire continent, or perhaps even two or more continents, spreading in every direction till it comes in contact with competing forms better adapted to the different environments. Such a genus may continue to exist during long geological epochs; but the time will generally come when either physical changes, or competing forms, or new enemies are too much for it, and it begins to lose its supremacy. First one then

another of its component species will dwindle away and become extinct, till at last only a few species remain. Sometimes these soon follow the others and the whole genus dies out, as thousands of genera have died out during the long course of the earth's life-history; but it will also sometimes happen that a few species will continue to maintain themselves in areas where they are removed from the influences that exterminated their fellows.

Cause of the Extinction of Species.—There is good reason to believe that the most effective agent in the extinction of species is the pressure of other species, whether as enemies or merely as competitors. If therefore any portion of the earth is cut off from the influx of new or more highly organised animals, we may there expect to find the remains of groups which have elsewhere become extinct. In islands which have been long separated from their parent continents these conditions are exactly fulfilled, and it is in such places that we find the most striking examples of the preservation of fragments of primeval groups of animals, often widely separated from each other, owing to their having been preserved at remote portions of the area of the once widespread parental group. There are many other ways in which portions of dying out groups may be saved. Nocturnal or subterranean modes of life may save a species from enemies or competitors, and many of the ancient types still existing have such habits. The dense gloom of equatorial forests also affords means of concealment and protection, and we sometimes find in such localities a few remnants of low types in the midst of a general assemblage

of higher forms. Some of the most ancient types now living inhabit caves like the Proteus, or bury themselves in mud like the Lepidosiren, or in sand like the Amphioxus, the last being the most primitive of all vertebrates; while the Galeopithecus and Tarsius of the Malay islands and the potto of West Africa, survive amid the higher mammalia of the Asiatic and African continents owing to their nocturnal habits and concealment in the densest forests.

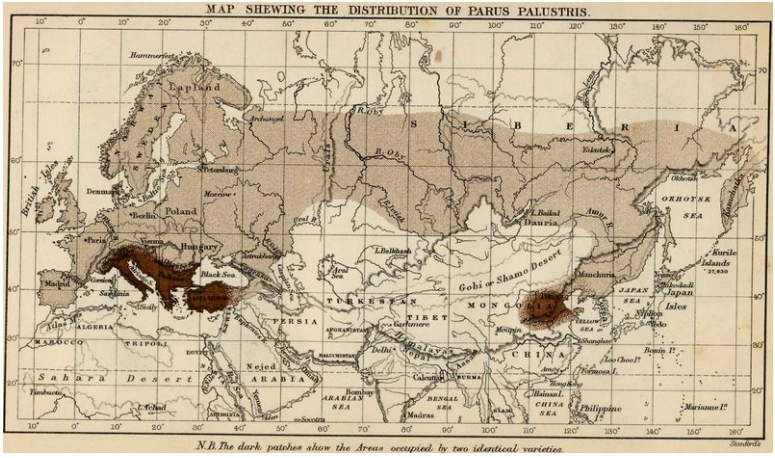
The Rise and Decay of Species and Genera.—The preceding sketch of the mode in which species and genera have arisen, have come to maturity, and then decay, leads us to some very important conclusions as to the mode of distribution of animals. When a species or a genus is increasing and spreading, it necessarily occupies a continuous area which gets larger and larger till it reaches a maximum; and we accordingly find that almost all extensive groups are thus continuous. When decay commences, and the group, ceasing to be in harmony with its environment, is encroached upon by other forms, the continuity may frequently be broken. Sometimes the outlying species may be the first to become extinct, and the group may simply diminish in area while keeping a compact central mass; but more often the process of extinction will be very irregular, and may even divide the group into two or more disconnected portions. This is the more likely to be the case because the most recently formed species, probably adapted to local conditions and therefore most removed from the general type of the group, will have the best

chance of surviving, and these may exist at several isolated points of the area once occupied by the whole group. We may thus understand how the phenomenon of discontinuous areas has come about, and we may be sure that when allied species or varieties of the same species are found widely separated from each other, they were once connected by intervening forms or by each extending till it overlapped the other's area.

Discontinuous Specific Areas, why Rare.—But although discontinuous generic areas, or the separation from each other of species whose ancestors must once have occupied conterminous or overlapping areas, is of frequent occurrence, yet undoubted cases of discontinuous specific areas are very rare, except, as already stated, when one portion of a species inhabits an island. A few examples among mammalia have been referred to in our first chapter, but it may be said that these are examples of the very common phenomenon of a species being only found in the station for which its organisation adapts it; so that forest or marsh or mountain animals are of course only found where there are forests, marshes, or mountains. This may be true, and when the separate forests or mountains inhabited by the same species are not far apart there is little that needs explanation; but in one of the cases referred to there was a gap of a thousand miles between two of the areas occupied by the species, and this being too far for the animal to traverse through an uncongenial territory, we are forced to the conclusion that it must at some former period and under different conditions have occupied a considerable portion

of the intervening area.

Among birds such cases of specific discontinuity are very rare and hardly ever quite satisfactory. This may be owing to birds being more rapidly influenced by changed conditions, so that when a species is divided the two portions almost always become modified into varieties or distinct species; while another reason may be that their powers of flight cause them to occupy on the average wider and less precisely defined areas than do the species of mammalia. It will be interesting therefore to examine the few cases on record, as we shall thereby obtain additional knowledge of the steps and processes by which the distribution of varieties and species has been brought about.



Discontinuity of the Area of Parus palustris.—Mr. Seebohm, who has travelled and collected in Europe, Siberia, and India, and possesses extensive and accurate knowledge of Palæarctic birds, has recently called attention to the varieties and sub-species of the marsh tit (*Parus palustris*), of which he has examined numerous specimens ranging from England to Japan.[11] The curious point is that those of Southern Europe and of China are exactly alike, while all over Siberia a very distinct form occurs, forming the sub-species *P. borealis*.[12] In Japan and Kamschatka other varieties are found, which have been named respectively *P. japonicus* and *P. camschatkensis* and another *P. songarus* in Turkestan and Mongolia. Now it all depends upon these forms being classed as sub-species or as true species whether this is or is not a case of discontinuous specific distribution. If *Parus borealis* is a distinct species from *Parus palustris*, as it is reckoned in Gray's *Hand List of Birds*, and also in Sharpe and Dresser's *Birds of Europe*, then *Parus palustris* has a most remarkable discontinuous distribution, as shown in the accompanying map, one portion of its area comprising Central and South Europe and Asia Minor, the other an undefined tract in Northern China, the two portions being thus situated in about the same latitude and having a very similar climate, but with a distance of about 4,000

[11] See *Ibis*, 1879, p. 32.

[12] In Mr. Seebohm's latest work, *Birds of the Japanese Empire* (1890), he says, "Examples from North China are indistinguishable from those obtained in Greece" (p. 82).

miles between them. If, however, these two forms are reckoned as sub-species only, then the area of the species becomes continuous, while only one of its varieties or sub-species has a discontinuous area. It is a curious fact that *P. palustris* and *P. borealis* are found together in Southern Scandinavia and in some parts of Central Europe, and are said to differ somewhat in their note and their habits, as well as in colouration.

Discontinuity of Emberiza schœniclus.—The other case is that of our reed bunting (*Emberiza schœniclus*), which ranges over almost all Europe and Western Asia as far as the Yenesai valley and North-west India. It is then replaced by another smaller species, *E. passerina*, which ranges eastwards to the Lena river, and in winter as far south as Amoy in China; but in Japan the original species appears again, receiving a new name (*E. pyrrhulina*), but Mr. Seebohm assures us that it is quite indistinguishable from the European bird. Although the distance between these two portions of the species is not so great as in the last example, being about 2,000 miles, in other respects the case is an interesting one, because the forms which occupy the intervening space are recognised by Mr. Seebohm himself as undoubted species.[13]

The European and Japanese Jays.—Another case somewhat resembling that of the marsh tit is afforded by the European

[13] *Ibis*, 1879, p. 40. In his *Birds of the Japanese Empire* (1890), Mr. Seebohm classes the Japanese and European forms as *E. schœniclus*, and thinks that their range is probably continuous across the two continents.

and Japanese jays (*Garrulus glandarius* and *G. japonicus*). Our common jay inhabits the whole of Europe except the extreme north, but is not known to extend anywhere into Asia, where it is represented by several quite distinct species. (See Map, Frontispiece.) But the great central island of Japan is inhabited by a jay (*G. japonicus*) which is very like ours, and was formerly classed as a sub-species only, in which case our jay would be considered to have a discontinuous distribution. But the specific distinctness of the Japanese bird is now universally admitted, and it is certainly a very remarkable fact that among the twelve species of jays which together range over all temperate Europe and Asia, one which is so closely allied to our English bird should be found at the remotest possible point from it. Looking at the map exhibiting the distribution of the several species, we can hardly avoid the conclusion that a bird very like our jay once occupied the whole area of the genus, that in various parts of Asia it became gradually modified into a variety of distinct species in the manner already explained, a remnant of the original type being preserved almost unchanged in Japan, owing probably to favourable conditions of climate and protection from competing forms.

Supposed Examples of Discontinuity among North American Birds.—In North America, the eastern and western provinces are so different in climate and vegetation, and are besides separated by such remarkable physical barriers—the arid central plains and the vast ranges of the Rocky Mountains and Sierra Nevada, that

we can hardly expect to find species whose areas may be divided maintaining their identity. Towards the north however the above-named barriers disappear, the forests being almost continuous from east to west, while the mountain range is broken up by passes and valleys. It thus happens that most species of birds which inhabit both the eastern and western coasts of the North American continent have maintained their continuity towards the north, while even when differentiated into two or more allied species their areas are often conterminous or overlapping.

Almost the only bird that seems to have a really discontinuous range is the species of wren, *Thryothorus bewickii*, of which the type form ranges from the east coast to Kansas and Minnesota, while a longer-billed variety, *T. bewickii spilurus*, is found in the wooded parts of California and as far north as Puget Sound. If this really represents the range of the species there remains a gap of about 1,000 miles between its two disconnected areas. Other cases are those of *Vireo bellii* of the middle United States and the sub-species *pusillus* of California; and of the purple red-finch, *Carpodacus purpureus*, with its variety *C. californicus*; but unfortunately the exact limits of these varieties are in neither case known, and though each one is characteristic of its own province, it is possible that they may somewhere become conterminous, though in the case of the red-finches this does not seem likely to be the fact.

In a later chapter we shall have to point out some remarkable cases of this kind where one portion of the species inhabits

an island; but the facts now given are sufficient to prove that the discontinuity of the area occupied by a single homogeneous species, by two varieties of a species, by two well-marked sub-species, and by two closely allied but distinct species, are all different phases of one phenomenon—the decay of ill-adapted, and their replacement by better-adapted forms, under the pressure of a change of conditions either physical or organic. We may now proceed with our sketch of the mode of distribution of higher groups.

Distribution and Antiquity of Families.—Just as *genera* are groups of allied species distinguished from all other groups by some well-marked structural characters, so *families* are groups of allied genera distinguished by more marked and more important characters, which are generally accompanied by a peculiar outward form and style of colouration, and by distinctive habits and mode of life. As a genus is usually more ancient than any of the species of which it is composed, because during its growth and development the original rudimentary species becomes supplanted by more and more perfectly adapted forms, so a family is usually older than its component genera, and during the long period of its life-history may have survived many and great terrestrial and organic changes. Many families of the higher animals have now an almost worldwide extension, or at least range over several continents; and it seems probable that all families which have survived long enough to develop a considerable variety of generic and specific forms have also at

one time or other occupied an extensive area.

Discontinuity a Proof of Antiquity.—Discontinuity will therefore be an indication of antiquity, and the more widely the fragments are scattered the more ancient we may usually presume the parent group to be. A striking example is furnished by the strange reptilian fishes forming the order or sub-order Dipnoi, which includes the Lepidosiren and its allies. Only three or four living species are known, and these inhabit tropical rivers situated in the remotest continents. The *Lepidosiren paradoxa* is only known from the Amazon and some other South American rivers. An allied species, *Lepidosiren annectens*, sometimes placed in a distinct genus, inhabits the Gambia in West Africa, while the recent discovery in Eastern Australia of the Ceratodus or mud-fish of Queensland, adds another form to the same isolated group. Numerous fossil teeth, long known from the Triassic beds of this country, and also found in Germany and India in beds of the same age, agree so closely with those of the living Ceratodus that both are referred to the same genus. No more recent traces of any such animal have been discovered, but the Carboniferous Ctenodus and the Devonian Dipterus evidently belong to the same group, while in North America the Devonian rocks have yielded a gigantic allied form which has been named Heliodus by Professor Newberry. Thus an enormous range in time is accompanied by a very wide and scattered distribution of the existing species.

Whenever, therefore, we find two or more living genera

belonging to the same family or order but not very closely allied to each other, we may be sure that they are the remnants of a once extensive group of genera; and if we find them now isolated in remote parts of the globe, the natural inference is that the family of which they are fragments once had an area embracing the countries in which they are found. Yet this simple and very obvious explanation has rarely been adopted by naturalists, who have instead imagined changes of land and sea to afford a direct passage from the one fragment to the other. If there were no cosmopolitan or very wide-spread families still existing, or even if such cases were rare, there would be some justification for such a proceeding; but as about one-fourth of the existing families of land mammalia have a range extending to at least three or four continents, while many which are now represented by disconnected genera are known to have occupied intervening lands or to have had an almost continuous distribution in tertiary times, all the presumptions are in favour of the former continuity of the group. We have also in many cases direct evidence that this former continuity was effected by means of existing continents, while in no single case has it been shown that such a continuity was impossible, and that it either was or must have been effected by means of continents now sunk beneath the ocean.

Concluding Remarks.—When writing on the subject of distribution it usually seems to have been forgotten that the theory of evolution absolutely necessitates the former existence of a whole series of extinct genera filling up the gap between the

isolated genera which in many cases now alone exist; while it is almost an axiom of "natural selection" that such numerous forms of one type could only have been developed in a wide area and under varied conditions, implying a great lapse of time. In our succeeding chapters we shall show that the known and probable changes of sea and land, the known changes of climate, and the actual powers of dispersal of the different groups of animals, were such as would have enabled all the now disconnected groups to have once formed parts of a continuous series. Proofs of such former continuity are continually being obtained by the discovery of allied extinct forms in intervening lands, but the extreme imperfection of the geological record as regards land animals renders it unlikely that this proof will be forthcoming in the majority of cases. The notion that if such animals ever existed their remains would certainly be found, is a superstition which, notwithstanding the efforts of Lyell and Darwin, still largely prevails among naturalists; but until it is got rid of no true notions of the former distribution of life upon the earth can be attained.

CHAPTER V
THE POWERS OF DISPERSAL OF ANIMALS AND PLANTS

Statement of the general question of Dispersal—The Ocean as a Barrier to the Dispersal of Mammals—The Dispersal of Birds—The Dispersal of Reptiles—The Dispersal of Insects—The Dispersal of Land Mollusca—Great Antiquity of Land-shells—Causes favouring the Abundance of Land-shells—The Dispersal of Plants—Special adaptability of Seeds for Dispersal—Birds as agents in the Dispersal of Seeds—Ocean Currents as agents in Plant Dispersal—Dispersal along Mountain-chains—Antiquity of Plants as affecting their Distribution.

In order to understand the many curious anomalies we meet with in studying the distribution of animals and plants, and to be able to explain how it is that some species and genera have been able to spread widely over the globe, while others are confined to one hemisphere, to one continent, or even to a single mountain or a single island, we must make some inquiry into the different powers of dispersal of animals and plants, into the nature of the barriers that limit their migrations, and into the character of the geological or climatal changes which have favoured or checked such migrations.

The first portion of the subject—that which relates to the

various modes by which organisms can pass over wide areas of sea and land—has been fully treated by Sir Charles Lyell, by Mr. Darwin, and many other writers, and it will only be necessary here to give a very brief notice of the best known facts on the subject, which will be further referred to when we come to discuss the particular cases that arise in regard to the faunas and floras of remote islands. But the other side of the question of dispersal—that which depends on geological and climatal changes—is in a far less satisfactory condition, for, though much has been written upon it, the most contradictory opinions still prevail, and at almost every step we find ourselves on the battle-field of opposing schools in geological or physical science. As, however, these questions lie at the very root of any general solution of the problems of distribution, I have given much time to a careful examination of the various theories that have been advanced, and the discussions to which they have given rise; and have arrived at some definite conclusions which I venture to hope may serve as the foundation for a better comprehension of these intricate problems. The four chapters which follow this are devoted to a full examination of these profoundly interesting and important questions, after which we shall enter upon our special inquiry—the nature and origin of insular faunas and floras.

The Ocean as a Barrier to the Dispersal of Mammals.—A wide extent of ocean forms an almost absolute barrier to the dispersal of all land animals, and of most of those which are aerial, since even birds cannot fly for thousands of miles without

rest and without food, unless they are aquatic birds which can find both rest and food on the surface of the ocean. We may be sure, therefore, that without artificial help neither mammalia nor land birds can pass over very wide oceans. The exact width they can pass over is not determined, but we have a few facts to guide us. Contrary to the common notion, pigs can swim very well, and have been known to swim over five or six miles of sea, and the wide distribution of pigs in the islands of the Eastern Hemisphere may be due to this power. It is almost certain, however, that they would never voluntarily swim away from their native land, and if carried out to sea by a flood they would certainly endeavour to return to the shore. We cannot therefore believe that they would ever swim over fifty or a hundred miles of sea, and the same may be said of all the larger mammalia. Deer also swim well, but there is no reason to believe that they would venture out of sight of land. With the smaller, and especially with the arboreal mammalia, there is a much more effectual way of passing over the sea, by means of floating trees, or those floating islands which are often formed at the mouths of great rivers. Sir Charles Lyell describes such floating islands which were encountered among the Moluccas, on which trees and shrubs were growing on a stratum of soil which even formed a white beach round the margin of each raft. Among the Philippine Islands similar rafts with trees growing on them have been seen after hurricanes; and it is easy to understand how, if the sea were tolerably calm, such a raft might be carried along by a current, aided by the wind acting

on the trees, till after a passage of several weeks it might arrive safely on the shores of some land hundreds of miles away from its starting-point. Such small animals as squirrels and field-mice might have been carried away on the trees which formed part of such a raft, and might thus colonise a new island; though, as it would require a pair of the same species to be thus conveyed at the same time, such accidents would no doubt be rare. Insects, however, and land-shells would almost certainly be abundant on such a raft or island, and in this way we may account for the wide dispersal of many species of both these groups.

Notwithstanding the occasional action of such causes, we cannot suppose that they have been effective in the dispersal of mammalia as a whole; and whenever we find that a considerable number of the mammals of two countries exhibit distinct marks of relationship, we may be sure that an actual land connection, or at all events an approach to within a very few miles of each other, has at one time existed. But a considerable number of identical mammalian families and even genera are actually found in all the great continents, and the present distribution of land upon the globe renders it easy to see how they have been able to disperse themselves so widely. All the great land masses radiate from the arctic regions as a common centre, the only break being at Behrings Strait, which is so shallow that a rise of less than a thousand feet would form a broad isthmus connecting Asia and America as far south as the parallel of 60° N. Continuity of land therefore may be said to exist already for all parts of the world

(except Australia and a number of large islands, which will be considered separately), and we have thus no difficulty in the way of that former wide diffusion of many groups, which we maintain to be the only explanation of most anomalies of distribution other than such as may be connected with unsuitability of climate.

The Dispersal of Birds.—Wherever mammals can migrate other vertebrates can generally follow with even greater facility. Birds, having the power of flight, can pass over wide arms of the sea, or even over extensive oceans, when these are, as in the Pacific, studded with islands to serve as resting places. Even the smaller land-birds are often carried by violent gales of wind from Europe to the Azores, a distance of nearly a thousand miles, so that it becomes comparatively easy to explain the exceptional distribution of certain species of birds. Yet on the whole it is remarkable how closely the majority of birds follow the same laws of distribution as mammals, showing that they generally require either continuous land or an island-strewn sea as a means of dispersal to new homes.

The Dispersal of Reptiles.—Reptiles appear at first sight to be as much dependent on land for their dispersal as mammalia, but they possess two peculiarities which favour their occasional transmission across the sea—the one being their greater tenacity of life, the other their oviparous mode of reproduction. A large boa-constrictor was once floated to the island of St. Vincent, twisted round the trunk of a cedar tree, and was so little injured by its voyage that it captured some sheep before it was killed.

The island is nearly two hundred miles from Trinidad and the coast of South America, whence the reptile almost certainly came.[14] Snakes are, however, comparatively scarce on islands far from continents, but lizards are often abundant, and though these might also travel on floating trees, it seems more probable that there is some as yet unknown mode by which their eggs are safely, though perhaps very rarely, conveyed from island to island. Examples of their peculiar distribution will be given when we treat of the fauna of some islands in which they abound.

The Dispersal of Amphibia and Fresh-water Fishes.—The two lower groups of vertebrates, Amphibia and fresh-water fishes, possess special facilities for dispersal, in the fact of their eggs being deposited in water, and in their aquatic or semi-aquatic habits. They have another advantage over reptiles in being capable of flourishing in arctic regions, and in the power possessed by their eggs of being frozen without injury. They have thus, no doubt, been assisted in their dispersal by floating ice, and by that approximation of all the continents in high northern latitudes which has been the chief agent in producing the general uniformity in the animal productions of the globe. Some genera of Batrachia have almost a world-wide distribution; while the tailed Batrachia, such as the newts and salamanders, are almost entirely confined to the northern hemisphere, some of the genera spreading over the whole of the north temperate zone. Fresh-water fishes have often a very wide range, the same species

[14] Lyell's *Principles of Geology*, ii., p. 369.

being sometimes found in all the rivers of a continent. This is no doubt chiefly due to the want of permanence in river basins, especially in their lower portions, where streams belonging to distinct systems often approach each other and may be made to change their course from one to the other basin by very slight elevations or depressions of the land. Hurricanes and water-spouts also often carry considerable quantities of water from ponds and rivers, and thus disperse eggs and even small fishes. As a rule, however, the same species are not often found in countries separated by a considerable extent of sea, and in the tropics rarely the same genera. The exceptions are in the colder regions of the earth, where the transporting power of ice may have come into play. High ranges of mountains, if continuous for long distances, rarely have the same species of fish in the rivers on their two sides. Where exceptions occur, it is often due to the great antiquity of the group, which has survived so many changes in physical geography that it has been able, step by step, to reach countries which are separated by barriers impassable to more recent types. Yet another and more efficient explanation of the distribution of this group of animals is the fact that many families and genera inhabit both fresh and salt water; and there is reason to believe that many of the fishes now inhabiting the tropical rivers of both hemispheres have arisen from allied marine forms becoming gradually modified for a life in fresh water. By some of these various causes, or a combination of them, most of the facts in the distribution of fishes can be explained without much

difficulty.

The Dispersal of Insects.—In the enormous group of insects the means of dispersal among land animals reach their maximum. Many of them have great powers of flight, and from their extreme lightness they can be carried immense distances by gales of wind. Others can survive exposure to salt water for many days, and may thus be floated long distances by marine currents. The eggs and larvæ often inhabit solid timber, or lurk under bark or in crevices of logs, and may thus reach any countries to which such logs are floated. Another important factor in the problem is the immense antiquity of insects, and the long persistence of many of the best marked types. The rich insect fauna of the Miocene period in Switzerland consisted largely of genera still inhabiting Europe, and even of a considerable number identical, or almost so, with living species. Out of 156 genera of Swiss fossil beetles no less than 114 are still living; and the general character of the species is exactly like that of the existing fauna of the northern hemisphere in a somewhat more southern latitude. There is, therefore, evidently no difficulty in accounting for any amount of dispersal among insects; and it is all the more surprising that with such powers of migration they should yet be often as restricted in their range as the reptiles or even the mammalia. The cause of this wonderful restriction to limited areas is, undoubtedly, the extreme specialisation of most insects. They have become so exactly adapted to one set of conditions, that when carried into a new country they cannot live. Many can

only feed in the larva state on one species of plant; others are bound up with certain groups of animals on whom they are more or less parasitic. Climatal influences have a great effect on their delicate bodies; while, however well a species may be adapted to cope with its enemies in one locality, it may be quite unable to guard itself against those which elsewhere attack it. From this peculiar combination of characters it happens, that among insects are to be found examples of the widest and most erratic dispersal and also of the extremest restriction to limited areas; and it is only by bearing these considerations in mind that we can find a satisfactory explanation of the many anomalies we meet with in studying their distribution.

The Dispersal of Land Mollusca.—The only other group of animals we need now refer to is that of the air-breathing mollusca, commonly called land-shells. These are almost as ubiquitous as insects, though far less numerous; and their wide distribution is by no means so easy to explain. The genera have usually a very wide, and often a cosmopolitan range, while the species are rather restricted, and sometimes wonderfully so. Not only do single islands, however small, often possess peculiar species of land-shells, but sometimes single mountains or valleys, or even a particular mountain side, possess species or varieties found nowhere else upon the globe. It is pretty certain that they have no means of passing over the sea but such as are very rare and exceptional. Some which possess an operculum, or which close the mouth of the shell with a diaphragm of secreted

mucus, may float across narrow arms of the sea, especially when protected in the crevices of logs of timber; while in the young state when attached to leaves or twigs they may be carried long distances by hurricanes.[15] Owing to their exceedingly slow motion, their powers of voluntary dispersal, even on land, are very limited, and this will explain the extreme restriction of their range in many cases.

Great Antiquity of Land-Shells.—The clue to the almost universal distribution of the several families and of many genera, is to be found, however, in their immense antiquity. In the Pliocene and Miocene formations most of the land-shells are either identical with living species or closely allied to them, while even in the Eocene almost all are of living genera, and one British Eocene fossil still lives in Texas. Strange to say, no true land-shells have been discovered in the Secondary formations, but they must certainly have abounded, for in the far more ancient Palæozoic coal measures of Nova Scotia two species belonging to the living genera Pupa and Zonites have been found in considerable abundance.

Land-shells have therefore survived all the revolutions the

[15] Mr. Darwin found that the large *Helix pomatia* lived after immersion in sea-water for twenty days. It is hardly likely that this is the extreme limit of their powers of endurance, but even this would allow of their being floated many hundred miles at a stretch, and if we suppose the shell to be partially protected in the crevice of a log of wood, and to be thus out of water in calm weather, the distance might extend to a thousand miles or more. The eggs of fresh-water mollusca, as well as the young animals, are known to attach themselves to the feet of aquatic birds, and this is probably the most efficient cause of their very wide diffusion.

earth has undergone since Palæozoic times. They have been able to spread slowly but surely into every land that has ever been connected with a continent, while the rare chances of transfer across the ocean, to which we have referred as possible, have again and again occurred during the almost unimaginable ages of their existence. The remotest and most solitary of the islands of the mid-ocean have thus become stocked with them, though the variety of species and genera bears a direct relation to the facilities of transfer, and the shell fauna is never very rich and varied, except in countries which have at one time or other been united to some continental land.

Causes Favouring the Abundance of Land-Shells.—The abundance and variety of land-shells is also, more than that of any other class of animals, dependent on the nature of the surface and the absence of enemies, and where these conditions are favourable their forms are wonderfully luxuriant. The first condition is the presence of lime in the soil, and a broken surface of country with much rugged rock offering crevices for concealment and hibernation. The second is a limited bird and mammalian fauna, in which such species as are especially shell-eaters shall be rare or absent. Both these conditions are found in certain large islands, and pre-eminently in the Antilles, which possess more species of land-shells than any single continent. If we take the whole globe, more species of land-shells are found on the islands than on the continents—a state of things to which no approach is made in any other group of animals whatever, but

which is perhaps explained by the considerations now suggested.

The Dispersal of Plants.—The ways in which plants are dispersed over the earth, and the special facilities they often possess for migration have been pointed out by eminent botanists, and a considerable space might be occupied in giving a summary of what has been written on the subject. In the present work, however, it is only in two or three chapters that I discuss the origin of insular floras in any detail; and it will therefore be advisable to adduce any special facts when they are required to support the argument in particular cases. A few general remarks only will therefore be made here.

Special Adaptability of Seeds for Dispersal.—Plants possess many great advantages over animals as regards the power of dispersal, since they are all propagated by seeds or spores, which are hardier than the eggs of even insects, and retain their vitality for a much longer time. Seeds may lie dormant for many years and then vegetate, while they endure extremes of heat, of cold, of drought, or of moisture which would almost always be fatal to animal germs. Among the causes of the dispersal of seeds De Candolle enumerates the wind, rivers, ocean currents, icebergs, birds and other animals, and human agency. Great numbers of seeds are specially adapted for transport by one or other of these agencies. Many are very light, and have winged appendages, pappus, or down, which enable them to be carried enormous distances. It is true, as De Candolle remarks, that we have no actual proofs of their being so carried; but this is not surprising

when we consider how small and inconspicuous most seeds are. Supposing every year a million seeds were brought by the wind to the British Isles from the Continent, this would be only ten to a square mile, and the observation of a life-time might never detect one; yet a hundredth part of this number would serve in a few centuries to stock an island like Britain with a great variety of continental plants.

When, however, we consider the enormous quantity of seeds produced by plants, that great numbers of these are more or less adapted to be carried by the wind, and that winds of great violence and long duration occur in most parts of the world, we are as sure that seeds must be carried to great distances as if we had seen them so carried. Such storms carry leaves, hay, dust, and many small objects to a great height in the air, while many insects have been conveyed by them for hundreds of miles out to sea and far beyond what their unaided powers of flight could have effected.

Birds as Agents in the Dispersal of Plants.—Birds are undoubtedly important agents in the dispersal of plants over wide spaces of ocean, either by swallowing fruits and rejecting the seeds in a state fit for germination, or by the seeds becoming attached to the plumage of ground-nesting birds, or to the feet of aquatic birds embedded in small quantities of mud or earth. Illustrations of these various modes of transport will be found in Chapter XII. when discussing the origin of the flora of the Azores and Bermuda.

Ocean-currents as Agents in Plant-dispersal.—Ocean-currents are undoubtedly more important agents in conveying seeds of plants than they are in the case of any other organisms, and a considerable body of facts and experiments have been collected proving that seeds may sometimes be carried in this way many thousand miles and afterwards germinate. Mr. Darwin made a series of interesting experiments on this subject, some of which will be given in the chapter above referred to.

Dispersal along Mountain Chains.—These various modes of transport are, as will be shown when discussing special cases, amply sufficient to account for the vegetation found on oceanic islands, which almost always bears a close relation to that of the nearest continent; but there are other phenomena presented by the dispersal of species and genera of plants over very wide areas, especially when they occur in widely separated portions of the northern and southern hemispheres, that are not easily explained by such causes alone. It is here that transmission along mountain chains has probably been effective; and the exact mode in which this has occurred is discussed in Chapter XXIII., where a considerable body of facts is given, showing that extensive migrations may be effected by a succession of moderate steps, owing to the frequent exposure of fresh surfaces of soil or *débris* on mountain sides and summits, offering stations on which foreign plants can temporarily establish themselves.

Antiquity of Plants as affecting their Distribution.—We have already referred to the importance of great antiquity in enabling

us to account for the wide dispersal of some genera and species of insects and land-shells, and recent discoveries in fossil botany show that this cause has also had great influence in the case of plants. Rich floras have been discovered in the Miocene, the Eocene, and the Upper Cretaceous formations, and these consist almost wholly of living genera, and many of them of species very closely allied to existing forms. We have therefore every reason to believe that a large number of our plant-species have survived great geological, geographical, and climatal changes; and this fact, combined with the varied and wonderful powers of dispersal many of them possess, renders it far less difficult to understand the examples of wide distribution of the genera and species of plants than in the case of similar instances among animals. This subject will be further alluded to when discussing the origin of the New Zealand flora, in Chapter XXII.

CHAPTER VI
GEOGRAPHICAL AND GEOLOGICAL CHANGES: THE PERMANENCE OF CONTINENTS

Changes of Land, and Sea, their Nature and Extent —Shore-deposits and Stratified Rocks—The Movements of Continents—Supposed Oceanic Formations; the Origin of Chalk—Fresh-water and Shore-deposits as proving the Permanence of Continents—Oceanic Islands as indications of the Permanence of Continents and Oceans—General Stability of Continents with constant Change of Form —Effect of Continental Changes on the Distribution of Animals—Changed Distribution proved by the Extinct Animals of Different Epochs—Summary of Evidence for the general Permanence of Continents and Oceans.

The changes of land and sea which have occurred in particular cases will be described when we discuss the origin and relations of the faunas of the different classes of islands. We have here only to consider the general character and extent of such changes, and to correct some erroneous ideas which are prevalent on the subject.

Changes of Land and Sea, their Nature and Extent.—It is a very common belief that geological evidence proves a complete

change of land and sea to have taken place over and over again. Every foot of dry land has undoubtedly, at one time or other, formed part of a sea-bottom, and we can hardly exclude the surfaces occupied by volcanic and fresh-water deposits, since, in many cases, if not in all, these rest upon a substratum of marine formations. At first sight, therefore, it seems a necessary inference that when the present continents were under water there must have been other continents situated where we now find the oceans, from which the sediments came to form the various deposits we now see. This view was held by so acute and learned a geologist as Sir Charles Lyell, who says:—"Continents, therefore, although permanent for whole geological epochs, shift their positions entirely in the course of ages."[16] Mr. T. Mellard Reade, late President of the Geological Society of Liverpool, so recently as 1878, says:—"While believing that the ocean-depths are of enormous age, it is impossible to resist other evidences that they have once been land. The very continuity of animal and vegetable life on the globe points to it. The molluscous fauna of the eastern coast of North America is very similar to that of Europe, and this could not have happened without littoral continuity, yet there are depths of 1,500 fathoms between these continents."[17] It is certainly strange that a geologist should not remember the recent and long-continued warm climates of the Arctic regions, and see that a connection of Northern Europe

[16] *Principles of Geology*, 11th Ed., Vol. I., p. 258.

[17] On Limestone as an Index of Geological Time.

by Iceland with Greenland and Labrador over a sea far less than a thousand fathoms deep would furnish the "littoral continuity" required. Again, in the same pamphlet Mr. Reade says:—"It can be mathematically demonstrated that the whole, or nearly the whole, of the sea-bottom has been at one time or other dry land. If it were not so, and the oscillations, of the level of the land with respect to the sea were confined within limits near the present continents, the results would have been a gradual diminution instead of development of the calcareous rocks. To state the case in common language, the calcareous portion of the rocks would have been washed out during the mutations, the destruction and redeposit of the continental rocks, and eventually deposited in the depths of the immutable sea far from land. Immense beds of limestone would now exist at the bottom of the ocean, while the land would be composed of sandstones and argillaceous shales. The evidence of chemistry thus confirms the inductions drawn from the distribution of animal life upon the globe."

So far from this being a "mathematical demonstration," it appears to me to be a complete misinterpretation of the facts. Animals did not create the lime which they secrete from the sea-water, and therefore we have every reason to believe that the inorganic sources which originally supplied it still keep up that supply, though perhaps in diminished quantity. Again, the great lime-secreters—corals—work in water of moderate depth, that is, near land, while there is no proof whatever that there is any considerable accumulation of limestone at the bottom

of the deep ocean. On the contrary, the fact ascertained by the *Challenger*, that beyond a certain depth the "calcareous" ooze ceases, and is replaced by red and grey clays, although the calcareous organisms still abound in the surface waters of the ocean, shows that the lime is dissolved again by the excess of carbonic acid usually found at great depths, and its accumulation thus prevented. As to the increase of limestones in recent as compared with older formations, it may be readily explained by two considerations: in the first place, the growth and development of the land in longer and more complex shore lines and the increase of sedimentary over volcanic formations may have offered more stations favourable to the growth of coral; while the solubility of limestone in rain-water renders the destruction of such rocks more rapid than that of sandstones and shales, and would thus, by supplying more calcareous matter in solution for secretion by limestone-forming organisms, lead to their comparative abundance in later as compared with earlier formations.

However weak we may consider the above-quoted arguments against the permanence of oceans, the fact that these arguments are so confidently and authoritatively put forward, renders it advisable to show how many and what weighty considerations can be adduced to justify the opposite belief, which is now rapidly gaining ground among students of earth-history.

Shore Deposits and Stratified Rocks.—If we go round the shores of any of our continents we shall almost always find a

considerable belt of shallow water, meaning thereby water from 100 to 150 fathoms deep. The distance from the coast line at which such depths are reached is seldom less than twenty miles, and is very frequently more than a hundred, while in some cases such shallow seas extend several hundred miles from existing continents. The great depth of a thousand fathoms is often reached at thirty miles from shore, but more frequently at about sixty or a hundred miles. Round the entire African coast for example, this depth is reached at distances varying from forty to a hundred and fifty miles (except in the Red Sea and the Straits of Mozambique), the average being about eighty miles.

Now the numerous specimens of sea-bottoms collected during the voyage of the *Challenger* show that true shore-deposits—that is, materials denuded from the land and carried down as sediment by rivers—are almost always confined within a distance of 50 or 100 miles of the coast, the finest mud only being sometimes carried 150 or rarely 200 miles. As the sediment varies in coarseness and density it is evident that it will sink to the bottom at unequal distances, the bulk of it sinking comparatively near shore, while only the very finest and almost impalpable mud will be carried out to the furthest limits. Beyond these limits the only deposits (with few exceptions) are organic, consisting of the shells of minute calcareous or siliceous organisms with some decomposed pumice and volcanic dust which floats out to mid-ocean. It follows, therefore, that by far the larger part of all stratified deposits, especially those which consist of sand or

pebbles or any visible fragments of rock, must have been formed within 50 or 100 miles of then existing continents, or if at a greater distance, in shallow inland seas receiving deposits from more sides than one, or in certain exceptional areas where deep ocean currents carry the *débris* of land to greater distances.[18]

If we now examine the stratified rocks found in the very centre of all our great continents, we find them to consist of sandstones, limestones, conglomerates, or shales, which must, as we have seen, have been deposited within a comparatively short distance of a sea-shore. Sir Archibald Geikie says:—"Among the thickest masses of sedimentary rock—those of the ancient Palæozoic systems—no features recur more continually than the alternations of different sediments, and the recurrence of surfaces covered with well-preserved ripple-marks, trails and burrows of annelides, polygonal and irregular desiccation marks, like the cracks at the bottom of a sun-dried muddy pool. These phenomena unequivocally point to shallow and even littoral waters. They occur from bottom to top of formations, which reach a thickness of several thousand feet. They can be interpreted only in one way, viz., that the formations in

[18] In his *Preliminary Report on Oceanic Deposit*, Mr. Murray says:—"It has been found that the deposits taking place near continents and islands have received their chief characteristics from the presence of the *debris* of adjacent lands. In some cases these deposits extend to a distance of over 150 miles from the coast." (*Proceedings of the Royal Society*, Vol. XXIV. p. 519.)"The materials in suspension appear to be almost entirely deposited within 200 miles of the land." (*Proceedings of the Royal Society of Edinburgh*, 1876-77, p. 253.)

question began to be laid down in shallow water; that during their formation the area of deposit gradually subsided for thousands of feet; yet that the rate of accumulation of sediment kept pace on the whole with this depression; and hence that the original shallow-water character of the deposits remained, even after the original sea-bottom had been buried under a vast mass of sedimentary matter." He goes on to say, that this general statement applies to the more recent as well as to the more ancient formations, and concludes—"In short, the more attentively the stratified rocks of the earth are studied, the more striking becomes the absence of any formations among them, which can legitimately be considered those of a deep sea. They have all been deposited in comparatively shallow water."[19]

The arrangement and succession of the stratified rocks also indicate the mode and place of their formation. We find them stretching across the country in one general direction, in belts of no great width though often of immense length, just as we should expect in shore deposits; and they often thin out and change from coarse to fine in a definite manner, indicating the position of the adjacent land from the *débris* of which they were originally formed. Again quoting Sir Archibald Geikie:—"The materials carried down to the sea would arrange themselves then as they do still, the coarser portions nearest the shore, the finer silt and mud furthest from it. From the earliest geological times the great

[19] *Geographical Evolution. (Proceedings of the Royal Geographical Society.* 1879, p. 426.)

area of deposit has been, as it still is, the marginal belt of sea-floor skirting the land. It is there that nature has always strewn the dust of continents to be."

The Movements of Continents.—As we find these stratified rocks of different periods spread over almost the whole surface of existing continents where not occupied by igneous or metamorphic rocks, it follows that at one period or another each part of the continent has been under the sea, but at the same time not far from the shore. Geologists now recognise two kinds of movements by which the deposits so formed have been elevated into dry land—in the one case the strata remain almost level and undisturbed, in the other they are contorted and crumpled, often to an enormous extent. The former often prevails in plains and plateaus, while the latter is almost always found in the great mountain ranges. We are thus led to picture the land of the globe as a flexible area in a state of slow but incessant change; the changes consisting of low undulations which creep over the surface so as to elevate and depress limited portions in succession without perceptibly affecting their nearly horizontal position; and also of intense lateral compression, supposed to be produced by partial subsidence along certain lines of weakness in the earth's crust, the effect of which is to crumple the strata and force up certain areas in great contorted masses, which, when carved out by subaërial denudation into peaks and valleys, constitute our great mountain systems.[20] In this way every part of a continent

[20] Professor Dana was, I believe, the first to point out that the regions which, after

may again and again have sunk beneath the sea, and yet as a whole may never have ceased to exist as a continent or a vast continental archipelago. And, as subsidence will always be accompanied by deposition, of sediments from the adjacent land, piles of marine strata many thousand feet thick may have been formed in a sea which was never very deep, by means of a slow depression either continuous or intermittent, or through alternate subsidences and elevations, each of moderate amount.

Supposed Oceanic Formations;—the Origin of Chalk.—There seems very good reason to believe that few, if any, of the rocks known to geologists correspond exactly to the deposits now forming at the bottom of our great oceans. The white oceanic mud, or Globigerina-ooze, found in all the great oceans at depths varying from 250 to nearly 3,000 fathoms, and almost constantly in depths under 2,000 fathoms, has, however, been supposed to be an exception, and to correspond exactly to our white and grey chalk. Hence some naturalists have maintained that there has probably been one continuous formation of chalk in the

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long undergoing subsidence and accumulating vast piles of sedimentary deposit have been elevated into mountain ranges, thereby become stiff and unyielding, and that the next depression and subsequent upheaval will be situated on one or the other sides of it; and he has shown that, in North America, this is the case with all the mountains of the successive geological formations. Thus, depressions, and elevations of extreme slowness but often of vast amount, have occurred successively in restricted adjacent areas; and the effect has been to bring each portion in succession beneath the ocean but always bordered on one or both sides by the remainder of the continent, from the denudation of which the deposits are formed which, on the subsequent upheaval, become mountain ranges. (*Manual of Geology*, 2nd Ed., p. 751.)

Atlantic from the Cretaceous epoch to the present day. This view has been adopted chiefly on account of the similarity of the minute organisms found to compose a considerable proportion of both deposits, more especially the pelagic Foraminifera, of which several species of Globigerina appear to be identical in the chalk and the modern Atlantic mud. Other extremely minute organisms whose nature is doubtful, called coccoliths and discoliths, are also found in both formations, while there is a considerable general resemblance between the higher forms of life. Sir Wyville Thomson tells us, that—"Sponges are abundant in both, and the recent chalk-mud has yielded a large number of examples of the group *porifera vitrea*, which find their nearest representatives among the Ventriculites of the white chalk. The echinoderm fauna of the deeper parts of the Atlantic basin is very characteristic, and yields an assemblage of forms which represent in a remarkable degree the corresponding group in the white chalk. Species of the genus Cidaris are numerous; some remarkable flexible forms of the Diademidæ seem to approach Echinothuria."[21] Now, as some explanation of the origin of chalk had long been desired by geologists, it is not surprising that the amount of resemblance shown to exist between it and some kinds of oceanic mud should have been at once seized upon, and the conclusion arrived at that chalk is a deep-sea oceanic formation exactly analogous to that which has been shown to cover large areas of the Atlantic, Pacific and Southern oceans.

[21] *Nature*, Vol. II., p. 297.

But there are several objections to this view which seem fatal to its acceptance. In the first place, no specimens of Globigerina-ooze from the deep ocean-bed yet examined agree even approximately with chalk in chemical composition, only containing from 44 to 79 per cent. of carbonate of lime, with from 5 to 11 per cent of silica, and from 8 to 33 per cent. of alumina and oxide of iron.[22] Chalk, on the other hand, contains usually from 94 to 99 per cent. of carbonate of lime, and a very minute quantity of alumina and silica. This large proportion of carbonate of lime implies some other source of this mineral, and it is probably to be found in the excessively fine mud produced by the decomposition and denudation of coral reefs. Mr. Dana, the geologist of the United States Exploring Expedition, found in the elevated coral reef of Oahu, one of the Sandwich Islands, a deposit closely resembling chalk in colour, texture, &c.; while in several growing reefs a similar formation of modern chalk undistinguishable from the ancient, was observed.[23] Sir Charles

[22] Sir W. Thomson, *Voyage of Challenger*, Vol. II., p. 374.

[23] The following is the analysis of the chalk at Oahu:—This chalk consists simply of comminuted corals and shells of the reef. It has been examined microscopically and found to be destitute of the minute organisms abounding in the chalk of England. (*Geology of the United States Exploring Expedition*, p. 150.) Mr. Guppy also found chalk-like coral limestones containing 95 p.c. of carbonate of lime in the Solomon Islands.The absence of *Globigerinæ* is a local phenomenon. They are quite absent in the Arafura Sea, and no *Globigerina*-ooze was found in any of the enclosed seas of the Pacific, but with these exceptions the *Globigerinæ* "are really found all over the bottom of the ocean." (Murray on Oceanic Deposits—*Proceedings of Royal Society*, Vol. XXIV., p. 523.)The above analysis shows a far closer resemblance to chalk than

Lyell well remarks that the pure calcareous mud produced by the decomposition of the shelly coverings of mollusca and zoophytes would be much lighter than argillaceous or arenaceous mud, and being thus transported to greater distances would be completely separated from all impurities.

Now the Globigerinæ have been shown by the *Challenger* explorations to abound in all moderately warm seas; living both at the surface, at various depths in the water, and at the bottom. It was long thought that they were surface-dwellers only, and that their dead tests sank to the bottom, producing the Globigerina-ooze in those areas where other deposits were absent or scanty. But the examination of the whole of the dredgings and surface-gatherings of the *Challenger* by Mr. H. B. Brady has led him to a different conclusion; for he finds numerous forms at the bottom quite distinct from those which inhabit the surface, while, when

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that of the *Globigerina*-ooze of the Atlantic, four specimens of which given by Sir W. Thomson (*Voyage of the Challenger* Vol. II. Appendix, pp. 374-376, Nos. 9, 10, 11 and 12) from the mid-Atlantic, show the following proportions:—In addition to the above there is a quantity of insoluble residue consisting of small particles of sanidine, augite, hornblende, and magnetite, supposed to be the product of volcanic dust or ashes carried either in the air or by ocean currents. This volcanic matter amounts to from 4.60 to 8.33 per cent. of the *Globigerina*-ooze of the mid-Atlantic, where it seems to be always present; and the small proportion of similar matter in true chalk is another proof that its origin is different, and that it was deposited far more rapidly than the oceanic ooze.The following analysis of chalk by Mr. D. Forbes will show the difference between the two formations:—(From *Quarterly Journal of the Geological Society*, Vol. XXVII.)The large proportion of carbonate of lime, and the very small quantity of silica, alumina, and insoluble *débris*, at once distinguish true chalk from the *Globigerina*-ooze of the deep ocean bed.

the same species live both at surface and bottom, the latter are always larger and have thicker and stronger cell-walls. This view is also supported by the fact that in many stations not far from our own shores Globigerinæ are abundant in bottom dredgings, but are never found on the surface in the towing-nets.[24] These organisms then exist almost universally where the waters are pure and are not too cold, and they would naturally abound most where the diffusion of carbonate of lime both in suspension and solution afforded them an abundant supply of material for their shelly coverings. Dr. Wallich believes that they flourish best where the warm waters of the Gulf Stream bring organic matter from which they derive nutriment, since they are wholly wanting in the course of the Arctic current between Greenland and Labrador. Dr. Carpenter also assures us that they are rigorously limited to warm areas; but Mr. Brady says that a dwarf variety of Globigerina was found in the soundings of the North Polar Expedition in Lat. 83° 19′ N.

Now with regard to the depth at which our chalk was formed, we have evidence of several distinct kinds to show that it was not profoundly oceanic. Mr. J. Murray, in the report already referred to, says: "The Globigerina-oozes which we get in shallow water resemble the chalk much more than those in deeper water, say over 1,000 fathoms."[25] This is important and weighty evidence,

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[24] Notes on Reticularian Rhizopoda; in *Microscopical Journal*, Vol. XIX., New Series, p. 84.

[25] *Proceedings of the Royal Society*, Vol. XXIV. p. 532.

and it is supported in a striking manner by the nature of the molluscan fauna of the chalk. Dr. Gwyn Jeffreys, one of our greatest authorities on shells, who has himself dredged largely both in deep and shallow water and who has no theory to support, has carefully examined this question. Taking the whole series of genera which are found in the Chalk formation, seventy-one in number, he declared that they are all comparatively shallow-water forms, many living at depths not exceeding 40 to 50 fathoms, while some are confined to still shallower waters. Even more important is the fact that the genera especially characteristic of the deep Atlantic ooze—Leda, Verticordia, Neæra, and the Bulla family—are either very rare or entirely wanting in the ancient Cretaceous deposits.[26]

Let us now see how the various facts already adduced will enable us to explain the peculiar characteristics of the chalk formation. Sir Charles Lyell tells us that "pure chalk, of nearly uniform aspect and composition, is met with in a north-west and south-east direction, from the north of Ireland to the Crimea, a distance of about 1,500 geographical miles; and in an opposite direction it extends from the south of Sweden to the south of Bordeaux, a distance of about 840 geographical miles." This marks the extreme limits within which true chalk is found, though it is by no means continuous. It probably implies, however, the existence across Central Europe of a sea somewhat larger than the Mediterranean. It may have been much

[26] See Presidential Address in Sect. D. of British Association at Plymouth, 1877.

larger, because this pure chalk formation would only be formed at a considerable distance from land, or in areas where there was no other shore deposit. This sea was probably bounded on the north by the old Scandinavian highlands, extending to Northern Germany and North-western Russia, where Palæozoic and ancient Secondary rocks have a wide extension, though now partially concealed by late Tertiary deposits; while on the south it appears to have been limited by land extending through Austria, South Germany, and the south of France, as shown in the map of Central Europe during the Cretaceous period in Professor Heer's *Primeval World of Switzerland*, p. 175. To the north the sea may have had an outlet to the Arctic Ocean between the Ural range and Finland. South of the Alps there was probably another sea, which may have communicated with the northern one just described, and there was also a narrow strait across Switzerland, north of the Alps, but, as might be expected, in this only marls, clays, sandstones, and limestones were deposited instead of true chalk. It is also a suggestive fact that both above and below the true chalk, in almost all the countries where it occurs, are extensive deposits of marls, clays, and even pure sands and sandstones, characterised by the same general types of fossil remains as the chalk itself. These beds imply the vicinity of land, and this is even more clearly proved by the occurrence, both in the Upper and Lower Cretaceous, of deposits containing the remains of land-plants in abundance, indicating a rich and varied flora.

Now all these facts are totally opposed to the idea of anything like oceanic conditions having prevailed in Europe during the Cretaceous period; but they are quite consistent with the existence of a great Mediterranean sea of considerable depth in its central portions, and occupying either at one or successive periods, the whole area of the Cretaceous formation. We may also note that the Maestricht beds in Belgium and the Faxoe chalk in Denmark are both highly coralline, the latter being, in fact, as completely composed of corals as a modern coral-reef; so that we have here a clear indication of the source whence the white calcareous mud was derived which forms the basis of chalk. If we suppose that during this period the comparatively shallow sea-bottom between Scandinavia and Greenland was elevated, forming a land connection between these countries, the result would be that a large portion of the Gulf Stream would be diverted into the inland European sea, and would bring with it that abundance of Globigerinæ, and other Foraminifera, which form such an important constituent of chalk. This sea was probably bordered with islands and coral-reefs, and if no very large rivers flowed into it we should have all the conditions for the production of the true chalk, as well as the other members of the Cretaceous formation. The products of the denudation of its shores and islands would form the various sandstones, marls, and clays, which would be deposited almost wholly within a few miles of its coasts; while the great central sea, perhaps at no time more than a few thousand feet deep and often much less, would receive

only the impalpable mud of the coral-reefs and the constantly falling tests of Foraminifera. These would imbed and preserve for us the numerous echinoderms, sponges, and mollusca, which lived upon the bottom, the fishes and turtles which swam in its waters, and sometimes the winged reptiles that flew overhead. The abundance of ammonites, and other cephalopods, in the chalk, is another indication that the water in which they lived was not very deep, since Dr. S. P. Woodward thinks that these organisms were limited to a depth of about thirty fathoms.

The best example of the modern formation of chalk is perhaps to be found on the coasts of sub-tropical North America, as described in the following passage:—

"The observations of Pourtales show that the steep banks of Bahama are covered with soft white lime mud. The lime-bottom, which consists almost entirely of Polythalamia, covers in greater depths the entire channel of Florida. This formation extends without interruption over the whole bed of the Gulf Stream in the Gulf of Mexico, and is continued along the Atlantic coast of America. The commonest genera met with in this deposit are Globigerina, Rotalia cultrata in large numbers, several Textilariæ, Marginulinæ, &c. Beside these, small free corals, Alcyonidæ, Ophiuræ, Mollusca, Crustacea, small fishes, &c., are found living in these depths. The whole sea-bottom appears to be covered with a vast deposit of white chalk still in formation."[27]

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[27] *Geological Magazine*, 1871, p. 426.

There is yet another consideration which seems to have been altogether overlooked by those who suppose that a deep and open island-studded ocean occupied the place of Europe in Cretaceous times. No fact is more certain than the considerable break, indicative of a great lapse of time, intervening between the Cretaceous and Tertiary formations. A few deposits of intermediate age have indeed been found, but these have been generally allocated either with the Chalk or the Eocene, leaving the gap almost as pronounced as before. Now, what does this gap mean? It implies that when the deposition of the various Cretaceous beds of Europe came to an end they were raised above the sea-level and subject to extensive denudation, and that for a long but unknown period no extensive portion of what is now European land was below the sea-level. It was only when this period terminated that large areas in several parts of Europe became submerged and received the earliest Tertiary deposits known as Eocene. If, therefore, Europe at the close of the Cretaceous period was generally identical with what it is now, and perhaps even more extensive, it is absurd to suppose that it was all, or nearly all, under water during that period; or in fact, that any part of it was submerged, except those areas on which we actually find Cretaceous deposits, or where we have good reason to believe they have existed; and even these need not have been all under water at the same time.

The several considerations now adduced are, I think, sufficient to show that the view put forth by some naturalists (and which

has met with a somewhat hasty acceptance by geologists) that our white chalk is an oceanic formation strictly comparable with that now forming at depths of a thousand fathoms and upwards in the centre of the Atlantic, gives a totally erroneous idea of the actual condition of Europe during that period. Instead of being a wide ocean, with a few scattered islands, comparable to some parts of the Pacific, it formed as truly a portion of the great northern continent as it does now, although the inland seas of that epoch may have been more extensive and more numerous than they are at the present day.[28]

Fresh-water and Shore Deposits as Proving the Permanence of Continents.—The view here maintained, that all known marine deposits have been formed near the coasts of continents and islands, and that our actual continents have been in continuous existence under variously modified forms during the whole

[28] In his lecture on *Geographical Evolution* (which was published after the greater part of this chapter had been written) Sir Archibald Geikie expresses views in complete accordance with those here advocated. He says:—"The next long era, the Cretaceous, was more remarkable for slow accumulation of rock under the sea than for the formation of new land. During that time the Atlantic sent its waters across the whole of Europe and into Asia. But they were probably nowhere more than a few hundred feet deep over the site of our continent, even at their deepest part. Upon their bottom there gathered a vast mass of calcareous mud, composed in great part of foraminifera, corals, echinoderms, and molluscs. Our English chalk, which ranges across the north of France, Belgium, Denmark, and the north of Germany, represents a portion of the deposits of that sea-floor." The weighty authority of the Director-General of the Geological Survey may perhaps cause some geologists to modify their views as to the deep-sea origin of chalk, who would have treated any arguments advanced by myself as not worthy of consideration.

period of known geological history, is further supported by another and totally distinct series of facts. In almost every period of geology, and in all the continents which have been well examined, there are found lacustrine, estuarine, or shore deposits, containing the remains of land animals or plants, thus demonstrating the continuous existence of extensive land areas on or adjoining the sites of our present continents. Beginning with the Miocene, or Middle Tertiary period, we have such deposits with remains of land-animals, or plants, in Devonshire and Scotland, in France, Switzerland, Germany, Croatia, Vienna, Greece, North India, Central India, Burmah, North America, both east and west of the Rocky Mountains, Greenland, and other parts of the Arctic regions. In the older Eocene period similar formations are widely spread in the south of England, in France, and to an enormous extent on the central plateau of North America; while in the eastern states, from Maryland to Alabama, there are extensive marine deposits of the same age, which, from the abundance of fossil remains of a large cetacean (Zeuglodon), must have been formed in shallow gulfs or estuaries where these huge animals were stranded. Going back to the Cretaceous formation we have the same indications of persisting lands in the rich plant-beds of Aix-la-Chapelle, and a few other localities on the Continent, as well as in coniferous fruits from the Gault of Folkestone; while in North America cretaceous plant-beds occur in New Jersey, Alabama, Kansas, the sources of the Missouri, the Rocky Mountains from New Mexico to the Arctic

Ocean, Alaska, California, and in Greenland and Spitzbergen; while birds and land reptiles are found in the Cretaceous deposits of Colorado and other districts near the centre of the Continent. Fresh-water deposits of this age are also found on the coast of Brazil. In the lower part of this formation we have the fresh-water Wealden deposits of England, extending into France, Hanover, and Westphalia. In the older Oolite or Jurassic formation we have abundant proofs of continental conditions in the fresh-water and "dirt"-beds of the Purbecks in the south of England, with plants, insects and mammals; the Bavarian lithographic stone, with fossil birds and insects; the earlier "forest marble" of Wiltshire, with ripple-marks, wood, and broken shells, indicative of an extensive beach; the Stonesfield slate, with plants, insects, and marsupials; and the Oolitic coal of Yorkshire and Sutherlandshire. Beds of the same age occur in the Rocky Mountains of North America, containing abundance of Dinosaurians and other reptiles, among which is the Atlantosaurus, the largest land-animal yet known to have existed on the earth. Professor O. C. Marsh describes it as having been between fifty and sixty feet long, and when standing erect at least thirty feet high![29] Such monsters could hardly have been developed except in an extensive land area. A small mammal, Dryolestes, has been discovered in the same deposits. A rich Jurassic flora has also been found in East Siberia and the Amur valley. The older Triassic deposits are very extensively

[29] *Introduction and Succession of Vertebrate Life in America*, by Professor O. C. Marsh. Reprinted from the *Popular Science Monthly*, March, April, 1878.

developed in America, and both in the Connecticut valley and the Rocky Mountains show tracks or remains of land reptiles, amphibians and mammalia, while coalfields of the same age in Virginia and Carolina produce abundance of plants. Here too are found the ancient mammal, Microlestes, of Wurtemberg, with the ferns, conifers, and Labyrinthodonts of the Bunter Sandstone in Germany; while the beds of rock-salt in this formation, both in England and in many parts of the Continent, could only have been formed in inland seas or lakes, and thus equally demonstrate continental conditions.

We now pass into the oldest or Palæozoic formations, but find no diminution in the proofs of continental conditions. The Permian formation has a rich flora often producing coal in England, France, Saxony, Thuringia, Silesia, and Eastern Russia. Coalfields of the same age occur in Ohio in North America. In the still more ancient Carboniferous formation we find the most remarkable proofs of the existence of our present land masses at that remote epoch, in the wonderful extension of coal beds in all the known continents. We find them in Ireland, England, and Scotland; in France, Spain, Belgium, Saxony, Prussia, Bohemia, Hungary, Sweden, Spitzbergen, Siberia, Russia, Greece, Turkey, and Persia; in many parts of continental India, extensively in China, and in Australia, Tasmania, and New Zealand. In North America there are immense coal fields, in Nova Scotia and New Brunswick, from Pennsylvania southward to Alabama, in Indiana and Illinois, in Missouri, and even so far west as Colorado;

and there is also a true coal formation in South Brazil. This wonderfully wide distribution of coal, implying, as it does, a rich vegetation and extensive land areas, carries back the proof of the persistence and general identity of our continents to a period so remote that none of the higher animal types had probably been developed. But we can go even further back than this, to the preceding Devonian formation, which was almost certainly an inland deposit often containing remains of fresh-water shells, plants, and even insects; while Professor Ramsay believes that he has found "sun-cracks and rain-pittings" in the Longmynd beds of the still earlier Cambrian formation.[30] If now, in addition to the body of evidence here adduced, we take into consideration the fresh-water deposits that still remain to be discovered, and those extensive areas where they have been destroyed by denudation or remain deeply covered up by later marine or volcanic formations, we cannot but be struck by the abounding proofs of the permanence of the great features of land and sea as they now exist; and we shall see how utterly gratuitous, and how entirely opposed to all the evidence at our command, are the hypothetical continents bridging over the deep oceans, by the help of which it is so often attempted to cut the Gordian knot presented by some anomalous fact in geographical distribution.

Oceanic Islands as Indications of the Permanence of Continents and Oceans.—Coming to the question from the other side, Mr. Darwin has adduced an argument of considerable

[30] *Physical Geography and Geology of Great Britain*, 5th Ed. p. 61.

weight in favour of the permanence of the great oceans. He says (*Origin of Species*, 6th Ed. p. 288): "Looking to existing oceans, which are thrice as extensive as the land, we see them studded with many islands; but hardly one truly oceanic island (with the exception of New Zealand, if this can be called a truly oceanic island) is as yet known to afford even a fragment of any Palæozoic or Secondary formation. Hence we may perhaps infer that during the Palæozoic and Secondary periods neither continents nor continental islands existed where our oceans now extend; for had they existed, Palæozoic and Secondary formations would in all probability have been accumulated from sediment derived from their wear and tear; and these would have been at least partially upheaved by the oscillations of level, which must have intervened during these enormously long periods. If then we may infer anything from these facts, we may infer that, where our oceans now extend, oceans have extended from the remotest period of which we have any record; and, on the other hand, that where continents now exist, large tracts of land have existed, subjected no doubt to great oscillations of level, since the Cambrian period." This argument standing by itself has not received the attention it deserves, but coming in support of the long series of facts of an altogether distinct nature, going to show the permanence of continents, the cumulative effect of the whole must, I think, be admitted to be irresistible.[31]

[31] Of late it has been the custom to quote the so-called "ridge" down the centre of the Atlantic as indicating an extensive ancient land. Even Professor Judd at one

General Stability of Continents with Constant Change of Form.—It will be observed that the very same evidence which has been adduced to prove the *general* stability and permanence of our continental areas also goes to prove that they have been subjected to wonderful and repeated changes in *detail*. Every square mile of their surface has been again and again under water, sometimes a few hundred feet deep, sometimes perhaps several thousands. Lakes and inland seas have been formed, have been

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time adopted this view, speaking of the great belt of Tertiary volcanoes "which extended through Greenland, Iceland, the Faroe Islands, the Hebrides, Ireland, Central France, the Iberian Peninsula, the Azores, Madeira, Canaries, Cape de Verde Islands, Ascension, St. Helena, and Tristan d'Acunha, and which constituted as shown by the recent soundings of H.M.S. *Challenger* a mountain-range, comparable in its extent, elevation, and volcanic character with the Andes of South America" (*Geological Mag.* 1874, p. 71). On examining the diagram of the Atlantic Ocean in the *Challenger Reports*, No. 7, a considerable part of this ridge is found to be more than 1,900 fathoms deep, while the portion called the "Connecting Ridge" seems to be due in part to the deposits carried out by the River Amazon. In the neighbourhood of the Azores, St. Paul's Rocks, Ascension, and Tristan d'Acunha are considerable areas varying from 1,200 to 1,500 fathoms deep, while the rest of the ridge is usually 1,800 or 1,900 fathoms. The shallower water is no doubt due to volcanic upheaval and the accumulation of volcanic ejections, and there may be many other deeply submerged old volcanoes on the ridge; but that it ever formed a chain of mountains "comparable in elevation with the Andes," there seems not a particle of evidence to prove. It is however probable that this ridge indicates the former existence of some considerable Atlantic islands, which may serve to explain the presence of a few identical genera, and even species of plants and insects in Africa and South America, while the main body of the fauna and flora of these two continents remains radically distinct.In my *Darwinism* (pp. 344-5) I have given an additional argument founded on the comparative height and area of land with the depth and area of ocean, which seems to me to add considerably to the weight of the evidence here submitted for the permanence of oceanic and continental areas.

filled up with sediment, and been subsequently raised into hills or even mountains. Arms of the sea have existed crossing the continents in various directions, and thus completely isolating the divided portions for varying intervals. Seas have been changed into deserts and deserts into seas. Volcanoes have grown into mountains, have been degraded and sunk beneath the ocean, have been covered with sedimentary deposits, and again raised up into mountain ranges; while other mountains have been formed by the upraised coral reefs of inland seas. The mountains of one period have disappeared by denudation or subsidence, while the mountains of the succeeding period have been rising from beneath the waves. The valleys, the ravines, and the mountain peaks, have been carved out and filled up again; and all the vegetable forms which clothe the earth and furnish food for the various classes of animals have been completely changed again and again.

Effect of Continental Changes on the Distribution of Animals.—It is impossible to exaggerate, or even adequately to conceive, the effect of these endless mutations on the animal world. Slowly but surely the whole population of living things must have been driven backward and forward from east to west, or from north to south, from one side of a continent or a hemisphere to the other. Owing to the remarkable continuity of all the land masses, animals and plants must have often been compelled to migrate into other continents, where in the struggle for existence under new conditions many would succumb; while

such as were able to survive would constitute those wide-spread groups whose distribution often puzzles us. Owing to the repeated isolation of portions of continents for long periods, special forms of life would have time to be developed, which, when again brought into competition with the fauna from which they had been separated, would cause fresh struggles of ever increasing complexity, and thus lead to the development and preservation of every weapon, every habit, and every instinct, which could in any way conduce to the safety and preservation of the several species.

Changed Distribution proved by the Extinct Animals of Different Epochs.—We thus find that, while the inorganic world has been in a state of continual though very gradual change, the species of the organic world have also been slowly changing in form and in the localities they inhabit; and the records of these changes and these migrations are everywhere to be found, in the actual distribution of the species no less than in the fossil remains which are preserved in the rocks. Everywhere the animals which have most recently become extinct resemble more or less closely those which now live in the same country; and where there are exceptions to the rule, we can generally trace them to some changed conditions which have led to the extinction of certain types. But when we go a little further back, to the late or middle Tertiary deposits, we almost always find, along with forms which might have been the ancestors of some now living, others which are only now found in remote regions and

often in distinct continents—clear indications of those extensive migrations which have ever been going on. Every large island contains in its animal inhabitants a record of the period when it was last separated from the adjacent continent, while some portions of existing continents still show by the comparative poverty and speciality of their animals that at no distant epoch they were cut off by arms of the sea and formed islands. If the geological record were more perfect, or even if we had as good a knowledge of that record in all parts of the world as we have in Europe and North America, we could arrive at much more accurate results than we are able to do with our present very imperfect knowledge of extinct forms of life; but even with our present scanty information we are able to throw much light upon the past history of our globe and its inhabitants, and can sketch out with confidence many of the changes they must have undergone.

Summary of Evidence for the General Permanence of Continents and Oceans.—As this question of the permanence of our continents or, rather, of the continental areas, lies at the root of all our inquiries into the past changes of the earth and its inhabitants, and as it is at present completely ignored by many writers, and even by naturalists of eminence, it will be well to summarise the various kinds of evidence which go to establish it.[32] We know as a fact that all sedimentary deposits have been

[32] In a review of Mr. T. Mellard Reade's *Chemical Denudation and Geological Time*, in *Nature* (Oct. 2nd, 1879), the writer remarks as follows:—"One of the funny notions

formed under water, but we also know that they were largely formed in lakes or inland seas, or near the coasts of continents or great islands, and that deposits uniform in character and more than 150 or 200 miles wide were rarely, if ever, formed at the same time. The further we go from the land the less rapidly deposition takes place, hence the great bulk of all the strata must have been formed near land. Some deposits are, it is true, continually forming in the midst of the great oceans, but these are chiefly organic and increase very slowly, and there is no proof that any part of the series of known geological formations exactly resembles them. Chalk, which is still believed to be such a deposit by many naturalists, has been shown, by its contained fossils, to be a comparatively shallow water formation—that is, one formed at a depth measured by hundreds rather than by

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of some scientific thinkers meets with no favour from Mr. Reade, whose geological knowledge is practical as well as theoretical. They consider that because the older rocks contain nothing like the present red clays, &c., of the ocean floor, that the oceans have always been in their present positions. Mr. Reade points out that the first proposition is not yet proved, and the distribution of animals and plants and the fact that the bulk of the strata on land are of marine origin are opposed to the hypothesis." We must leave it to our readers to decide whether the "notion" developed in this chapter is "funny," or whether such hasty and superficial arguments as those here quoted from a "practical geologist" have any value as against the different classes of facts, all pointing to an opposite conclusion, which have now been briefly laid before them, supported as they are by the expressed opinion of so weighty an authority as Sir Archibald Geikie, who, in the lecture already quoted says:—"From all this evidence we may legitimately conclude that the present land of the globe, though formed in great measure of marine formations, has never lain under the deep sea; but that its site must always have been near land. Even its thick marine limestones are the deposits of comparatively shallow water."

thousands of fathoms. The nature of the formations composing all our continents also proves the continuity of those continents. Everywhere we find clearly marked shore and estuarine deposits, showing that every part of the existing land has in turn been on the sea-shore; and we also find in all periods lacustrine formations of considerable extent with remains of plants and land animals, proving the existence of continents or extensive lands, in which such lakes or estuaries could be formed. These lacustrine deposits can be traced back through every period, from the newer Tertiary to the Devonian and Cambrian, and in every continent which has been geologically explored; and thus complete the proof that our continents have been in existence under ever changing forms throughout the whole of that enormous lapse of time.

On the side of the oceans we have also a great weight of evidence in favour of their permanence and stability. In addition to their enormous depths and great extent, and the circumstance that the deposits now forming in them are distinct from anything found upon the land-surface, we have the extraordinary fact that the countless islands scattered over their whole area (with one or two exceptions only and those comparatively near to continental areas) never contain any Palæozoic or Secondary rocks—that is, have not preserved any fragments of the supposed ancient continents, nor of the deposits which must have resulted from their denudation during the whole period of their existence! The supposed exceptions are New Zealand and the Seychelles Islands,

both situated near to continents and not really oceanic, leaving almost the whole of the vast areas of the Atlantic, Pacific, Indian, and Southern oceans, without a solitary relic of the great islands or continents supposed to have sunk beneath their waves.

CHAPTER VII
CHANGES OF CLIMATE WHICH HAVE INFLUENCED THE DISPERSAL OF ORGANISMS: THE GLACIAL EPOCH

Proofs of the Recent Occurrence of a Glacial Epoch—Moraines—Travelled Blocks—Glacial Deposits of Scotland: the "Till"—Inferences from the Glacial Phenomena of Scotland—Glacial Phenomena of North America—Effects of the Glacial Epoch on Animal Life—Warm and Cold Periods—Palæontological Evidence of Alternate Cold and Warm Periods—Evidence of Interglacial Warm Periods on the Continent and in North America—Migrations and Extinctions of Organisms caused by the Glacial Epoch.

We have now to consider another set of physical revolutions which have profoundly affected the whole organic world. Besides the wonderful geological changes to which, as we have seen, all continents have been exposed, and which must, with extreme slowness, have brought about the greater features of the dispersal of animals and plants throughout the world, there has been also a long succession of climatal changes, which, though very slow and gradual when measured by centuries, may have sometimes been

rapid as compared with the slow march of geological mutations.

These climatal changes may be divided into two classes, which have been thought to be the opposite phases of the same great phenomenon—cold or even glacial epochs in the Temperate zones on the one hand, and mild or even warm periods extending into the Arctic regions on the other. The evidence for both these changes having occurred is conclusive; and as they must be taken account of whenever we endeavour to explain the past migrations and actual distribution of the animal world, a brief outline of the more important facts and of the conclusions they lead to must be here given.

Proofs of the Recent Occurrence of a Glacial Epoch.—The phenomena that prove the recent occurrence of glacial epochs in the temperate regions are exceedingly varied, and extend over very wide areas. It will be well therefore to state, first, what those facts are as exhibited in our own country, referring afterwards to similar phenomena in other parts of the world.

Perhaps the most striking of all the evidences of glaciation are the grooved, scratched, or striated rocks. These occur abundantly in Scotland, Cumberland, and North Wales, and no rational explanation of them has ever been given except that they were formed by glaciers. In many valleys, as, for instance, that of Llanberris in North Wales, hundreds of examples may be seen, consisting of deep grooves several inches wide, smaller furrows, and striæ of extreme fineness wherever the rock is of sufficiently close and hard texture to receive such marks. These grooves

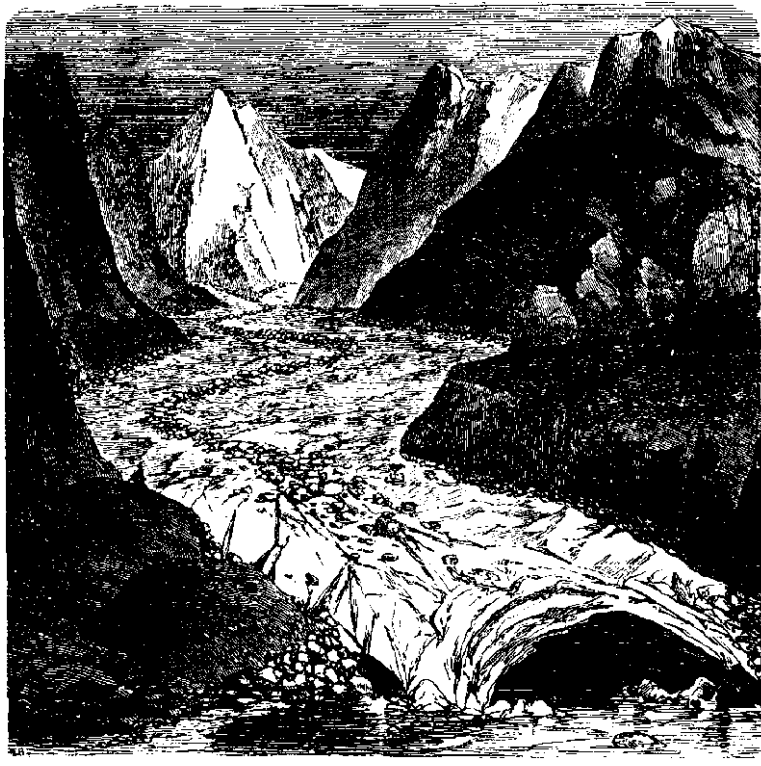
or scratches are often many yards long, they are found in the bed of the valley as well as high up on its sides, and they are almost all without exception in one general direction—that of the valley itself, even though the particular surface they are upon slopes in another direction. When the native covering of turf is cleared away from the rock the grooves and striæ are often found in great perfection, and there is reason to believe that such markings cover, or have once covered, a large part of the surface. Accompanying these markings we find another, hardly less curious phenomenon, the rounding off or planing down of the hardest rocks to a smooth undulating surface. Hard crystalline schists with their strata nearly vertical, and which one would expect to find exposing jagged edges, are found ground off to a perfectly smooth but never to a flat surface. These rounded surfaces are found not only on single rocks but over whole valleys and mountain sides, and form what are termed *roches moutonnées*, from their often having the appearance at a distance of sheep lying down.

Now these two phenomena are actually produced by existing glaciers, while there is no other known or even conceivable cause that could have produced them. Whenever the Swiss glaciers retreat a little, as they sometimes do, the rocks in the bed of the valley they have passed over are found to be rounded, grooved, and striated just as are those of Wales and Scotland. The two sets of phenomena are so exactly identical that no one who has ever compared them can doubt that they are due to the same causes.

But we have further and even more convincing evidence. Glaciers produce many other effects besides these two, and whatever effects they produce in Switzerland, in Norway, or in Greenland, we find examples of similar effects having been produced in our own country. The most striking of these are moraines and travelled blocks.

Moraines.—Almost every existing glacier carries down with it great masses of rock, stones, and earth, which fall on its surface from the precipices and mountain slopes which hem it in, or the rocky peaks which rise above it. As the glacier slowly moves downward, this *débris* forms long lines on each side, or on the centre whenever two glacier-streams unite, and is deposited at its termination in a huge mound called the terminal moraine. The decrease of a glacier may often be traced by successive old moraines across the valley up which it has retreated. When once seen and examined, these moraines can always be distinguished almost at a glance. Their position is most remarkable, having no apparent natural relation to the form of the valley or the surrounding slopes, so that they look like huge earthworks formed by man for purposes of defence. Their composition is equally peculiar, consisting of a mixture of earth and rocks of all sizes, usually without any arrangement, the rocks often being huge angular masses just as they had fallen from the surrounding precipices. Some of these rock masses often rest on the very top of the moraine in positions where no other natural force but that of ice could have placed them. Exactly similar mounds are found

in the valleys of North Wales and Scotland, and always where the other evidences of ice-action occur abundantly.



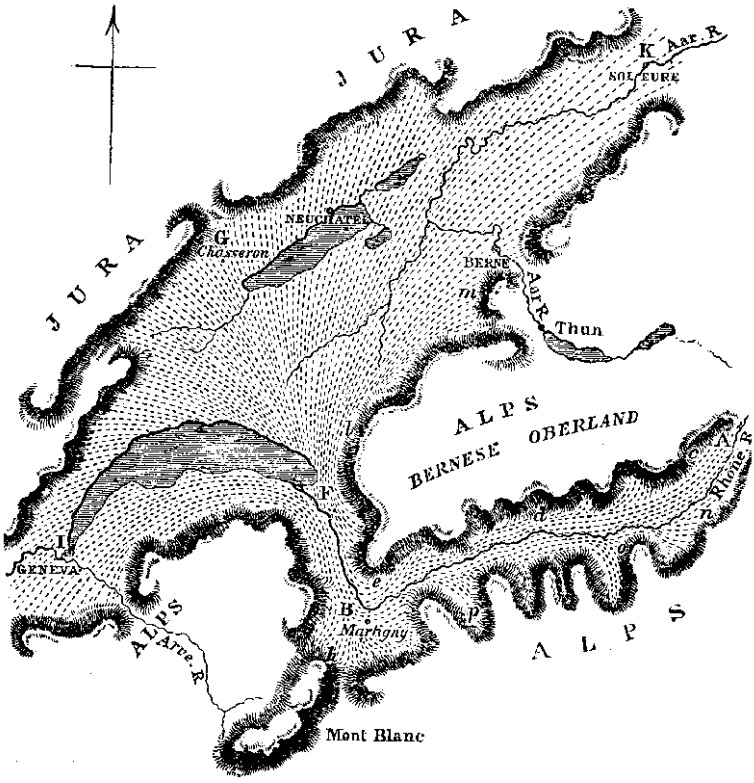
A GLACIER WITH MORAINES.

Travelled Blocks.—The phenomenon of travelled or perched blocks is also a common one in all glacier countries, marking out

very clearly the former extent of the ice. When a glacier fills a lateral valley, its foot will sometimes cross over the main valley and abut against its opposite slope, and it will deposit there some portion of its terminal moraine. But in these circumstances the end of the glacier not being confined laterally will spread out, and the moraine matter will be distributed over a large surface, so that the only well-marked token of its presence will be the larger masses of rock that may have been brought down. Such blocks are found abundantly in many of the districts of our own country where other marks of glaciation exist, and they often rest on ridges or hillocks over which the ice has passed, these elevations consisting sometimes of loose material and sometimes of rock *different from that of which the blocks are composed*. These are called travelled blocks, and can almost always be traced to their source in one of the higher valleys from which the glacier descended. Some of the most remarkable examples of such travelled blocks are to be found on the southern slopes of the Jura. These consist of enormous angular blocks of granite, gneiss, and other crystalline rocks, quite foreign to the Jura mountains, but exactly agreeing with those of the Alpine range fifty miles away across the great central valley of Switzerland. One of the largest of these blocks is forty feet diameter, and is situated 900 feet above the level of the Lake of Neufchatel. These blocks have been proved by Swiss geologists to have been brought by the ancient glacier of the Rhone which was fed by the whole Alpine range from Mont Blanc to the Furka Pass.

This glacier must have been many thousand feet thick at the mouth of the Rhone valley near the head of the Lake of Geneva, since it spread over the whole of the great valley of Switzerland, extending from Geneva to Neufchatel, Berne, and Soleure, and even on the flanks of the Jura, reached a maximum height of 2,015 feet above the valley. The numerous blocks scattered over the Jura for a distance of about a hundred miles vary considerably in the material of which they are composed, but they are found to be each traceable to a part of the Alps corresponding to their position, on the theory that they have been brought by a glacier spreading out from the Rhone valley. Thus, all the blocks situated to the east of a central point G (see map) can be traced to the eastern side of the Rhone valley (*l e d*), while those found towards Geneva have all come from the west side (*p h*). It is also very suggestive that the highest blocks on the Jura at G have come from the eastern shoulder of Mont Blanc in the direct line *h* B F G. Here the glacier would naturally preserve its greatest thickness, while as it spread out eastward and westward it would become thinner. We accordingly find that the travelled blocks on either side of the central point become lower and lower, till near Soleure and Geneva they are not more than 500 feet above the valley. The evidence is altogether so conclusive that, after personal examination of the district in company with eminent Swiss geologists, Sir Charles Lyell gave up the view he had first adopted—that the blocks had been carried by floating ice during

a period of submergence—as altogether untenable.[33]



MAP SHOWING THE COURSE OF THE ANCIENT GLACIER OF THE RHONE AND THE DISTRIBUTION OF ERRATIC BLOCKS ON THE JURA.

[33] *Antiquity of Man*, 4th Ed. pp. 340-348.

The phenomena now described demonstrate a change of climate sufficient to cover all our higher mountains with perpetual snow, and fill the adjacent valleys with huge glaciers at least as extensive as those now found in Switzerland. But there are other phenomena, best developed in the northern part of our islands, which show that even this state of things was but the concluding phase of the glacial period, which, during its maximum development, must have reduced the northern half of our island to a condition only to be paralleled now in Greenland and the Antarctic regions. As few persons besides professed geologists are acquainted with the weight of evidence for this statement, and as it is most important for our purpose to understand the amount of the climatal changes the northern hemisphere has undergone, I will endeavour to make the evidence intelligible, referring my readers for full details to Dr. James Geikie's descriptions and illustrations.[34]

Glacial Deposits of Scotland: the "Till."—Over almost all the lowlands and in most of the highland valleys of Scotland there are immense superficial deposits of clay, sand, gravel, or drift, which can be traced more or less directly to glacial action. Some of these are moraine matter, others are lacustrine deposits, while others again have been formed or modified by the sea during periods of submergence. But below them all, and often resting

[34] *The Great Ice Age and its Relation to the Antiquity of Man.* By James Geikie, F.R.S. (Isbister and Co., 1874.)

directly on the rock-surface, there are extensive layers of a very tough clayey deposit known as "till." The till is very fine in texture, very tenacious, and often of a rock-like hardness. It is always full of stones, all of which are of rude form, but with the angles rubbed off, and almost always covered with scratches and striæ often crossing each other in various directions. Sometimes the stones are so numerous that there seems to be only just enough clay to unite them into a solid mass, and they are of all sizes, from mere grit up to rocks many feet in diameter. The "till" is found chiefly in the low-lying districts, where it covers extensive areas sometimes to a depth of a hundred feet; while in the highlands it occurs in much smaller patches, but in some of the broader valleys forms terraces which have been cut through by the streams. Occasionally it is found as high as two thousand feet above the sea, in hollows or hill-sides, where it seems to have been protected from denudation.

The "till" is totally unstratified, and the rock-surfaces on which it almost always rests are invariably worn smooth, and much grooved and striated when the rock is hard; but when it is soft or jointed, it frequently shows a greatly broken surface. Its colour and texture, and the nature of the stones it contains, all correspond to the character of the rock of the district where it occurs, so that it is clearly a local formation. It is often found underneath moraines, drift, and other late glacial deposits, but never overlies them (except in special cases to be hereafter referred to), so that it is certainly an earlier deposit.

Throughout Scotland, where "till" is found, the glacial striæ, perched blocks, *roches moutonnées*, and other marks of glacial action, occur very high up the mountains to at least 3,000 and often even to 3,500 feet above the sea, while all lower hills and mountains are rounded and grooved on their very summits; and these grooves always radiate outwards from the highest peaks and ridges towards the valleys or the sea.

Inferences from the Glacial Phenomena of Scotland.—Now all these phenomena taken together render it certain that the whole of Scotland was once buried in a vast sea of ice, out of which only the highest mountains raised their summits. There is absolutely no escape from this conclusion; for the facts which lead to it are not local—found only in one spot or one valley—but general throughout the entire length and breadth of Scotland; and are besides supported by such a mass of detailed corroborative evidence as to amount to absolute demonstration. The weight of this vast ice-sheet, at least three thousand feet in maximum thickness, and continually moving seaward with a slow grinding motion like that of all existing glaciers, must have ground down the whole surface of the country, especially all the prominences, leaving the rounded rocks as well as the grooves and striæ we still see marking the direction of its motion. All the loose stones and rock-masses which lay on the surface would be pressed into the ice; the harder blocks would serve as scratching and grinding tools, and would thus themselves become rounded, scratched, and striated, as we see them, while all the softer masses would be

ground up into impalpable mud along with the material planed off the rocky projections of the country, leaving them in the condition of *roches moutonnées*.

The peculiar characters of the "till," its fineness and tenacity, correspond closely with the fine matter which now issues from under all glaciers, making the streams milky white, yellow, or brown, according to the nature of the rock. The sediment from such water is a fine unctuous, sticky deposit, only needing pressure to form it into a tenacious clay; and when "till" is exposed to the action of water, it dissolves into a similar soft, sticky, unctuous mud. The present glaciers of the Alps, being confined to valleys which carry off a large quantity of drainage water, lose this mud perhaps as rapidly as it is formed; but when the ice covered the whole country, there was comparatively little drainage water, and thus the mud and stones collected in vast compact masses in all the hollows, and especially in the lower flat valleys, so that, when the ice retreated, the whole country was more or less covered with it. It was then, no doubt, rapidly denuded by rain and rivers, but, as we have seen, great quantities remain to the present day to tell the tale of its wonderful formation.[35]

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[35] This view of the formation of "till" is that adopted, by Dr. Geikie, and upheld by almost all the Scotch, Swiss, and Scandinavian geologists. The objection however is made by many eminent English geologists, including the late Mr. Searles V. Wood, Jun., that mud ground off the rocks cannot remain beneath the ice, forming sheets of great thickness, because the glacier cannot at the same time grind down solid rock and yet pass over the surface of soft mud and loose stones. But this difficulty will

There is good evidence that, when the ice was at its maximum, it extended not only over the land, but far out to sea, covering

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disappear if we consider the numerous fluctuations in the glacier with increasing size, and the additions it must have been constantly receiving as the ice from one valley after another joined together, and at last produced an ice-sheet covering the whole country. The grinding power is the motion and pressure of the ice, and the pressure will depend on its thickness. Now the points of maximum thickness must have often changed their positions, and the result would be that the matter ground out in one place would be forced into another place where the pressure was less. If there were no lateral escape for the mud, it would necessarily support the ice over it just as a water-bed supports the person lying on it; and when there was little drainage water, and the ice extended, say, twenty miles in every direction from a given part of a valley where the ice was of less than the average thickness, the mud would necessarily accumulate at this part simply because there was no escape for it. Whenever the pressure all round any area was greater than the pressure on that area, the *débris* of the surrounding parts would be forced into it, and would even raise up the ice to give it room. This is a necessary result of hydrostatic pressure. During this process the superfluous water would no doubt escape through fissures or pores of the ice, and would leave the mud and stones in that excessively compressed and tenacious condition in which the "till" is found. The unequal thickness and pressure of the ice above referred to would be a necessary consequence of the inequalities in the valleys, now narrowing into gorges, now opening out into wide plains, and again narrowed lower down; and it is just in these openings in the valleys that the "till" is said to be found, and also in the lowlands where an ice-sheet must have extended for many miles in every direction. In these lowland valleys the "till" is both thickest and most wide-spread, and this is what we might expect. At first, when the glaciers from the mountains pushed out into these valleys, they would grind out the surface beneath them into hollows, and the drainage-water would carry away the *débris*. But when they spread all over the surface from sea to sea, and there was little or no drainage water compared to the enormous area covered with ice, the great bulk of the *débris* must have gathered under the ice wherever the pressure was least, and the ice would necessarily rise as it accumulated. Some of the mud would no doubt be forced out along lines of least resistance to the sea, but the friction of the stone-charged "till" would be so enormous that it would be impossible for any large part of it to be disposed of in this way.

all the Scottish islands, and stretching in one connected sheet to Ireland and Wales, where all the evidences of glaciation are as well marked as in Scotland, though the ice did not of course attain quite so great a thickness.[36]

It is evident that the change of climate requisite to produce such marvellous effects in the British Isles could not have been local, and we accordingly find strikingly similar proofs that Scandinavia and all northern Europe have also been covered with a huge ice-sheet; while we have already seen that a similar gigantic glacier buried the Alps, carrying granitic blocks to the Jura, where it deposited them at a height of 3,450 feet above the sea; while to the south, in the plains of Italy, the terminal moraines left by the retreating glaciers have formed extensive hills, those of Ivrea the work of the great glacier from the Val d'Aosta being fifteen miles across and from 700 to 1,500 feet high.

Glacial Phenomena in North America.—In North America the marks of glaciation are even more extensive and striking than in Europe, stretching over the whole of Canada and to the south of the great lakes as far as latitude 39°. There is, in all

[36] That the ice-sheet was continuous from Scotland to Ireland is proved by the glacial phenomena in the Isle of Man, where "till" similar to that in Scotland abounds, and rocks are found in it which must have come from Cumberland and Scotland, as well as from the north of Ireland. This would show that glaciers from each of these districts reached the Isle of Man, where they met and flowed southwards down the Irish Sea. Ice-marks are traced over the tops of the mountains which are nearly 2,000 feet high. (See *A Sketch of the Geology of the Isle of Man*, by John Horne, F.G.S. *Trans. of the Edin. Geol. Soc.* Vol. II. pt. 3, 1874.)

these countries, a wide-spread deposit like the "till" of Scotland, produced by the grinding of the great ice-sheet when it was at its maximum thickness; and also extensive beds of moraine-matter, true moraines, and travelled blocks, left by the glaciers as they retreated towards the mountains and finally withdrew into the upland valleys. There are, also, in Britain, Scandinavia, and North America, proofs of the submersion of the land beneath the sea to a depth of upwards of a thousand feet; but this is a subject we need not here enter upon, as our special object is to show the reality and amount of that wonderful and comparatively recent change of climate termed the glacial epoch.

Many persons, even among scientific men, who have not given much attention to the question, look upon the whole subject of the glacial epoch as a geological theory made to explain certain phenomena which are otherwise a puzzle; and they would not be much surprised if they were some day told that it was all a delusion, and that Mr. So-and-so had explained the whole thing in a much more simple way. It is to prevent my readers being imposed upon by any such statements or doubts, that I have given this very brief and imperfect outline of the nature, extent, and completeness of the evidence on which the existence of the glacial epoch depends. There is perhaps no great conclusion in any science which rests upon a surer foundation than this; and if we are to be guided by our reason at all in deducing the unknown from the known, the past from the present, we cannot refuse our assent to the reality of the glacial epoch of the northern

hemisphere in all its more important features.

Effects of the Glacial Epoch on Animal Life: Warm and Cold Periods. —It is hardly necessary to point out what an important effect this great climatal cycle must have had upon all living things. When an icy mantle crept gradually over much of the northern hemisphere till large portions of Europe and North America were reduced to the condition of Greenland now, the greater part of the animal life must have been driven southward, causing a struggle for existence which must have led to the extermination of many forms, and the migration of others into new areas. But these effects must have been greatly multiplied and intensified if, as there is very good reason to believe, the glacial epoch itself—or at least the earlier and later phases of it—consisted of two or more alternations of warm and cold periods.

The evidence that such was the case is very remarkable. The "till," as we have seen, could only have been formed when the country was entirely buried under a large ice-sheet of enormous thickness, and when it must therefore have been, in all the parts so covered, almost entirely destitute of animal and vegetable life. But in several places in Scotland fine layers of sand and gravel with beds of peaty matter, have been found resting on "till" and again covered by "till." Sometimes these intercalated beds are very thin, but in other cases they are twenty or thirty feet thick, and in them have been found remains of the extinct ox, the Irish elk, the horse, reindeer and mammoth. Here we have evidence of two distinct periods of intense cold, and an

intervening milder period sufficiently prolonged for the country to become covered with vegetation and stocked with animal life. In some districts borings have proved the existence of no less than four distinct formations of "till" separated from each other by beds of sand from two to twenty feet in thickness.[37] Facts of a similar nature have been observed in other parts of our islands. In the east of England, Mr. Skertchly (of the Geological Survey) enumerates four distinct boulder clays with intervening deposits of gravels and sands.[38] Mr. Searles V. Wood, Jun., classes the most recent (Hessle) boulder clay as "post-glacial," but he admits an intervening warmer period, characterised by southern forms of mollusca and insects, after which glacial conditions again prevailed with northern types of mollusca.[39] Elsewhere he says: "Looking at the presence of such fluviatile mollusca as *Cyrena fluminalis* and *Unio littoralis* and of such mammalia as the hippopotamus and other great pachyderms, and of such a littoral Lusitanian fauna as that of the Selsea bed where it is mixed up with the remains of some of those pachyderms, as well as of some other features, it has seemed to me that the climate of the earlier part of the post-glacial period in England was possibly even warmer than our present climate; and that it was succeeded

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[37] *The Great Ice Age*, p. 177.

[38] These are named, in descending order, Hessle Boulder Clay, Purple Boulder Clay, Chalky Boulder Clay, and Lower Boulder Clay—below which is the Norwich Crag.

[39] "On the Climate of the Post-Glacial Period." *Geological Magazine*, 1872, pp. 158, 160.

by a refrigeration sufficiently severe to cause ice to form all round our coasts, and glaciers to accumulate in the valleys of the mountain districts; and that this increased severity of climate was preceded, and partially accompanied, by a limited submergence, which nowhere apparently exceeded 300 feet, and reached that amount only in the northern counties of England."[40] This decided admission of an alternation of warm and cold climates since the height of the glacial epoch by so cautious a geologist as Mr. Wood is very important, as is his statement of an accompanying *depression* of the land, accompanying the increased cold, because many geologists maintain that a greater elevation of the land is the true and sufficient explanation of glacial periods.

Further evidence of this alternation is found both in the Isle of Man and in Ireland, where two distinct boulder clays have been described with intervening beds of gravels and sands.

Palæontological Evidence of Alternate Cold and Warm Periods.—Especially suggestive of a period warmer than the present, immediately following glacial conditions, is the occurrence of the hippopotamus in caves, brick-earths, and gravels of palæolithic age. Entire skeletons of this animal have been found at Leeds in a bed of dark blue clay overlaid by gravel. Further north at Kirkdale cave, in N. Lat. 54° 15′, remains of the hippopotamus occur abundantly along with those of the *Elephas antiquus*, *Rhinoceros hemitœchus*, reindeer, bear, horse, and other quadrupeds, and with countless remains of the hyænas

[40] *Geological Magazine*, 1876, p. 396.

which devoured them; while it has also been found in cave deposits in Glamorganshire, at Durdham Down near Bristol, and in the post-Pliocene drifts of England and France.

The fact of the hippopotamus having lived at 54° N. Lat. in England immediately after the glacial period seems quite inconsistent with a mere gradual amelioration of climate from that time till the present day. The entirely tropical distribution of the existing animal and the large quantity of vegetable food which it requires both indicate a much warmer climate than now prevails in any part of Europe. The problem, however, is complicated by the fact that, both in the cave-deposits and river gravels, its remains are often found associated with those of animals that imply a cold climate, such as the reindeer, the mammoth, or the woolly rhinoceros. At this time the British Isles were joined to the Continent, and a great river formed by the union of the Rhine, the Elbe and all the eastern rivers of England, flowed northward through what is now the German Ocean. The hippopotamus appears to have been abundant in Central Europe before the glacial epoch, but during the height of the cold was probably driven to the south of France, whence it may have returned by way of the Rhone valley, some of the tributaries of that river approaching those of the Rhine within a mile or two a little south-west of Mulhausen, whence it would easily reach Yorkshire. Professor Boyd Dawkins supposes that at this time our summers were warm, as in Middle Asia and the United States, while the winters were cold, and that the southern and

northern animals migrated to and fro over the great plains which extended from Britain to the Continent. The following extract indicates how such a migration was calculated to bring about the peculiar association of sub-tropical and arctic forms.

"It must not, however, be supposed that the southern animals migrated from the Mediterranean area as far north as Yorkshire in the same year, or the northern as far south as the Mediterranean. There were, as we shall see presently, secular changes of climate in Pleistocene Europe, and while the cold was at its maximum the arctic animals arrived at the southern limit, and while it was at its minimum the spotted hyæna and hippopotamus and other southern animals roamed to their northern limit. Thus every part of the middle zone has been successively the frontier between the northern and southern groups, and consequently their remains are mingled together in the caverns and river-deposits, under conditions which prove them to have been contemporaries in the same region. In some of the caverns, such as that of Kirkdale, the hyæna preyed upon the reindeer at one time of the year and the hippopotamus at another. In this manner the association of northern and southern animals may be explained by their migration according to the seasons; and their association over so wide an area as the middle zone, by the secular changes of climate by which each part of the zone in turn was traversed by the advancing and retreating animals."[41]

When we consider that remains of the hippopotamus have

[41] *Early Man in Britain and his Place in the Tertiary Period*, p. 113.

been found in the caves of North Wales and Bristol as well as in those of Yorkshire, associated in all with the reindeer and in some with the woolly rhinoceros or the mammoth, and that the animal must have reached these localities by means of slow-flowing rivers or flooded marshes by very circuitous routes, we shall be convinced that these long journeys from the warmer regions of South Europe could not have been made during the short summers of the glacial period. Thus the very existence of such an animal in such remote localities closely associated with those implying almost an arctic winter climate appears to afford a strong support to the argument for the existence of warm inter-glacial or post-glacial periods.

Evidence of Interglacial Warm Periods on the Continent and in North America.—Besides the evidence already adduced from our own islands, many similar facts have been noted in other countries. In Switzerland two glacial periods are distinctly recognised, between which was a warm period when vegetation was so luxuriant as to form beds of lignite sufficiently thick to be worked for coal. The plants found in these deposits are similar to those now inhabiting Switzerland—pines, oaks, birches, larch, etc., but numerous animal remains are also found, showing that the country was then inhabited by an elephant (*Elephas antiquus*), a rhinoceros (*Rhinoceros megarhinus*), the urus (*Bos primigenius*), the red deer (*Cervus elephas*), and the cave-bear, (*Ursus spelæus*); and there were also abundance of insects.[42]

[42] Heer's *Primæval World of Switzerland* Vol. II., pp. 148-168.

In Sweden also there are two "tills," the lower one having been in places partly broken up and denuded before the upper one was deposited, but no interglacial deposits have yet been found. In North America more complete evidence has been obtained. On the shores of Lake Ontario sections are exposed showing three separate beds of "till" with intervening stratified deposits, the lower one of which has yielded many plant remains and fresh-water organisms. These deposits are seen to extend continuously for more than nine miles, and the fossiliferous interglacial beds attain a thickness of 140 feet. Similar beds have been discovered near Cleveland, Ohio, consisting, first of "till" at the lake-level, secondly of about 48 feet of sand and loam, and thirdly of unstratified "till" full of striated stones—six feet thick.[43] On the other side of the continent, in British Columbia, Mr. G. M. Dawson, geologist to the North American Boundary Commission, has discovered similar evidence of two glaciations divided from each other by a warm period.

This remarkable series of observations, spread over so wide an area, seems to afford ample proof that the glacial epoch did not consist merely of one process of change, from a temperate to a cold and arctic climate, which having reached a maximum, then passed slowly and completely away; but that there were certainly two, and probably several more alternations of arctic and temperate climates.

It is evident, however, that if there have been, not two

[43] Dr. James Geikie in *Geological Magazine*, 1878, p. 77.

only, but a series of such alternations of climate, we could not possibly expect to find more than the most slender indications of them, because each succeeding ice-sheet would necessarily grind down or otherwise destroy much of the superficial deposits left by its predecessors, while the torrents that must always have accompanied the melting of these huge masses of ice would wash away even such fragments as might have escaped the ice itself. It is a fortunate thing therefore, that we should find any fragments of these interglacial deposits containing animal and vegetable remains; and just as we should expect, the evidence they afford seems to show that the later phase of the cold period was less severe than the earlier. Of such deposits as were formed on land during the coming on of the glacial epoch when it was continually increasing in severity hardly a trace has been preserved, because each succeeding extension of the ice being greater and thicker than the last, destroyed what had gone before it till the maximum was reached.

Migrations and Extinction of Organisms caused by the Glacial Epoch.—Our last glacial epoch was accompanied by at least two considerable submergences and elevations of the land, and there is some reason to think, as we have already explained, that the two classes of phenomena are connected as cause and effect. We can easily see how such repeated submergences and elevations would increase and aggravate the migrations and extinctions that a glacial epoch is calculated to produce. We can therefore hardly fail to be right in attributing the wonderful changes in animal

and vegetable life that have occurred in Europe and N. America between the Miocene Period and the present day, in part at least, to the two or more cold epochs that have probably intervened. These changes consist, first, in the extinction of a whole host of the higher animal forms, and secondly, in a complete change of types due to extinction and migration, leading to a much greater difference between the vegetable and animal forms of the eastern and western hemisphere than before existed. Many large and powerful mammalia lived in our own country in Pliocene times and apparently survived a part of the glacial epoch; but when it finally passed away they too had disappeared, some having become altogether extinct while others continued to exist in more southern lands. Among the first class are the sabre-toothed tiger, the extinct Siberian camel (Merycotherium), three species of elephant, two of rhinoceros, two bears, five species of deer, and the gigantic beaver; among the latter are the hyæna, bear, and lion, which are considered to be only varieties of those which once inhabited Britain. Down to Pliocene times the flora of Europe was very similar to that which now prevails in Eastern Asia and Eastern North America. The late Professor Asa Gray has pointed out that hundreds of species of trees and shrubs of peculiar genera which still flourish in those countries are now completely wanting in Europe, and there is good reason to believe that these were exterminated during the glacial period, being cut off from a southern migration, first by the Alps, and then by the Mediterranean; whereas in eastern America and Asia

the mountain chains run in a north and south direction, and there is nothing to prevent the flora from having been preserved by a southward migration into a milder region.[44]

Our next two chapters will be devoted to a discussion of the causes which brought about the glacial epoch, and that still more extraordinary climatic phenomenon—the mild climate and luxuriant vegetation of the Arctic zone. If my readers will follow me with the care and attention so difficult and interesting a problem requires and deserves, they will find that I have grappled with all the more important facts which have to be accounted for, and have offered what I believe is the first complete and sufficient explanation of them. The important influence of climatal changes on the dispersal of animals and plants is a sufficient justification for introducing such a discussion into the present volume.

[44] This subject is admirably discussed in Professor Asa Gray's Lecture on "Forest Geography and Archæology" in the *American Journal of Science and Arts*, Vol. XVI. 1878.

CHAPTER VIII
THE CAUSES OF GLACIAL EPOCHS

Various Suggested Causes—Astronomical Causes of Changes of Climate—Difference of Temperature caused by Varying Distance of the Sun—Properties of Air and Water, Snow and Ice, in Relation to Climate—Effects of Snow on Climate—High Land and Great Moisture Essential to the Initiation of a Glacial Epoch—Perpetual Snow nowhere Exists on Lowlands—Conditions Determining the Presence or Absence of Perpetual Snow—Efficiency of Astronomical Causes in Producing Glaciation—Action of Meteorological causes in Intensifying Glaciation—Summary of Causes of Glaciation—Effect of Clouds and Fog in cutting off the Sun's Heat—South Temperate America as Illustrating the Influence of Astronomical Causes on Climate—Geographical Changes how far a Cause of Glaciation—Land acting as a Barrier to Ocean-currents—The theory of Interglacial Periods and their Probable Character—Probable Effect of Winter in *Aphelion* on the Climate of Britain—The Essential Principle of Climatal Change Restated—Probable Date of the last Glacial Epoch—Changes of the Sea-level dependent on Glaciation—The Planet Mars as bearing on the Theory of Excentricity as a Cause of Glacial Epochs.

No less than seven different causes have been at various times

advanced to account for the glacial epoch and other changes of climate which the geological record proves to have taken place. These, as enumerated by Mr. Searles V. Wood, Jun., are as follows:—

1. A decrease in the original heat of our planet.
2. Changes in the obliquity of the ecliptic.
3. The combined effect of the precession of the equinoxes and of the excentricity of the earth's orbit.
4. Changes in the distribution of land and water.
5. Changes in the position of the earth's axis of rotation.
6. A variation in the amount of heat radiated by the sun.
7. A variation in the temperature of space.

Of the above, causes (1) and (2) are undoubted realities; but it is now generally admitted that they are utterly inadequate to produce the observed effects. Causes (5) (6) and (7) are all purely hypothetical, for though such changes may have occurred there is no evidence that they have occurred during geological time; and it is besides certain that they would not, either singly or combined, be adequate to explain the whole of the phenomena. There remain causes (3) and (4), which have the advantage of being demonstrated facts, and which are universally admitted to be capable of producing *some* effect of the nature required, the only question being whether, either alone or in combination, they are adequate to produce all the observed effects. It is therefore to these two causes that we shall confine our inquiry, taking first those astronomical causes whose complex and wide reaching

effects have been so admirably explained and discussed by Dr. Croll in numerous papers and in his work—"Climate and Time in their Geological Relations."

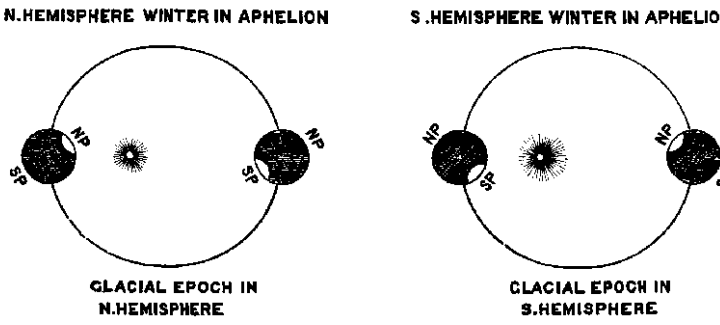

DIAGRAM SHOWING THE ALTERED POSITION OF THE POLES AT INTERVALS OF 10,500 YEARS PRODUCED BY THE PRECESSION OF THE EQUINOXES AND THE MOTION OF THE APHELION; AND ITS EFFECT ON CLIMATE DURING A PERIOD OF HIGH EXCENTRICITY.

Astronomical Causes of Changes of Climate.—The earth moves in an elliptical orbit round the sun, which is situated in one of the foci of the ellipse, so that the distance of the sun from us varies during the year to a considerable amount. Strange to say we are now three millions of miles nearer to the sun in winter than in summer, while the reverse is the case in the southern hemisphere;

and this must have some effect in making our northern winters less severe than those of the south temperate zone. But the earth moves more rapidly in that part of its orbit which is nearer to the sun, so that our winter is not only milder, but several days shorter, than that of the southern hemisphere. The distribution of land and sea and other local causes prevent us from making any accurate estimate of the effects due to these differences; but there can be no doubt that if our winter were as long as our summer is now and we were also three million miles further from the sun at the former period, a very decided difference of climate would result—our winter would be colder and longer, our summer hotter and shorter. Now there is a combination of astronomical revolutions (the precession of the equinoxes and the motion of the aphelion) which actually brings this change about every 10,500 years, so that after this interval the condition of the two hemispheres is reversed as regards nearness to the sun in summer, and comparative duration of summer and winter; and this change has been going on throughout all geological periods. (*See* Diagram.) The influence of the present phase of precession is perhaps seen in the great extension of the antarctic ice-fields, and the existence of glaciers at the sea-level in the southern hemisphere, in latitudes corresponding to that of England; but it is not supposed that similar effects were produced with us at the last cold period, 10,500 years ago, because we are exceptionally favoured, by the Gulf-stream warming the whole North Atlantic ocean and by the prevalence of westerly winds which convey

that warmth to our shores; and also by the comparatively small quantity of high land around the North Pole which does not encourage great accumulations of ice. But besides this change in the relation of our seasons to the earth's *aphelion* and *perihelion* there is another and still more important astronomical factor in the change of magnitude of the excentricity itself. This varies very largely, though very slowly, and it is now nearly at a minimum. It also varies very irregularly; but its amount has been calculated for several million years back. Fifty thousand years ago it was rather less than it is now, but it then increased, and when we come to a hundred thousand years ago there is a difference of eight and a half millions of miles between our distance from the sun in *aphelion* and *perihelion* (as the most distant and nearest points of the earth's orbit are termed). At a hundred and fifty thousand years back it had decreased somewhat—to six millions of miles; but then it increased again, till at two hundred thousand years ago it was ten and a quarter, and at two hundred and ten thousand years ten and a half millions of miles. By reference to the accompanying diagram, which includes the last great period of excentricity, we find, that for the immense period of a hundred and sixty thousand years (commencing about eighty thousand years ago) the excentricity was very great, reaching a maximum of three and a half times its present amount at almost the remotest part of this period, at which time the length of summer in one hemisphere and of winter in the other would be nearly twenty-eight days in excess.

Now, during all this time, our position would change, as above described (and as indicated on the diagram), every ten thousand five hundred years; so that we should have alternate periods of very long and cold winters with short hot summers, and short mild winters with long cool summers. In order to understand the important effects which this would produce we must ascertain two things—first, what actual difference of temperature would be caused by varying distances of the sun, and, secondly, what are the properties of snow and ice in regard to climate.

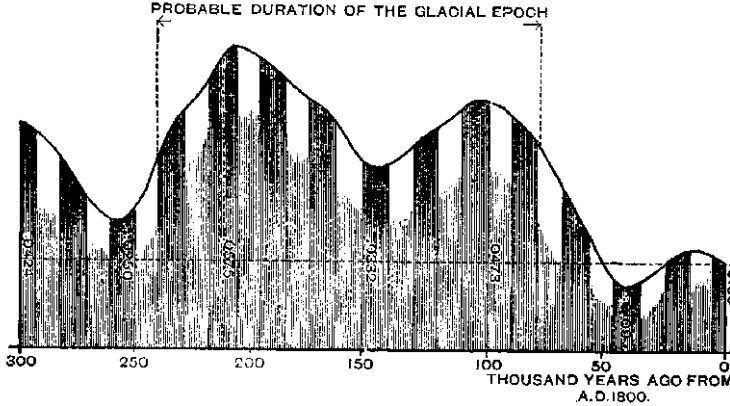

DIAGRAM OF EXCENTRICITY AND PRECESSION.

The dark and light bands mark the phases of precession, the dark showing short mild winters, and the light long cold winters, the contrast being greater as the excentricity is higher. The horizontal dotted line shows the amount of the present

excentricity. The figures show the maxima and minima of excentricity during the last 300,000 years from Dr. Croll's Tables.

Differences of Temperature Caused by Varying Distances of the Sun.—On this subject comparatively few persons have correct ideas owing to the unscientific manner in which we reckon heat by our thermometers. The zero of Fahrenheit's thermometer is thirty-two degrees below the freezing point of water, and that of the centigrade thermometer, the freezing point itself, both of which are equally misleading when applied to cosmical problems. If we say that the mean temperature of a place is 50° F., or 10° C., these figures tell us nothing of how much the sun warms that place, because if the sun were withdrawn the temperature would fall far below either of the zero points. In the last Arctic Expedition a temperature of -74° F. was registered, or 106° below the freezing point of water; and as at the same time the earth, at a depth of two feet, was only, -13° F. and the sea water +28° F., both influencing the temperature of the air, we may be sure that even this intense cold was not near the possible minimum temperature. By various calculations and experiments which cannot be entered upon here, it has been determined that the temperature of space, independent of solar (but not of stellar) influence, is about -239° F., and physicists almost universally adopt this quantity in all estimates of cosmical temperature. It follows, that if the mean temperature of the

earth's surface at any time is 50° F. it is really warmed by the sun to an amount measured by 50 + 239 = 289° F., which is hence termed its absolute temperature. Now during the time of the glacial epoch the greatest distance of the sun in winter was 98¼ millions of miles, whereas it is now, in winter, only 91½ millions of miles, the mean distance being taken as 93 million miles. But the quantity of heat received from the sun is inversely as the square of the distance, so that it would then be in the proportion of 8,372 to 9,613 now, or nearly one seventh less than its present amount. The mean temperature of England in January is about 37° F., which equals 276° F. of absolute temperature. But the above-named fraction of 276° is 237, the difference, 39, representing the amount which must be deducted to obtain the January temperature during the glacial epoch, which will therefore be -2° F. But this is a purely theoretic result. The actual temperature at that time might have been very different from this, because the temperature of a place does not depend so much on the amount of heat it receives directly from the sun, as on the amount brought to it or carried away from it by warm or cold winds. We often have it bitterly cold in the middle of May when we are receiving as much sun heat as many parts of the tropics, but we get cold winds from the iceberg-laden North Atlantic, and this largely neutralises the effect of the sun. So we often have it very mild in December if south-westerly winds bring us warm moist air from the Gulf-stream. But though the above method does not give correct results for any one time

or place, it will be more nearly correct for very large areas, because all the sensible surface-heat which produces climates necessarily comes from the sun, and its proportionate amount may be very nearly calculated in the manner above described. We may therefore say, generally, that during our winter, at the time of the glacial epoch, the northern hemisphere was receiving so much less heat from the sun as was calculated to lower its surface temperature on an average about 39° F., while during the height of summer of the same period it would be receiving so much more heat as would suffice, other conditions being equal, to raise its mean temperature about 48° above what it is now. The winter, moreover, would be long and the summer short, the difference being twenty-six days.

We have here certainly an amount of cold in winter amply sufficient to produce a glacial period,[45] especially as this cold

[45] In a letter to *Nature* of October 30th, 1879, the Rev. O. Fisher calls attention to a result arrived at by Pouillet, that the temperature which the surface of the ground would assume if the sun were extinguished would be -128° F. instead of -239° F. If this corrected amount were used in our calculations, the January temperature of England during the glacial epoch would come out 17° F., and this Mr. Fisher thinks not low enough to cause any extreme difference from the present climate. In this opinion, however, I cannot agree with him. On the contrary, it would, I think, be a relief to the theory were the amounts of decrease of temperature in winter and increase in summer rendered more moderate, since according to the usual calculation (which I have adopted) the differences are unnecessarily great. I cannot therefore think that this modification of the temperatures, should it be ultimately proved to be correct (which is altogether denied by Dr. Croll), would be any serious objection to the adoption of Dr. Croll's theory of the Astronomical and Physical causes of the Glacial Epoch.The reason of the theoretical increase of summer heat being greater than the decrease of

would be long continued; but at the same time we should have almost tropical heat in summer, although that season would be somewhat shorter. How then, it may be asked, could such a climate have the effect supposed? Would not the snow that fell in winter be all melted by the excessively hot summer? In order to answer this question we must take account of certain properties of water and air, snow and ice, to which due weight has not been given by writers on this subject.

Properties of Air and Water, Snow and Ice, in Relation to Climate.—The great aerial ocean which surrounds us has the wonderful property of allowing the heat-rays from the sun to pass through it without its being warmed by them; but when the earth is heated the air gets warmed by contact with it, and also to a considerable extent by the heat radiated from the warm earth, because, although pure dry air allows such dark heat-rays to pass freely, yet the aqueous vapour and carbonic acid in the air intercept and absorb them. But the air thus warmed by the earth is in continual motion owing to changes of density. It rises up and flows off, owing to the greater weight of the cooler air which forces it up and takes its place; and thus heat can never

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winter cold is because we are now nearest the sun in winter and farthest in summer, whereas we calculate the temperatures of the glacial epoch for the phase of precession when the *aphelion* was in winter. A large part of the increase of temperature would no doubt be used up in melting ice and evaporating water, so that there would be a much less increase of sensible heat; while only a portion of the theoretical lowering of temperature in winter would be actually produced owing to equalising effect of winds and currents, and the storing up of heat by the earth and ocean.

accumulate in the atmosphere beyond a very moderate degree, the excessive sun-heat of the tropics being much of it carried away to the upper atmosphere and radiated into space. Water also is very mobile; and although it receives and stores up a great deal of heat, it is for ever dispersing it over the earth. The rain which brings down a certain portion of heat from the atmosphere, and which often absorbs heat from the earth on which it falls, flows away in streams to the ocean; while the ocean itself, constantly impelled by the winds, forms great currents, which carry off the surplus heated water of the tropics to the temperate and even to the polar regions, while colder water flows from the poles to ameliorate the heat of the tropics. An immense quantity of sun-heat is also used up in evaporating water, and the vapour thus produced is conveyed by the aerial currents to distant countries, where, on being condensed into rain, it gives up much of this heat to the earth and atmosphere.

The power of water in carrying away heat is well exhibited by the fact of the abnormally high temperature of arid deserts and of very dry countries generally; while the still more powerful influence of moving air may be appreciated, by considering the effects of even our northern sun in heating a tightly-closed glass house to far above the temperature produced by the vertical sun of the equator where the free air and abundance of moisture exert their beneficial influence. Were it not for the large proportion of the sun's heat carried away by air and water the tropics would become uninhabitable furnaces—as would indeed *any* part of the

earth where the sun shone brightly throughout a summer's day.

We see, therefore, that the excess of heat derived from the sun at any place cannot be stored up to an important amount owing to the wonderful dispersing agency of air and water; and though some heat does penetrate the ground and is stored up there, this is so little in proportion to the whole amount received, and the larger part of it is so soon given out from the surface layers, that any surplus heat that may be thus preserved during one summer of the temperate zones rarely or never remains in sufficient quantity to affect the temperature of the succeeding summer, so that there is no such thing as an accumulation of earth-heat from year to year. But, though heat cannot, cold can be stored up to an almost unlimited amount, owing to the peculiar property water possesses of becoming solid at a moderately low temperature; and as this is a subject of the very greatest importance to our inquiry—the whole question of the possibility of glacial epochs and warm periods depending on it—we must consider it in some detail.

Effects of Snow on Climate.—Let us then examine the very different effects produced by water falling as a liquid in the form of rain, or as a solid in the form of snow, although the two may not differ from each other more than two or three degrees in temperature. The rain, however much of it may fall, runs off rapidly into streams and rivers, and soon reaches the ocean, a small portion only sinking into the earth and another portion evaporating into the atmosphere. If cold it cools the air

and the earth somewhat while passing through or over them, but produces no permanent effect on temperature, because a few hours of sunshine restore to the air or the surface-soil all the heat they had lost. But if snow falls for a long time, the effect, as we all know, is very different, *because it has no mobility*. It remains where it fell and becomes compacted into a mass, and it then keeps the earth below it and the air above, at or near the freezing-point till it is all melted. If the quantity is great it may take days or weeks to melt; and if snow continues falling it goes on accumulating all over the surface of a country (which water cannot do), and may thus form such a mass that the warmth of the whole succeeding summer may not be able to melt it. It then produces perpetual snow, such as we find above a certain altitude on all the great mountains of the globe; and when this takes place *cold* is rendered permanent, no amount of sun-heat warming the air or the earth much above the freezing-point. This is illustrated by the often-quoted fact that, at 80° N. Lat., Captain Scoresby had the pitch melted on one side of his ship by the heat of the sun, while water was freezing on the other side owing to the coldness of the air.

The quantity of heat required to melt ice or snow is very great, as we all know by experience of the long time masses of snow will remain unmelted even in warm weather. We shall however be better able to appreciate the great effect this has upon climate, by a few figures showing what this amount really is. In order to melt one cubic foot of ice, as much heat is required as would

heat a cubic foot of water from the freezing point to 176° F., or two cubic feet to 88° F. To melt a layer of ice a foot thick will therefore use up as much heat as would raise a layer of ice-cold water two feet thick to the temperature of 88° F.; and the effect becomes still more easily understood if we estimate it as applied to air, for to melt a layer of ice only 1½ inches thick would require as much heat as would raise a stratum of air 800 feet thick from the freezing point to the tropical heat of 88° F.! We thus obtain a good idea, both of the wonderful power of snow and ice in keeping down temperature, and also of the reason why it requires so long a time to melt away, and is able to go on accumulating to such an extent as to become permanent. These properties would, however, be of no avail if it were liquid, like water; hence it is the state of solidity and almost complete immobility of ice that enables it to produce by its accumulation such extraordinary effects in physical geography and in climate, as we see in the glaciers of Switzerland and the ice-capped interior of Greenland.

High Land and great Moisture Essential to the Initiation of a Glacial Epoch.—Another point of great importance in connection with this subject, is the fact, that this permanent storing up of cold depends entirely on the annual amount of snow-fall in proportion to that of the sun and air-heat, and not on the actual cold of winter, or even on the average cold of the year.[46] A place may be intensely cold in winter and may have a

[46] Dr. Croll says this "is one of the most widespread and fundamental errors within the whole range of geological climatology." The temperature of the snow itself is,

short arctic summer, yet, if so little snow falls that it is quickly melted by the returning sun, there is nothing to prevent the summer being hot and the earth producing a luxuriant vegetation. As an example of this we have great forests in the extreme north of Asia and America where the winters are colder and the summers shorter than in Greenland in Lat. 62° N., or than in Heard Island and South Georgia, both in Lat. 53° S. in the Southern Ocean, and almost wholly covered with perpetual snow and ice. At the "Jardin" on the Mount Blanc range, above the line of perpetual snow, a thermometer in an exposed situation marked -6° F. as the lowest winter temperature: while in many parts of Siberia mercury freezes during several weeks in winter, showing a temperature below -40° F.; yet here the summers are hot, all the snow disappears, and there is a luxuriant vegetation. Even in the very highest latitudes reached by our last Arctic Expedition there is very little perpetual snow or ice, for Captain Nares tells us that north of Haye's Sound, in Lat. 79° N., the mountains were remarkably free from ice-cap, while extensive tracts of land were free from snow during summer, and covered with a rich vegetation with abundance of bright flowers. The reason of this is evidently the scanty snow-fall, which rendered it sometimes difficult to obtain enough to form shelter-banks around the ships; and this was north of 80° N. Lat., where the sun was absent for

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he says, one of the main factors. (*Climate and Cosmology*, p. 85.) But surely the temperature of the snow must depend on the temperature of the air through which it falls.

142 days.

Perpetual Snow Nowhere Exists on Lowland Areas.—It is a very remarkable and most suggestive fact, that nowhere in the world at the present time are there any extensive lowlands covered with perpetual snow. The Tundras of Siberia and the barren grounds of N. America are all clothed with some kind of summer vegetation;[47] and it is only where there are lofty mountains or plateaus—as in Greenland, Spitzbergen, and Grinnell's Land—that glaciers, accompanied by perpetual snow, cover the country, and descend in places to the level of the sea. In the Antarctic regions there are extensive highlands and lofty mountains, and these are everywhere exposed to the influence of moist sea-air; and it is here, accordingly, that we find the nearest approach to a true ice-cap covering the whole circumference of the Antarctic continent, and forming a girdle of ice-cliffs which almost everywhere descend to the sea. Such Antarctic islands as South Georgia, South Shetland, and Heard Island, are often said to have perpetual snow at sea-level; but they are all very mountainous, and send down glaciers into the sea, and as they are exposed to moist sea-air on every side, the precipitation, almost

[47] In an account of Prof. Nordenskjöld's recent expedition round the northern coast of Asia, given in *Nature*, November 20th, 1879, we have the following passage, fully supporting the statement in the text. "Along the whole coast, from the White Sea to Behring's Straits, no glacier was seen. During autumn the Siberian coast is nearly free of ice and snow. There are no mountains covered all the year round with snow, although some of them rise to a height of more than 2,000 feet." It must be remembered that the north coast of Eastern Siberia is in the area of supposed greatest winter cold on the globe.

all of which takes the form of snow even in summer, is of course unusually large.[48]

That high land in an area of great precipitation is the necessary condition of glaciation, is well shown by the general state of the two polar areas at the present time. The northern part of the north temperate zone is almost all land, mostly low but with elevated borders; while the polar area is, with the exception of Greenland and a few other considerable islands, almost all water. In the southern hemisphere the temperate zone is almost all water, while the polar area is almost all land, or is at least inclosed by a ring of high and mountainous land. The result is that in the north the polar area is free from any accumulation of permanent ice (except on the highlands of Greenland and Grinnell's Land), while in the south a complete barrier of ice of enormous thickness appears to surround the pole. Dr. Croll shows, from the measured height of numerous Antarctic icebergs (often miles in length) that the ice-sheet from which they are the broken outer fragments must be from a mile to a mile and a half in thickness.[49] As this is the thickness of the outer edge of the ice it must be far thicker inland; and we thus find that the Antarctic continent is at this very time suffering glaciation to quite as great an extent as we have reason to believe occurred

[48] Dr. Croll objects to this argument on the ground that Greenland and the Antarctic continent are probably lowlands or groups of islands. (*Climate and Cosmology*, Chap. V.)

[49] "On the Glacial Epoch," by James Croll. *Geol. Mag.* July, August, 1874.

in the same latitudes of the northern hemisphere during the last glacial epoch.

The accompanying diagrams show the comparative state of the two polar areas both as regards the distribution of land and sea, and the extent of the ice-sheet and floating icebergs. The much greater quantity of ice at the south pole is undoubtedly due to the presence of a large extent of high land, which acts as a condenser, and an unbroken surrounding ocean, which affords a constant supply of vapour; and the effect is intensified by winter being there in *aphelion*, and thus several days longer than with us, while the whole southern hemisphere is at that time farther from the sun, and therefore receives less heat.

We see, however, that with less favourable conditions for the production and accumulation of ice, Greenland is glaciated down to Lat. 61°. What, then, would be the effect if the Antarctic continent, instead of being confined almost wholly within the south polar circle, were to extend in one or two great mountainous promontories far into the temperate zone? The comparatively small Heard Island in S. Lat. 53° is even now glaciated down to the sea. What would be its condition were it a northerly extension of a lofty Antarctic continent? We may be quite sure that glaciation would then be far more severe, and that an ice-sheet corresponding to that of Greenland might extend to beyond the parallel of 50° S. Lat. Even this is probably much too low an estimate, for on the west coast of New Zealand in S. Lat. 43° 35′ a glacier even now descends to within 705 feet of

the sea-level; and if those islands were the northern extension of an Antarctic continent, we may be pretty sure that they would be nearly in the ice-covered condition of Greenland, although situated in the latitude of Marseilles.

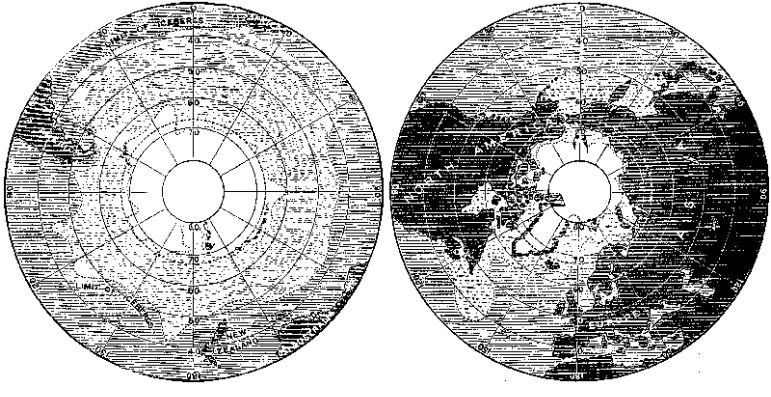

Diagram of the approximate extent of Permanent and Floating Ice around the North and the South Poles. (After Petermann.)

Conditions Determining the Presence or Absence of Perpetual Snow.—It is clear, then, that the vicinity of a sea or ocean to supply moisture, together with high land to serve as a condenser of that moisture into snow, are the prime essentials of a great accumulation of ice; and it is fully in accordance with this view that we find the most undoubted signs of extensive glaciation in the west of Europe and the east of North America, both washed by the Atlantic and both having abundance of high

land to condense the moisture which it supplies. Without these conditions cold alone, however great, can produce no glacial epoch. This is strikingly shown by the fact, that in the very coldest portions of the two northern continents—Eastern Siberia and the north-western shores of Hudson's Bay—there is no perennial covering of snow or ice whatever. No less remarkable is the coincidence of the districts of greatest glaciation with those of greatest rainfall at the present time. Looking at a rain-map of the British Isles, we see that the greatest area of excessive rainfall is the Highlands of Scotland, then follows the west of Ireland, Wales, and the north of England; and these were glaciated pretty nearly in proportion to the area of country over which there is an abundant supply of moisture. So in Europe, the Alps and the Scandinavian mountains have excessive rainfall, and have been areas of excessive glaciation, while the Ural and Caucasian mountains, with less rain, never seem to have been proportionally glaciated. In North America the eastern coast has an abundant rainfall, and New England with North-eastern Canada seems to have been the source of much of the glaciation of that continent.[50]

[50] "The general absence of recent marks of glacial action in Eastern Europe is well known; and the series of changes which have been so well traced and described by Prof. Szabó as occurring in those districts seems to leave no room for those periodical extensions of 'ice-caps' with which some authors in this country have amused themselves and their readers. Mr. Campbell, whose ability to recognise the physical evidence of glaciers will scarcely be questioned, finds quite the same absence of the proof of extensive ice-action in North America, westward of the meridian of Chicago." (Prof. J. W. Judd in *Geol. Mag.* 1876, p. 535.)The same author notes

the diminution of marks of ice-action on going eastward in the Alps; and the Altai Mountains far in Central Asia show no signs of having been largely glaciated. West of the Rocky Mountains, however, in the Sierra Nevada and the coast ranges further north, signs of extensive old glaciers again appear; all which phenomena are strikingly in accordance with the theory here advocated, of the absolute dependence of glaciation on abundant rainfall and elevated snow-condensers and accumulators.

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