THE PROBLEMS OF DISTRIBUTION AND THEIR SOLUTION.

PART I.

PERSONS whose acquaintance with the methods of biological study cannot be regarded as either extensive or profound, may nevertheless regard themselves as perfectly capable of detailing exactly and succinctly the four chief points involved in the consideration of any living being. The history of an animal or plant, however superficially that history may be viewed, presents a series of problems which it is the business of the biologist to solve. These problems resolve themselves sooner or later into four questions, the replies to which, if given in full detail, supply us with a perfect knowledge of the present and past life of the organism and its race. Query the first, concerning the living being—animal or plant, monad or man—resolves itself into the inquiry, "what is it?" To this question the science of *morphology*, or that of *structure*, affords a reply. The external form and the internal anatomy of the organism are investigated under this primary question of the biologist. The animal mechanism and the nature and relations of plant-tissues and organs fall naturally within the scope of this question and its reply. But the organism possesses its vital activities as well as its structural details. In the essence of its nature, it presents for our study those actions through which it maintains its own individual existence, and that of its race or species likewise. A second question thus becomes imperative, and inquires, "how does it live?" To this query it is the province of *physiology*, as the science of *functions*, to reply. Summarising the life of any organism, three terms may be found to denote the sum total of its vital activity. It firstly nourishes itself, and thus engages in the exercise of the function of *nutrition*. It thuswise provides for the maintenance of its individual frame. But as the death of individuals thins out the ranks of the species, the exercise of a second function, that of *reproduction*, provides for the continuance of the race in time. Then, lastly, the animal or plant, whatever its sphere or place in the organic series, or in the world at large, exhibits certain relations to its surroundings. Deprived of

the means for exhibiting this relationship, the living being becomes practically as the dead things around it. It is the power of relating itself to its environments which gives to the living body its chief

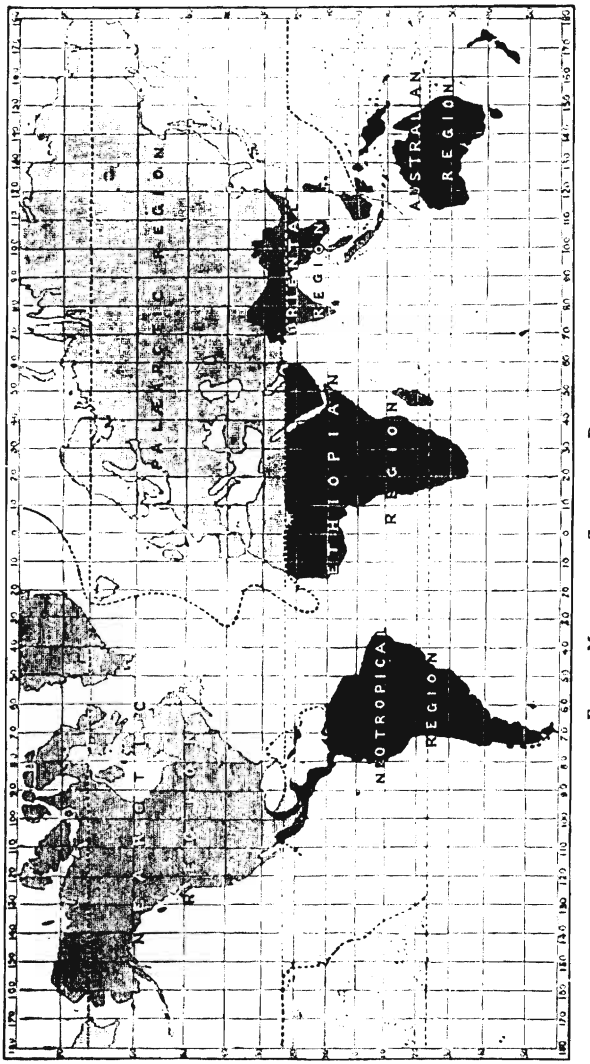

FIG. 1. MAP OF THE ZOOLOGICAL PROVINCES.

characteristics. It is the action and reaction of the organism upon the world around it, and its adaptation to its surroundings, which impart to the animal or plant its plainest differences from the

inorganic things around. Hence we distinguish a third function of the living being; that of *innervation* or *relation.* Exercised through the medium of a nervous system or its representative tissues, this function of relation regulates and controls, whilst it connects and harmonises, the other actions of which life's activities consist. The animal or plant, regarded from a physiological standpoint, lives thus a threefold existence, and performs a triple round of duties. It nourishes itself, it reproduces its race, and it develops and exhibits relations with its surroundings. The knowledge which demonstrates how these functions are performed answers the second of our four questions—"how does it live?"

Structure and functions, all-important as their detail may be for the understanding of animal and plant histories, do not, however, constitute or bound the entire range of biological observation. The inquiries of even the childish stage of man's culture concerning the living as well as the non-living universe, include, above all other points, the inquiry, "where is it found?" Especially natural does such a question appear when applied to the living tenants of the globe. When we ask ourselves where any organism is found, in what quarter of the globe it is plentiful, where it is scarce, or where, lastly, it is never to be discovered, we are in reality approaching topics which lead us tolerably near to the ultimate questions of all biological study. It is the science of *distribution* which professes to answer the questions relating to the whereabouts of animals and plants in the world as it now exists, and in anterior epochs of our globe as well. Distribution thus includes two most natural divisions or lines of inquiry. It summarises the existing life of the globe in its inquiries regarding the geography of living things, or their *distribution in space*, as it is technically termed; whilst it no less succinctly attempts the solution of the problems relating to the past history of animals and plants, when, proceeding to avail itself of the information collected by geology, it pictures for us *their distribution in time.*

The knowledge of the structure, functions, and distribution of a living being, once comprehended all that science could hope to know of its history. Contenting itself with the fact that living beings are, biology might regard the knowledge which these three queries, "what," "how," and "where" supplied, as all-sufficient for the furthest mental demands. But the newer epoch of biology includes a fourth question in its list of queries concerning living things. It presents for solution yet another problem, in the terms of which is focussed all the knowledge gained in other departments of biological research. This fourth query is that which demands to know "how

the living being has come to be what it now is"—or "how it has attained to its present place and position in the animal or plant series." The mere terms of such a question presuppose that the living population of our globe has undergone progressive development. It postulates change and alteration as natural conditions of existence, and it inquires how, in the case of each animal or plant, such change has operated—in what direction it has sped, and how it has affected and modified the living organism. Thus stated, there can be no difficulty in recognising the theory of evolution or development as that which purports to supply this mental demand, and to reply to the inquiry concerning the past history of animals and plants in relation to their present position and genealogical connections. Time was when the need for such a question was non-existent. So long as mankind regarded the world of life as presenting a fixity of constitution, there could exist no question of wide organic change for the biologist to meet and answer. With a firm and undisturbed belief in the special and independent "creation" of each species of living beings, the mind could experience no philosophic or other necessity for any inquiry into a past of modification and change. Possessing the idea that stability of organisation and form was the rule of existence, men had not learned to look for a past wherein, as in a glass darkly, might be discerned the birth of new species arising through the modification of the old. But the germ idea of such an evolution of life existed and prevailed long before the age which has seen its full fruition. Here and there evidence is to be found that, even in classic ages, the great problem of problems concerning the how and why of the universe itself was growing apace in the minds of men. Aristotle, remarking that rain falls not to make the corn grow, any more than it descends to spoil the crops, asks, "what therefore hinders the different parts (of the body) from having this merely accidental relation in nature?" So also Lucretius, in another department of inquiry, shadowed forth the atomic constitution of things, and paved the way for the thoughts of the after ages, when Lamarck, Erasmus Darwin, Goethe, and, in our own day, Charles Darwin, Wallace, and others, have busied themselves with the problems of the development of the teeming population of the globe. Thus arises the philosophic necessity for a fourth question—that of the *ætiology* or causation of living beings. This question, utilising all the knowledge gained by the sciences of structure, physiology, and distribution, endeavours to show how the organic world has grown and progressed towards the perfection it exhibits before our waiting eyes to-day.

This brief sketch of the four great questions of biology may serve to show the exact position which the study of Distribution bears to the other departments of natural-history research. Taking its stand as a distinct branch of inquiry; dealing with the causes which have placed animals and plants in their distinct regions; investigating the conditions which make for or contend against the diffusion of animals and plants on the surface of the globe—the science of distribution presents problems and attempts the solution of questions involving, it may be, the furthest knowledge of present and past alike, which is at our command. Nor must we neglect to note that the study of distribution relates that present history, in the most intimate fashion, with the past of the globe. The continuity of the past with the present is too much a ruling idea of the biological mind to allow the importance of the geological factors in the world's problems to be overlooked. Not a few of the knotty points of distribution are soluble from the side of geology alone. If, therefore, for no other reason than that it links present and past so intimately together, thus making the unbroken continuity of causation a necessity in biological explanation, the study of distribution would take its place in the first rank of the sciences of to-day Bearing in mind this twofold division of distribution into that *in space* (or "geographical distribution") and that *in time* (or "geological distribution"), we may now profitably proceed to inquire into the history of the growth and progress of this department of inquiry.

If we turn to text-books on natural history, written even some ten years ago, we shall discover that, whatever may be the importance of the study, the science of distribution is of comparatively recent growth. The information dispensed in these manuals of biology resolves itself for the most part into a brief recital of the countries in which different animals and plants are found. Thus the facts of distribution, which an intelligent child is now taught in the nursery, comprehend all that was known, even in recent science, respecting the habitats of animals and plants. To know that lions occur in Africa, and tigers in India; to learn that the giraffe and the hippopotamus are tenants of Ethiopia, and that rhinoceroses occur both in Asia and Africa; to be able to say definitely that kangaroos never occur without the bounds of Australian islands, or that humming-birds are found in the New World alone; to know where palms grow or where cacti abound—these were the only facts which the "distribution" of twenty years ago included. The plain enumeration of these or any other facts, however, does not raise them to the rank of a science. The mere mention of the detached countries in which

plants and animals occur, does not constitute a philosophical piece of information calculated to explain either itself or any correlated facts of natural history. That method alone converts any body of details into a science, which places them in harmony with each other, and which, connecting them by, it may be, even a transcendental bond, links them together as parts of a whole. To know, for example, that the existing horse walks upon the greatly developed third toe of each foot, to become aware that the horse likewise possesses two rudimentary toes on each foot, are mere facts, valuable enough perhaps in themselves, but useless, so long as they remain isolated, for any higher or philosophical reasoning concerning the horse or any other animal form. Once, however, let these facts be placed in true harmony with other details regarding the equine race, and the science—that is, the true knowledge—of horses is then constituted. Thus, if we discover that the horses of the present are connected by a complete series of gradations with the horses of the past; and that we may pass by graduated stages from the one-toed horse of to-day to the five-toed Mesozoic ancestors of the race, we at once rise into the region of a philosophy which, through correlated facts, seeks to teach us the origin of the equine species. If, further, knowing that horses were believed to have first been introduced into the New World at the Mexican Conquest, we suppose that in its distribution the horse is a strictly Old World form, that isolated fact tells us but little of the history of the race. Even if we discover that the fossil remains of horses occur in the Tertiary deposits of America as well as in those of Europe, the knowledge of that fact may certainly enlarge our ideas of the former distribution of horses, but of itself the fact does not place us in possession of any connected details concerning the general history of the form in question. But when, by bringing these varied facts into relation with each other, we seek to construct a pedigree of the equine race, we then illustrate the higher use of our knowledge, in that we cause that knowledge to explain itself.

Of all the facts of distribution, the same opinion may be expressed. Formerly, to say that a given animal was found in this land or that, was accounted the beginning and end of distributional science. The influence of evolution, and the growth of newer ideas concerning the modification of species, have together created for us a literally new science of distribution. The ideas which prevailed a quarter of a century ago regarding the fixity of species, and the consequent fixation within certain limits of their habitats, demanded no further exercise of scientific acumen than that necessary to say

from what region any given organism was derived, or from what tracts it was absent. With altered ideas of the constitution of the animal and plant worlds, higher and better because truer conceptions of the manner and causes of the distribution of life on the globe grew apace. In the days of Edward Forbes, the doctrine of "specific centres" held its own as representing the foremost science of its day and generation. With the dogma of the special and independent creation of each species of living beings left utterly unquestioned, it was of all logical processes the most natural that a "special centre" of creation should be sought and found for each species. This theoretical "specific centre" was allocated, *cæteris paribus*, in the region where the species was found to be most abundantly represented. The diffusion of a species beyond its centre was due, it was held, to such favouring influences as continuous land surfaces, the presence of food in surrounding regions, favourable temperatures and climates, and like conditions. The limitation of a species to its centre or original area was held, conversely, to depend upon an absence of the conditions favouring migration and dispersion. The presence of rivers, lakes, or seas, the existence of land-barriers in the shape of mountain-chains, extremes of temperature and vicissitudes of climate and other causes, were regarded as the means whereby a species was confined more or less strictly within its area.

But the growth of the idea that the existing species of animals and plants were the descendants, by ordinary generation, of pre-existing species, wrought a wonderful and sweeping change in biological opinions concerning distribution, as in every other department of natural history science. The theory of the separate and detached placing of animals and plants here and there over the surface of the earth, in obedience to no ascertainable law, was soon driven to the wall as a weak invention possessing no logical standpoint whatever. Affording no reason for the marvellous diversities of life's distribution, the doctrine of "specific centres" was soon consigned to the limbo reserved for the myths and traditions of biology. To say that providential reasons—namely, the necessity of a fatty dietary on the part of the Esquimaux—accounted for the presence of seals and whales in the Arctic regions, or similarly, that farinaceous plants grew most plentifully in the tropics because the inhabitants thereof fed upon their products, might indeed satisfy primitive minds, preferring to bring scientific facts under the sway of dogma rather than to test dogma by the logic of facts. Moreover, all such apologetic attempts at correlating the facts of distribution with theoretical interpretations

of the designs of Providence missed their mark, because in placing man in the first place, and the distribution of life in the second, they reversed not merely the chronological order of affairs, but subverted the real aspect of the case. Thus, clearly, no explanation of the "whys" of distribution was forthcoming from former aspects of this study, just as the "hows" of the science were equally neglected. The newer era of research inaugurated by the publication and growth of Mr. Darwin's opinions, derived no small share of its power and progress from its ability to explain the "how" and "why," not merely of distribution, but of other departments of biology. Evolution, for example, gave a reasonable explanation of the *metamorphosis* or series of changes through which many animals pass, externally to the egg, in their development. The tadpole, as every schoolboy knows, grows to be a frog through successive changes converting it from a fish-like organism into the type of the air-breathing terrestrial adult. The caterpillar, through equally well marked alterations of form, becomes the butterfly or moth. Under the old idea of zoological causation, either form undergoes metamorphosis, because, to quote the words of Kirby and Spence, "it is the will of the Creator." "This, however," as Sir John Lubbock remarks, "is a confession of faith, not an explanation of metamorphosis." Evolution satisfactorily and finally replaces the want of rational ideas of metamorphosis by a higher idea of satisfactory causation, namely, heredity. The frog passes in its development through a metamorphosis, because its ancestor was a fish-like organism. It repeats, as an individual frog, the history of its race. So, also, an insect may directly or indirectly be credited with demonstrating, by the course of its development, its origin from lower stages of life. The development of every animal is a brief recapitulation of the descent of its species. Obscured, and often imperfect, that biography may be, but nevertheless it is plainly outlined before the seeking eye and understanding mind.

If evolution has thus assisted our comprehension of why an animal passes through apparently useless stages in the course of its development, no less clearly has that theory brought to light the meaning of the previously isolated facts of distribution. It was evolution which played to these facts the part of a guardian genius; marshalling their ranks into order and arrangement, and demonstrating that relationship between them which it is the province of science to explain. It is necessary to dwell upon the influence which evolution has exerted upon the study of distribution, simply because the latter science practically dates its origin from the day when the modifica

tion of existing species as a means of natural creation of new races of animals and plants was recognised. And it is with the greater satisfaction that one may dwell upon this mutual relationship of distribution and the theory of development, since the due appreciation of the clear explanation which the facts of distribution receive from evolution at large, constitutes a powerful counterproof of the truth of that theory. It is not surprising, therefore, to find Professor Huxley saying that "no truths brought to light by biological investigation were better calculated to inspire distrust of the dogmas intruded upon science in the name of theology, than those which relate to the distribution of animals and plants on the surface of the earth. Very skilful accommodation was needed," continues Huxley, "if the limitation of sloths to South America, and of the ornithorhynchus to Australia, was to be reconciled with the literal interpretation of the history of the deluge; and with the establishment of the existence of distinct provinces of distribution, any serious belief in the peopling of the world by migration from Mount Ararat came to an end. Under these circumstances, only one alternative was left for those who denied the occurrence of evolution—namely, the supposition that the characteristic animals and plants of each great province were created as such within the limits in which we find them. And as the hypothesis of "specific centres" thus formulated was heterodox from the theological point of view, and unintelligible from the scientific aspect, it may be passed over without further notice as a phase of transition from the creational to the evolutional hypothesis. In fact," adds Huxley, "the strongest and most conclusive arguments in favour of evolution are those which are based upon the facts of geographical taken in conjunction with those of geological, distribution."

Or if we turn for a moment to the opinion of Mr. Darwin himself, we shall find an equally clear expression of the futility of the attempt to explain distribution on any other save an evolutionary understanding. In his classical work, the "Origin of Species," Darwin remarks the fact that "neither the similarity nor the dissimilarity of the inhabitants of various regions can be wholly accounted for by climatal and other physical conditions." He secondly notes the fact, "that barriers of any kind, or obstacles to free migration, are related in a close and important manner to the differences between the productions of various regions;" and a third fact noted by Darwin is "the affinity of the productions of the same continent or of the same sea, though the species themselves are distinct at different points and stations." Again, Darwin remarks that, "in discussing

this subject we shall be enabled at the same time to consider a point equally important for us, namely, whether the several species of a genus, which must on our theory all be descended from a common progenitor, can have migrated, undergoing modification during their migration, from some one area. If, when most of the species inhabiting one region are different from those of another region, though closely allied to them, it can be shown that migration from the one region to the other has probably occurred at some former period, our general view will be much strengthened, for the explanation," adds Darwin, "is obvious on the principle of descent with modification. A volcanic island, for instance, upheaved and formed at the distance of a few hundreds of miles from a continent, would probably receive from it in the course of time a few colonists, and their descendants, though modified, would still be related by inheritance to the inhabitants of that continent. Cases of this kind are common, and are, as we shall hereafter see, inexplicable on the theory of independent creation."

If further evidence were desirable concerning the influence of evolution as explanatory of the distribution of living beings in the past and present of the earth, such opinion might be culled from Sir Charles Lyell. The late eminent geologist remarks, that Buffon, when speculating on "philosophical possibilities," in 1755, urged, "that whilst the same temperature might have been expected, all other circumstances being equal, to produce the same beings in different parts of the globe, both in the animal and vegetable kingdoms, yet it is an undoubted fact, that when America was discovered, its indigenous quadrupeds were all dissimilar to those previously known in the Old World." "Thus Buffon," says Lyell, "caught sight at once of a general law in the geographical distribution of organic beings, namely, the limitation of groups of distinct species to regions separated from the rest of the globe by certain natural barriers." In conformity with the doctrine of special centres of creation, as Lyell remarks, the "natural barriers" of Buffon held a perfectly logical place. Separate creations in the New World, and special creations in the Old, separated by intervening oceans, served fully to explain the reasons of the divergence between the animal populations in question. "But," adds Lyell (in further alluding to the close correspondence between the fossil forms and the living beings of any given area), "the intimate connection between the geographical distribution of the fossil and recent forms of mammalia, points to the theory (without absolutely demonstrating its truth), that the existing species of animals and plants . . . . are of derivative origin,

and not primordial or independent creations." Last of all, Mr. Alfred Russel Wallace—to whose labours we owe much, if not the greater part, of the light which has been thrown on the formerly obscure problems of distribution—testifies in the most direct terms to the value of the theory of evolution. Towards the firm establishment of this theory he himself has made many important contributions, and has thus aided its place and power in explaining the laws regulating the development of life on the surface of the globe. "We further have to make use of the theory of 'descent with modification,'" says Mr. Wallace, "as the only possible key to the interpretation of the facts of distribution; and this theory," he adds, "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." Again, we find a sentence worth quoting, and worth bearing in mind, when Mr. Wallace remarks, that "if we keep in view these facts—that the minor features of the earth's surface are everywhere slowly changing; that the forms, and structure, and habits of all living things are also slowly changing; while the great features of the earth, the continents, and oceans, and loftiest mountain ranges, only change after very long intervals, and with extreme slowness; we must see that the present distribution of animals upon the several parts of the earth's surface is the final product of all these wonderful revolutions in organic and inorganic nature."

The proposition that in the existing world we may find a reflex of those causes which have wrought out the scheme of life's distribution over the surface of the globe, has received the tacit sanction and approval of all competent biologists. This result has been attained through the slow but sure and progressive advance of modern ideas concerning the uniformity of natural law and physical causation. The teachings of evolution in biology are but the reflections of "uniformity" in geology. As the doctrine of uniformity has taught us that the physical forces represented in and by the internal heat, water, frost, snow, and chemical action, are the agencies which from all time past have been sculpturing and moulding our earth's features —as we trace in the physical actions of the present the key to the activities of the past—so in biology we assume, and assume logically, that the ordinary activities of life, the processes of variation and change, and the influence of environments on the living form, are the

agencies which mould the world of life now, as in the earliest æons, and as in the beginning itself. Rejecting the idea of uniformity in science, we fall back on the catastrophism of primitive geology and on the "special creation" of those early times of biology, when fabulous theory represented the exact observation of to-day. Accepting, however, the theories of "uniformity" in the inorganic world and of "evolution" in the living universe, we unite the sciences in a circle, outside the magnificent unity of which no fact of inorganic nature or of the living world can be presumed to exist.

The division of the world's surface for the purposes of ordinary geography is obviously unsuited to the wants of the biologist. The geographical survey of the earth is of necessity a matter of politics. The greater nation tends to obliterate the smaller; allocation of territory is largely a matter of division of spoil; and the outlines and boundaries of the countries of the world reflect the kaleidoscopic change which marks the arena of political strife and its concomitant warfare for its own. For scientific purposes, then, the standpoints of the political geographer are unavailable. Save in so far as the march of civilisation means and implies the destruction and repression of the animals and plants which are either useful or useless and dangerous to man, the distribution of life on the globe is comparatively unaffected by the divisions whereby man demarcates his territorial possessions from those of his neighbours. A rat may pass as placid an existence under the Czar as under British rule: a kangaroo will live as successfully beneath Dutch as under English sovereignty; but there may be more prospect of length of days for the hippopotamus under existing circumstances than under an extension of civilisation in the north of Africa. Neglecting, then, the political divisions of the world, the biologist divides the earth's surface into regions, the boundaries of which are determined solely by the distribution of the animals and plants included within their limits. Sweeping aside the lines of demarcation which human powers and aims have constructed, the naturalist constructs a new biological geography, whose continents and countries are under the unceasing sway and sovereignty of those natural forces, agencies, and laws which from all time past have affected the destinies of the earth and its tenants. It is on the very threshold of distribution that we begin to note the wide variations between the former and present methods of studying life's development over the globe's surface. Formerly, the range of any living being was denoted simply by the name of the country or continent in which it occurred.

But it is evident that such a method of indicating an animal's

territory is in the highest degree indefinite. To speak, for instance, of India as the habitat of the tiger, is to imperfectly indicate the range of that animal, which extends over at least two-thirds of the continent, besides being found in the Eastern Archipelago. Or, if we select one or two common British quadrupeds, we may find the anomalies of the common method of naming the habitats of animals to be equally well represented. For instance, the badger is commonly described as being found in Europe. Such a method of denoting its range tends to imply that its distribution is limited to that continent. But in point of fact, the badger ranges eastwards from Central Asia to Amoor, and southwards to North Africa as well. The otter's distribution ranges to North Africa, and extends to Siberia ; the hedgehog is found from Central Asia to Amoor, like the badger ; and the mole extends as far as Central Asia. Certain of our birds fall equally without the common indications of distribution. Our grey wagtail (*Motacilla sulphurea*) extends to North Africa, and occurs also in Central Asia, China, and Malaya ; and the house-sparrow, fieldfare, starling, and crow, have a distribution varying from Britain to North Africa and Central Asia. The inadequacy of ordinary descriptive geography to indicate the range of these animals can therefore be readily understood. In the nature of things, the distribution of animals and plants follows certain laws which have left their impress upon the boundaries of land-regions likewise. It remains for us to see how the earth's surface has been mapped out by these laws into natural continents or regions, each characterised by its own characteristic fauna and flora. The popular description of animal and plant distribution, moreover, besides affording no exact details of the boundaries of its regions, gives no information concerning the causes which limit an animal to a small area in one case, or which extend an animal's range over a wide area in another. On the contrary, when, taking as our guide the natural divisions of earth's population, we discover the exact distribution of animals and plants, we lay thereby the foundation of the knowledge which shows how that distribution has been attained and regulated. It is not sufficient, for instance, for any intellectual purpose, to know why kangaroos are found in Australia alone. The mind

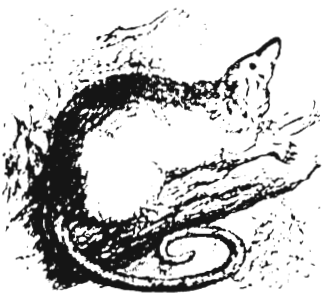

Fig. 2. Opossum.

naturally proceeds further, and inquires, why should these animals be limited to the region in question? It by no means conveys any adequate information concerning the distribution of the marsupial or "pouched" order of quadrupeds to be told that all known members of the group, kangaroos included, are confined to the Australian region, with the single exception of the true opossums or *Didelphidæ*—these latter animals occurring in the New World, but being absent from Australia. The natural queries, why should kangaroos be confined to Australia, and why should the opossums (Fig. 2) alone of all marsupials be found without the bounds of Australia, are not answered by the mere geographical descriptions of former days. Nor do these descriptions indicate why, to select other examples, Australia is practically destitute of all higher quadrupeds; or why antelopes have their head-quarters in Africa, where, south of the great desert, deer do not typically occur, whilst deer are found in all other regions save Australia. So also the mere note of an animal's country as politically defined, and the mention of the fact that bears inhabit Europe, Asia, and North America, gives no explanation why these animals are absent from tropical and South Africa. The pigs, again, are common over Europe and Asia down to New Guinea, yet Southern Africa knows not this race any more than it includes the deer amongst its denizens. Nor can we explain according to ordinary geographical notions, why tapirs should exist in regions so far apart as Malaya and South Africa, or why camels and llamas should inhabit the Asian deserts and the slopes of the Andes respectively. Or, last of all, how impossible of explanation, on ordinary grounds, is the fact that the anthropoid or man-like apes occur in regions so widely separated as Western Africa and Borneo. It is clear, therefore, that our glance at the world's geography in relation to the distribution of life must go deeper into the nature of things than do the common descriptions of the countries tenanted by animal and plant races. Here, as in other departments of scientific inquiry, we require to refer to a former state of things, and to glance backwards in time for the true solution of the problems of life's development over the globe. The naturalist of to-day thoroughly endorses Mr. Wallace's statement, that "to the older school of naturalists the native country of an animal was of little importance except in so far as climates differed. . . . . A group of animals was said to inhabit the 'Indies'; and important differences of structure were often overlooked from the idea that creatures equally adapted to live in hot countries, and with certain general resemblances, would naturally be related to each other. . . . . To the modern naturalist,

on the other hand, the native country (or 'habitat,' as it is technically termed) of an animal or a group of animals is a matter of the first importance; and as regards the general history of life upon the globe, may be considered to be one of its essential characters."

That certain divisions, or "regions," bounded by distinct lines of demarcation, exist to represent the natural method of distribution of animals or plants on the earth's surface, is a fact readily provable. For example, one of the most remarkable results attained through the investigation of the distribution of animals and plants, is the fact that a line passing between the little islands of Bali and Lombok in the eastern archipelago, and separating Borneo, Java, and the Philippines from Celebes, New Guinea, and Australia (see Fig. 1), serves as a boundary between two regions exhibiting the greatest diversity in their animal and plant life. On the Borneo side of this line we have a rich collection of higher quadruped life—man-like apes, lemurs, monkeys, antelopes, tigers, rhinoceroses, and other forms—along with the babblers, hill-tits, bulbuls, crows, hornbills, pheasants, and jungle-fowl among the birds. On the Australian side, not a single higher quadruped (if we except a few bats, and rodents of recent introduction) is native; and the kangaroos and their neighbours represent the fulness of quadruped life in the archipelago. The special birds of the archipelago have for the most part disappeared. The bulbuls, pheasants, barbets, and vultures, find no place in the Australian islands; but in their place we find the curious honey-suckers, the piping crows, the lyre-birds, the cockatoos, lories, and parroquets, the brush-turkey and mound birds, emus and cassowaries, and other characteristic forms. It is difficult to imagine a change of fauna so complete as that which meets the eye of the traveller as he passes across the narrow straits of Lombok to enter the Australian region. Yet the divergence is of the most characteristic nature, and depends upon the causes which lie at the root not merely of physical but of biological change. The remarkable fact that the animals common to Europe and Central Asia pass into Africa north of the desert, but are not, as a rule, found in India, is similarly explicable on the ground that the distribution of life shows us the natural divisions and natural geography of the globe. It now remains to investigate the limits and boundaries of these divisions (or "zoological regions," as they are named), to indicate the more familiar types of life resident in each, and to ascertain, last of all, the chief facts which, when brought into scientific relationship, serve to explain how and why the life of the earth has been thus distributed.

Mr. Sclater, the secretary of the Zoological Society of London, proposed, from a consideration of the bird-life of the globe, to divide the earth's surface into six provinces or regions. These regions, whilst indicating the distribution of the birds, likewise serve to show that of the quadrupeds; whilst it is found that they also represent the essential features of the distribution of still lower grades of life. Mr. Sclater's six divisions have received, with one or two modifications, the common approval of naturalists. Professor Huxley, it is true, has proposed a somewhat different division of the earth's surface, and it may be convenient in the first place to note this latter arrangement. Making four provinces from the consideration of the distribution of fauna, Huxley divides the earth's surface as follows:—

Zoological Province	Geographical Equivalents
I. Ornithogæa or Nova-Zelanian	New Zealand alone.
II. Antarctogæa or Australian	Australia, Tasmania, and Negrito Islands.
III. Dendrogæa or Austro-Columbian	South America, Central America, and Mexico.
IV. Arctogæa	
Having as sub-provinces	(1) North America (N. of Mexico). (2) Africa (S. of Sahara). (3) Hindostan. (4) Europe, Asia (except India), and Africa (N. of desert).

The effect of this arrangement is to bring prominently into view the biological peculiarities of New Zealand, Australia, and South America, and to relate more nearly together those quarters of the globe (Europe, Asia, India, and Africa) which possess more features in common than the other and more specialised provinces. With all deference to such high authority as Professor Huxley in himself represents, one objection to his system of zoological geography may be found in the fact that the claims of New Zealand to rank as a distinct zoological region are highly debateable. Again, in the system propounded by Mr. Sclater, the geographical equivalents of Huxley's *Arctogæa* are practically retained, and the not inconsiderable merit of simplicity, as well as considerations relating to the distinctness of the fauna, may weigh in the minds of naturalists as favouring the adoption of Mr. Sclater's provinces of distribution.

These provinces or regions, depicted in Fig. 1, are as follows:

I. Palæarctic Region	includes Europe, Africa N. of the Desert, and Asia (except India and the Eastern Peninsula).
II. Oriental (or Indian) Region	includes India and the Eastern Peninsula and Archipelago to "Wallace's Line."

III. Australian Region . .	Australia, New Guinea, New Zealand, and Eastern Archipelago S. of "Wallace's Line."
IV. Ethiopian Region . .	Africa S. of the Desert, and Madagascar.
V. Nearctic Region . .	North America, down to Central America.
VI. Neotropical Region . .	South America, West Indian Islands, and Southern Mexico.

Beginning with the *Palæarctic Region* (Fig. 1), or the first of the six great provinces into which the biologist maps out the earth's surface, we may, in each case, firstly define the geographical boundaries of the province; next note the leading groups of living beings which characterise the region; and finally discuss its sub-regions wherever these latter present any features of striking interest. The constitution and limits of the Palæarctic Region introduce us at once to the revolution in geographical ideas which the study of distribution entails. We shall find therein a typical instance of that apparently arbitrary division of continents and piecing together of diverse lands, beneath which lies, in reality, the true relationship of the land areas of our globe. The Palæarctic Region of the biologist consists (1) of Europe in its entirety; (2) Asia, except India and the Eastern Peninsula, along with as much of Africa as lies north of the desert. In the "mind's eye" we must, therefore, separate out the areas just mentioned from those with which, in ordinary geography, they are so intimately associated, and, piecing them together, form a great zoological province. This province is characterised, as are the other five divisions, by the possession of animals and plants which, for the most part, remain characteristic of its limits. Here and there we may detect a commingling with the forms of adjoining regions, and occasionally we may meet with a group which is common to two or more regions. Sometimes we see groups—such as the crows, swallows, owls, and pigeons among birds, or the rats and mice among quadrupeds—which have representatives in every region, and are thus cosmopolitan, or nearly so, in their distribution. But, apart from these exceptional instances, the main zoological and botanical features of each region are readily distinguishable; and no less so, as a rule, are the sub-regions into which each province is divided from considerations connected with the prevalence of special groups of animals in certain localities.

The quadrupeds of the Palæarctic Region include many familiar forms. As compared with the region most closely resembling it—namely, the Nearctic—this first region possesses a much greater variety of quadrupeds and birds. A very fair representation of all the higher animals is found in the Palæarctic province. With the

exception of the monkey of Gibraltar—an importation from Northern Africa—and the Japanese ape, no apes occur in this region. The bats are not markedly peculiar, but the whole of the mole family, save one American and two Oriental species, is included within its limits. Of carnivora it has a fair share, although the larger beasts of prey are well-nigh absent. There are numerous lynxes; wolves, foxes, and bears are plentiful but not peculiar; the badgers occur typically here, whilst Japan has a peculiar dog (*Nyctereutes*) and a special otter (*Lutronectes*). The Ungulates, or hoofed animals, include the camels, which are typical tenants of the Palæarctic Region; there are six genera of deer peculiar to the region, along with seven peculiar genera of the ox family (chiefly antelopes), such as the chamois and saiga. This region may be described as the head-quarters of the sheep and goats, since but two species (one American and one Indian) exist without its bounds. The *Rodentia*, or "gnawers," are well represented likewise. Twenty-seven rodents occur nowhere else, and those genera occurring in other regions—such as the voles, pikas, and dormice—still possess representatives in the Palæarctic territory. The birds of this region, like the quadrupeds, present us with many well-known genera and species. The true pheasants are wholly limited to this region, if we except one species found in Formosa; the corncrake, the great bustard, and the sand-grouse, are specially Palæarctic. Of smaller birds this region has likewise its typical representatives. The grasshopper-warblers (*Locustella*), the true warblers (including the robins), the bearded titmouse, the wrynecks, the magpies, choughs, and nutcrackers are characteristic of this region. The reptiles and amphibians are relatively few. There are, however, at least two genera of snakes, seven genera of lizards, eight frogs and toads, and eight newts and salamanders which the region claims as its own. The fresh-water fishes peculiar to this territory, it may be added, number about twenty genera. The sub-regions number four. Of these, Central and Northern Europe, with their peculiar Desman-rat and chamois, form one. The Mediterranean borders constitute another, and contain as peculiar animals the fallow-deer, the elephant shrews, the hyæna, the porcupine, and the coney. The Siberian sub-region forms a third, and is the special home of the yak, or hairy bison of Thibet, the Thibetan antelopes, and a peculiar mole; whilst in the fourth sub-region, formed by Japan and Northern China, we find special forms of monkeys, moles, and other quadrupeds, the most notable being a carnivorous animal, the *Æluropus*.

Turning next to the *Ethiopian* region, we discover this latter

province to include Africa south of the desert, whilst the island of Madagascar forms a notable sub-region. In Ethiopia there are many characteristic quadrupeds and peculiar birds which do not occur outside the limits of the region. On the west coast occur two of the four genera of anthropoid apes—the gorilla and chimpanzee. Here also are found the baboons; and the lemurs, having their head-quarters in Madagascar, also occur on the mainland. The lion possesses the continent as ruler of the carnivora; the spotted hyæna is found here alone; the hyæna-dog and aard wolf are likewise typically Ethiopian. No less special to this territory are the zebras, giraffe, hippopotamus; whilst the region has likewise its own species of rhinoceroses. More than seventy species of antelopes (Fig. 7) attest the fact that the race finds its home in this territory; and the African elephant is a peculiar genus and species. But the deficiencies in the quadruped-population of Ethiopia are likewise interesting; and we thus detect the absence of the deer, bears, and oxen, so conspicuous in other regions. The birds of the region are numerous. Limited to Ethiopia are the plantain-eaters, ground hornbills, colies, secretary bird, whydah-finches, ox-peckers, guinea fowls, and the ostriches; we look in vain for the wrens, creepers, nuthatches, pheasants, and jungle-fowl in the lists of Ethiopian fauna. The reptiles, amphibians, and fishes at present include three families of snakes, one family of lizards, one of toads, and three of fresh-water fishes, as absolutely peculiar to the region. The puff-adders and chameleons represent reptiles peculiar to the province under consideration. Whilst the Palæarctic Region possesses 35 genera of mammals peculiar to itself as well as 57 genera of birds, the Ethiopian boasts of 90 peculiar quadruped genera, and 179 genera of land birds absolutely confined within its limits.

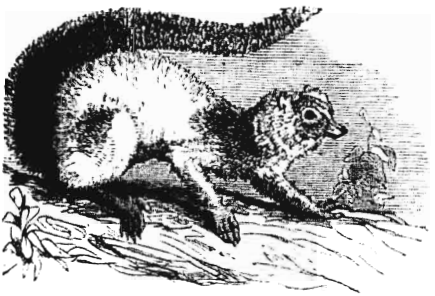

FIG. 3. THE LEMUR.

The Ethiopian sub-regions number four—being named the East, West, and South African, and Malagasay or Madagascar provinces respectively. Of these the Madagascar sub-region alone demands a passing notice. Including, besides the great island from which it derives its name, the Mauritius, Bourbon, Rodriguez, and the Seychelles and Comoro Islands, the Madagascar sub-region becomes

notable in zoological eyes from its forming the head-quarters of the lemurs or lower apes, and of the Insectivora. In addition to these quadrupeds, Madagascar possesses a few special carnivora (*e.g. Cryptoprocta*) of small size; but in this island the apes, lions, leopards, antelopes, and other familiar quadrupeds of Africa are entirely wanting. In Madagascar there are represented 12 families, 27 genera, and 65 species of quadrupeds. Of these three families and 20 genera are exclusively found in the island, and all the species of these families and genera are similarly peculiar, except perhaps a few of the bats. Extremely peculiar it is to find the lemurs so typical (including two families and 34 species) of Madagascar; these animals being represented on the west coast by two forms, and in Africa by one group, whilst they flourish elsewhere in numbers only in the Eastern Archipelago and in Southern India. As regards its bird-population, Madagascar owns 111 species of land birds, of which only 12 are identical with species inhabiting the adjacent continents. Thirty-three genera of birds are peculiar to the island, these genera including fifty species. Of Madagascar Mr. Wallace remarks, in speaking of its quadruped fauna, "the assemblage of animals above-noted is remarkable, and seems to indicate a very ancient connection with the southern portion of Africa, before the apes, ungulates, and felines had entered it. The lemurs, which are here so largely developed, are represented by a single group in Africa, with two forms on the west coast. They also reappear under peculiar and isolated forms in Southern India and Malaya, and are evidently but the remains of a once wide-spread group, since in Eocene times they inhabited North America and Europe, and very probably the whole northern hemisphere." Again, remarking of the birds of Madagascar, Mr. Wallace says: "So many perfectly isolated and remarkable groups are certainly nowhere else to be found; and they fitly associate with the wonderful aye-aye (*Chiromys*), the insectivorous Centetidæ, and carnivorous *Cryptoprocta* among the mammalia. They speak to us plainly of enormous antiquity, of long-continued isolation; and not less plainly of a lost continent or continental island in which so many, and various, and highly organised creatures could have been gradually developed in a connected fauna of which we have here but the fragmentary remains."

The *Oriental* region, formerly known as the "Indian" region, possesses boundaries of highly interesting nature. Comprising Asia south of the Palæarctic region, it includes India, the eastern peninsula, and the Malay archipelago as far as Borneo, Java, and the Philippines. Its southern or lower boundary is marked by a special line—

"Wallace's line"—which passes through a narrow but extremely deep channel—the Straits of Lombok—running between the little islands of Bali and Lombok (Fig. 1), and extending northward and eastward, leaves on its Australian side Lombok, Celebes, and adjoining islands. No fact of distribution, as has been already remarked, is more noteworthy than the sharp demarcation of the Oriental from the Australian region. In the Oriental province itself are found all the conditions for a rich development of life. There is variety in its physical contour; it is broken up into islands and peninsulas; it has its alternations of high mountain and valley, of hill and plain; its river-systems are many and extensive; its temperature is that of the equatorial zone, and its vegetation is in consequence varied and profuse.

Peculiar to the Indian region are at least three families of quadrupeds, that of the flying-lemurs, that of the Tarsiers, or spectre-lemurs, and that of the Tupaias, or squirrel-shrews. There are also many genera confined to this province, although possessing family representatives elsewhere. Thus there are monkeys of the genus *Presbyter*, and the special genera of true lemurs in this region; twelve peculiar civet cats find a home here; whilst three species of antelopes, five rhinoceroses, and the flying-squirrels (*Pteromys*) are typically Oriental in their distribution. Nor must we neglect the species which are limited to this province. The orang-outans and gibbons, two of the four kinds of highest apes, are included amongst its denizens; the tiger, the Indian elephant, sun-bears and honey-bears, the tapir, and the chevrotains or mouse-deer, lend their presence to aid in forming a diverse fauna of the most interesting kind.

Conspicuous among its birds are the tailor-birds, which are peculiar to the region, as also are the laughing thrushes. There are peculiar genera of woodpeckers, cuckoos, and hornbills. The minivets and grass-green fruit-thrushes are also characteristic Oriental birds. The sun-birds are represented by three genera; bee-eaters and kingfishers are likewise included in the Oriental aviary; and goatsuckers and whiskered swifts also fall to be enumerated. Only two parrot-genera are Oriental in distribution; the pigeons of the province being the fruit-eating *Treron* and *Carpophaga*. It is in this region that the races of "poultry" find their original home. The true jungle fowl, from one species of which all our domestic fowls have sprung, occurs widespread in this region. The peacocks, argus pheasants, and fire-backed pheasants, are also typical denizens of the Oriental province, and may fitly close the list of its bird inhabitants.

The reptiles of the Indian region are numerous, but there are

only some three small families of snakes which are peculiar and limited to the region. The reptile population, apart from its specifically distinct character, is varied enough, however. It includes a whole host of snakes; amongst lizards it numbers the water-lizards (or *Varanidæ*), the skinks, the geckos, and the iguanas (*Iguanidæ*). The crocodiles are numerous, and fresh-water tortoises, amongst other genera, abound. The tree frogs and true frogs are well represented, and in its fresh-water fishes this region is peculiar. The Oriental province, to sum up, possesses at least twelve families of vertebrates peculiar to itself. Of the 118 genera of quadrupeds, 54 are confined to this province; and whilst 342 genera of land birds inhabit the region, 165 are absolutely confined to it. There are some four sub-regions included in the Oriental region. These do not demand special mention here, but it may be remarked that the Malayan sub-region—including the Eastern Peninsula, Borneo, Sumatra, Java, and the Philippines—is to be accounted the most typical area of the Oriental region. It is in the Malayan sub-region that we see the features of the Oriental province in their most typical development in most varied array.

Selecting as our fourth region the *Australian* province, the striking characters of this region have already been commented upon. Crossing "Wallace's line," we enter upon a biological territory marked by more peculiar features and by more divergent lines than those which separate the flora and fauna of any other two regions from one another. In Australia and New Guinea—as was to be expected from the fact of these islands presenting the chief areas of the region—the specialised character of its animals and plants is best seen. In Celebes this character is still preserved, although the denizens of that island do not present the special features of Australia, whilst the influence of Oriental migrations is clearly traceable. Of the life of New Zealand, which along with Polynesia falls within the Australian region, a more pronounced opinion may be expressed. The animals and plants of the New Zealand islands are in many respects so peculiar that, as we have seen, it has been proposed to include these areas in a special region. But, as we shall hereafter note, there exist other considerations which, whilst explanatory of the divergence of New Zealand from the Australian types, nevertheless show its fundamental alliance therewith. Thus New Zealand comes, logically enough, to form a part of the Australian region.

Primarily, then, in the Australian region we find at once striking likenesses to, and differences from, the New Zealand flora.

Sir Joseph Hooker, speaking of the relations between the plant-life of the two regions, says : " Under whatever aspect I regard the flora of Australia and of New Zealand, I find all attempts to theorise on the possible causes of their community of feature frustrated by anomalies in distribution, such as I believe no two other similarly situated countries in the globe present. Everywhere else I recognise a parallelism or harmony in the main common features of contiguous floras, which conveys the impression of their generic affinity at least being affected by migration from centres of dispersion in one of them, or in some adjacent country. In this case it is widely different. Regarding the question from the Australian point of view, it is impossible, in the present state of science, to reconcile the fact of *Acacia*, *Eucalyptus*, *Casuarina*, *Callitris*, &c., being absent in New Zealand, with any theory of trans-oceanic migration that may be adopted to explain the presence of other Australian plants in New Zealand ; and it is very difficult to conceive of a time or of conditions that could explain these anomalies, except by going back to epochs when the prevalent botanical as well as geographical features of each were widely different from what they are now. On the other hand, if I regard the question from the New Zealand point of view, I find such broad features of resemblance, and so many connecting links that afford irresistible evidence of a close botanical connection, that I cannot abandon the conviction that these great differences will present the least difficulties to whatever theory may explain the whole case." Thus, whilst there are clear botanical affinities between Australia and New Zealand, these likenesses are really limited to plants which form the characteristic part of the New Zealand flora ; and these plants, for the most part, belong to temperate species.

If the relations between New Zealand and Australia in the matter of their respective floras are so intricate, the relations between the animal populations of these areas are equally interesting. We may briefly glance, in the first place, at the New Zealand fauna, and then, by way of contrast, concern ourselves more especially with the animal life of Australia. The New Zealand islands, in superficial area, attain a size nearly equal to that of Italy. Their distance from Australia is about 1,200 miles ; their vegetation is abundant and well distributed, owing to the absence of desert-lands. The zoology of New Zealand is peculiar. It has no native quadrupeds, if we except a couple of bats ; it possesses an almost Hibernian freedom from reptiles in that it has no snakes, only three genera of lizards, and but one frog. There are 34 genera of land birds, and of these

16 are absolutely confined to New Zealand; and to these are to be added five special genera of aquatic birds, making 21 marked genera in all. Amongst their birds, these islands include the chief species of "wingless" forms. The Moas of New Zealand represent an extinct wingless race, whilst the curious *Apteryx* (Fig. 4) remains to represent the wingless tribes of to-day. The winged birds include special forms of starlings (*Creadion: Heterolocha*, &c.); the curious crook-billed plovers (*Anarhynchus*), which alone of all birds have the bill twisted to the side; and species of swallows, fly-catchers, &c., are also included in the ornithological catalogue of these islands. In New Zealand is found the kakapoe (*Stringops habroptilus*) or owl-parrot, which burrows in the ground, and whose powers of flight have deteriorated; and the curious *Notornis*, a peculiar genus of rails, likewise possessing short and useless wings, may be lastly mentioned amongst the bird productions of these islands.

FIG. 4. APTERYX.

Included amongst the few lizards of New Zealand is the famous *Hatteria*, which in reality forms a connecting link between lizards and crocodiles, and even shows bird-affinities in its ribs. Hatteria thus remains isolated and solitary in its structure amid the lizard-class.

Turning now to Australia itself, we note that land to be the abode of the lower quadrupeds comprised within the two orders *Monotremata* and *Marsupialia*, which are represented by the *Ornithorhynchus* and *Echidna*, and by the kangaroos (Fig. 5), wombats, phalangers, and allied animals respectively. No monotreme whatever, and no marsupial forms—save the single family of the New World opossums—exist without the boundaries of Australia. These animals represent in

FIG. 5. KANGAROO.

their varied types the orders of higher mammals distributed over the other regions of the earth; and the Australian region thus presents us with the home and head-quarters of the lowest, and, in point of time or geological sequence, the earliest, quadrupeds. Whatever higher quadrupeds—such as the sheep, oxen, horses, etc.—the colonisation of Australia has been the means of introducing into that region, it must be borne in mind that all the native mammals of Australia are of the lower grades, and are, with the exception of the American opossums (which do not occur in Australia), absolutely limited to that region. Even the world-wide rodents, represented here by a few rats and mice, are probably of relatively late introduction.

In respect of its birds, whilst Australia possesses species of the familiar thrushes, warblers, shrikes, crows, &c. of the other regions, it yet exhibits certain peculiar forms of bird-life. The bird-absentees are of themselves typical, for Australia has no representatives of the vultures, pheasants, woodpeckers, barbets, and other birds which are so characteristic of even the Oriental territory. But it has, nevertheless, a rich ornithology of its own, in its birds of paradise, its most typical honey-suckers, its lyre-birds, its scrub-birds, its parroquets, its cockatoos, its mound-birds, and its cassowaries. These are typically Australian forms; and there are bird-families sparingly found in other parts of the world—such as the swallow-shrikes and flower-peckers—but which are well represented in Australia. Lastly, there are families of birds—such as the kingfishers, pigeons, weaver-finches—well represented in other provinces, and which are, as a rule, better represented in Australia than in other provinces.

The reptiles of Australia do not present any special features for remark. Snakes and lizards are plentiful; and the Australian amphibians number frogs and toads, but no newts, in their ranks. Thus the Australian region, to sum up, possesses representatives of eighteen families of quadrupeds, eight of these families being absolutely confined to this region. It has seventy-one families of birds, sixteen being peculiar; it possesses four peculiar families out of thirty-one of reptiles; and it has only one family of amphibians, out of a total of eleven, confined within its limits.

Passing now to the western hemisphere, we find the New World divided into the *Nearctic* and *Neotropical* Regions (Fig. 1). The former includes North America in its arctic and temperate regions, and is bounded on the south by a line running between Cape Lucas on the west, and the Rio Grande del Norte on the east; the boundary line dipping southwards from this point in a tongue which extends well-nigh to the isthmus of Tehuantepec. Between the life of the

Nearctic and Palæarctic Regions there is a striking resemblance. In North American forests, the wolves, lynxes, foxes, bears, elks, deer, beavers, hares, squirrels, pikas, and marmots of Europe are represented often by similar species; and the bison of Western Europe represents the buffalo of the Nearctic prairies. But North America has its own peculiar quadrupeds likewise. For instance, the skunk and other two genera of weasels are found nowhere but in Nearctic lands. Then there are the carnivorous racoons which are likewise special forms; and among the rodents, the pouched rats (*Saccomyidæ*), the jumping mouse, the tree porcupines, and prairie dogs are peculiar. The Insectivora number three peculiar genera of moles. The pronghorn antelope (Fig. 6) and the mountain-goat are absolutely Nearctic. The opossums complete the list of peculiar mammals of the region; whilst the absentees may be summarised in the remark that the Nearctic Region is chiefly notable for its absence of wild horses and pigs, dormice, oxen, and hedgehogs, and true mice and rats (*Mus*). The single native sheep, as against the twenty species of sheep and goats of the Palæarctic Region, also typifies a remarkable deficiency of a widely distributed quadruped family.

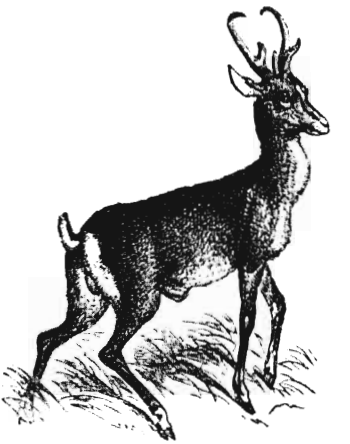

FIG. 6. PRONGHORN ANTELOPE.

The small birds of the Nearctic Region are, as a rule, well marked off from those of the Palæarctic province. The North American warblers belong to different families from the Palæarctic forms; the Nearctic flycatchers belong likewise to different groups from those at home; and the starlings are really "hangnests," or *Icteridæ*. The birds peculiar to the Nearctic Region are in turn well defined. The mocking-birds and blue-jays, the special cuckoos and the tanagers; the humming-birds; the wild turkeys and turkey buzzards, are all limited to this province. The humming-birds of the New World present certain extraordinary limitations in their distribution within the limits of the two regions comprising the Western hemisphere. The peaks and valleys of the Andes possess each its own species. On Pinchincha a peculiar species occurs, 14,000 feet above the sea level, and nowhere else; another has been

found only inside the crater of the extinct volcano of Chiriqui in Veragua; a third occurs only on Chimborazo; and of another species only one specimen has ever been seen, the bird in question having been obtained, over forty years ago, in the Andes of Northern Peru.

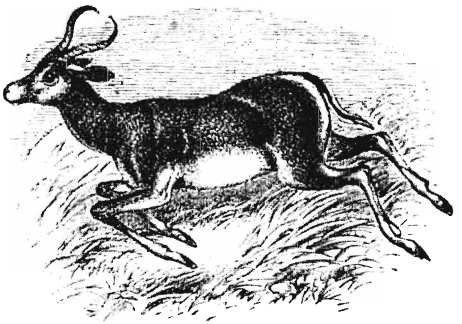

FIG. 7. ANTELOPE.

Again, the presence of such distinct reptiles as the rattlesnakes among serpents, and the true iguanas among lizards, is highly characteristic of Nearctic lands. This region, lastly, may be described as the home of the tailed amphibians or newt-tribe. Nine families—two peculiar to the region—and fifteen special genera represent the newts and salamanders, which include in their ranks the sirens, amphiumas, and two forms related to the European proteus of the caves of Carniola and the giant salamander of Japan respectively. There are also five families of fresh-water fishes—including two families of the rare ganoids—to be enumerated amongst the specific animal belongings of this large area.

There can be no question of the clear distinctness of the Nearctic Region from all other regions, including the Palæarctic, to which, however, in the general characters of its animal life, it is so closely allied. The species that are really common are northern or Arctic forms, a fact which to some extent would seem to point to former land connections in the north as a cause of the similarity. Notwithstanding the likeness in question, the Palæarctic and Nearctic regions are essentially distinct; and there are no reasonable grounds for any scheme of uniting their varied interests in one common biological territory.

The Neotropical region extends from the southern limits of the Nearctic region, and includes the remainder of the New World—that is, Central and South America—with the West Indian Islands as a sub-region of the territory. No region of the world, if we except the Australian province, presents such a variety of interesting biological features as the Neotropical province. Whether regarded in the light of its existing life and of the diversity of animal and plant species it presents to view, or studied in the relations of its present animals to the geological past, the Neotropical area equals, if,

indeed, it does not in some features excel in interest, the great island-continent itself. The monkeys of the Neotropical region, for example, are totally different from those of any other region of the globe. They are broad-nosed, and usually possess prehensile tails adapting them for an active life amid the dense forests of the region. Those apes have no callosities; their thumbs are less perfectly developed than in Old World apes; and cheek-pouches are also wanting. They include (Fig. 8) the spider monkeys, howlers, capuchins, marmosets, and many other peculiar and special forms. The bats are likewise peculiar, in that they are represented by the famous vampires and other blood-sucking species. The rodents are the chinchillas, the curious capybara, the pacas, and agoutis and tree porcupines, possessing, like the apes, prehensile tails. The carnivora include the racoons, which take the place in this region of the weasels of the Old World. Deer and llamas represent the ruminants of the region; and the tapir and peccaries represent other forms of hoofed quadrupeds. It is the group of the *Edentate* quadrupeds, however, which finds in Neotropical territory its peculiar home. If the marsupial kangaroos and wombats characterise Australia as their head-quarters, no less typically in South America do the sloths, true ant-eaters (Fig. 9), and armadillo (Fig. 10) represent the fulness of Edentate development. With the exception of a few species of scaly ant-eaters or pangolins (Fig. 11) occurring in

Fig. 8. Spider Monkey.

Fig. 9. Ant-Eater.

the Ethiopian and Oriental regions, and the "aardvark" or ground hog of South Africa, the Edentate mammals are absolutely confined to the Neotropical Region; and it is in the recent deposits of South America that we likewise discover the fossil remains of those huge extinct edentata, of which the *Megatherium*, *Mylodon*, and *Glyptodon* are well-known representatives. Last of all, the marsupial opossums, an apparent remnant of Australian life, find their home in the Neotropical area. As remarkable exceptions and absentees from the lists of South American quadrupeds may be mentioned the *Insectivora*, of which order—represented by the moles, shrews, and hedgehogs—not an example exists in this area, if we except a little shrew in the north, and one genus in the West Indian Islands. Then, also, we may note the absence of sheep and oxen; there are none of the civets, so widely spread over other areas; and there is an absence of the large carnivora, and of the elephants and rhinoceroses of the Old World.

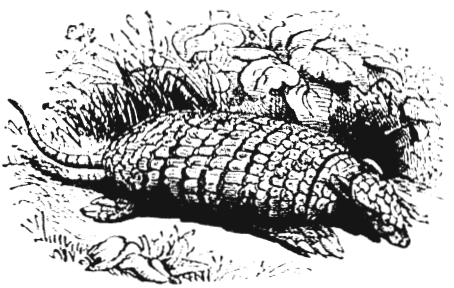

FIG. 10. ARMADILLO.

Equally notable are the birds of the region. The smaller Passerine birds of the region (Formicaroid Passeres), curiously enough, want the singing muscles of the larynx, as a rule. To this group belong the ant-thrushes, tree creepers, tyrants, chatterers, and manakins. Other typical birds of this area are the tanagers, toucans, puffbirds, todies, and motmots. No less typical are the macaws, the curious curassows and tinamous, the sun bitterns and the horned screamers; and the humming-birds are likewise among the veritable gems of South American ornithology. The humming-birds, ranging from Sitka to Patagonia, from the plains to the towering heights of the Andes, are absolutely confined to the New World. "No naturalist," says Mr. Wallace, "can study

FIG. 11. PANGOLIN.

in detail this single family of birds, without being profoundly impressed with the vast antiquity of the South American continent, its long isolation from the rest of the land surface of the globe, and the persistence through countless ages of all the conditions requisite for the development and increase of varied forms of animal life." The curassows are distant relatives of the mound-birds of Australia; and the tinamous possess affinities with the ostrich-tribe itself; whilst in such peculiar Neotropical birds as the *Cariama* of Brazil, the sun bitterns and horned screamers, we see types of birds, either intermediate between other families, or standing solitary and isolated in the bird class, testifying again by these peculiarities of structure to the lapse of time which has passed since their evolution from some common and now extinct type.

The snakes of the region are numerous and peculiar, and the lizards are equally varied. The true crocodiles and the New World alligators co-exist in this region, and the tortoises attain considerable development in this region. The tailed newts are well-nigh absent, however; frogs and toads are abundant; and the fishes of South America present us with numerous types, many of the species and 120 genera at least being confined to the waters of the area.

Central America, as might be expected, shows less clearly the characteristic features of the southern portion of the continent. There we find a commingling of Nearctic with Neotropical forms, but the latter predominate, and as far north as Mexico we may trace the howling monkeys and armadillos of the southern region.

In the case of the West Indian islands, forming the *Antillean* sub-region of the Neotropical province, however, we meet with greater variations from the fauna of the continent. No better instance of the apparently arbitrary, but nevertheless logical and scientific, method of mapping off the earth's surface for biological purposes, could well be selected, than the zoologist's classification of the West Indian Islands. For, encircling Cuba, Hayti, Jamaica, Porto Rico, St. Vincent, Barbadoes, and many other islets in his biological line, he places outside this line Tobago, Trinidad, Margarita, and Curaçoa. The elimination of these latter islands from the "zoological" West Indies, whilst they form characteristic islands of the geographical Antilles, is readily explicable. Trinidad and its three neighbouring islands in their zoology differ entirely from the other West Indian Islands, but agree with the adjoining coast of South America in the character of their included animals and plants. Scientifically and zoologically, they are therefore parts of South America; they belong to the Brazilian sub-region, and not to the West Indian sub-province.

Their affinity to the continent in the matter of their botany and zoology, and their wide divergence from the other West Indian Islands, point clearly to their relatively late detachment from the South American coasts. Their constitution as islands was attained, in other words, at a date much more recent than that at which the other islands of the group received their status as independent lands. Of Trinidad and its neighbouring islets nothing peculiar in a zoological sense can be detailed. We may, therefore, turn to the typical West Indies themselves.

Rich in vegetation and all that contributes to the support of animal life, the West Indies are poor in representatives of the higher groups. But they compensate the zoological mind for poverty in numbers by peculiarities of type. No apes or carnivora are native to the West Indies, and the characteristic edentates of South America —the sloths, ant-eaters, and armadillos—are likewise wholly absent. But bats are abundant, and the rodents are peculiar. *Capromys*, one of these rodents, inhabits Cuba, Jamaica; and *Plagiodontia* is found in Hayti alone. These two genera are thus exclusively limited to the West Indies. In addition, an agouti is found in St. Vincent, and other islands; and a rare species of mouse (*Hesperomys*) is found in Hayti and Martinique. If the West Indian rodents are peculiar, so likewise are the Insectivora belonging to the curious genus *Solenodon*. Two species of Solenodon occur, one in Cuba, the other in Hayti. These animals are allied to the Madagascar "tenrecs." They possess an extremely elongated nose, a long and scaly tail, and powerful claws. The fur is coarse, and the teeth are peculiar in some respects.

The entire zoological history of the West Indian Islands tends to show their distinctness as a biological region. Their fauna bears a decidedly Neotropical character in its essential details, but it is likewise a fauna which has undergone extensive modification through a long separation from the ancient mainland of which these islands once formed part.

The biological divisions of the globe having thus been detailed the task of investigating the causes which have wrought out the existing distribution of life on its surface yet remains. These preliminary studies form the material facts whereupon we may erect a solid hypothesis concerning the means whereby the living population of the earth has been modified, assorted, and arranged. We may accordingly marshal the facts in due order, that we may connect them by a theoretical bond—using hypothesis, thus legitimately, as a guide to the discovery of truth.

ANDREW WILSON.

THE PROBLEMS OF DISTRIBUTION AND THEIR SOLUTION.

PART II.

HAVING summarised in the preceding article[1] the chief facts relating to the distribution of the higher animals on the surface of the globe, and having indicated the boundaries of the six great regions into which, from a consideration of the distribution of life, the biologist divides the land areas of the earth, we may now enter upon the consideration of the explanations which biology is prepared to afford of the facts in question. It is necessary to bear in mind the cardinal fact that only two theories are possible respecting the distribution of life on the earth; as, indeed only two explanations may be offered concerning any other cosmical phenomena, whether relating to the world of life or to that of inorganic matter. In other words, we must either assume, in the first place, with regard to the distribution of life, or to the origin of species itself, that a supernatural, and therefore inexplicable, fiat in the beginning of things, created each species separately and independently, and placed it directly or indirectly in its special locality or home; or, secondly, we may elect to believe, on the theory of evolution, that the varied tribes of living beings are the descendants of pre-existing species; that variation and modification constitute great and continuously operating factors in moulding the living form; that species extend or limit their range of habitat according to the facilities or obstacles presented by their surroundings; and lastly, that physical and geological changes of the earth's surface are continually operating and influencing at once the relations of species, and the character and distribution of the life of any given area. Such are the two hypotheses which now, as of yore, appeal for acceptance, as explanatory of the living universe and its constitution. The first theory is entirely dogmatic and theological in its terms. Stamped by the *imprimatur* of the churches, it commended itself in a readily understood fashion to

[1] See *Gentleman's Magazine* for July.

the unscientific mind. An exercise of that unquestioning faith which the intellectual mind finds but chains and bondage in its endeavour to rightly interpret the facts of nature in their own light, is all-sufficient to establish the theory of the special creation of animal and plant species in their several localities, as a revelation of Supreme power. But the mind which accepts special creation dare not face nature. There is for such a mind no appeal to the external facts which surround it in the universe of life. There can be no intellectual analysis of belief in such a case; no intelligent questioning of the why and wherefore of the phenomena which the theorist endeavours to explain. The theory of evolution, on the other hand, finds its glory and its strength in its fearless interpretation of nature. There exists no peculiarity of life which it may not seek to explain. It is fettered by no considerations save those which foster reverence for truth, and which make for appreciation of the knowledge that "grows from more to more." Best of all, it has nothing to fear from the advancing tide of knowledge which itself has created and fostered; and it submits its deductions fearlessly and fully to every new light which the increase of research can direct upon them. Sir Joseph Hooker has put the case of Evolution *versus* Special Creation in the most forcible fashion, when, in speaking of the origin of species, he says: "There are two opinions accepted as accounting for this: one, that of independent creation, that species were created under their present form, singly or in pairs or in numbers; the other, that of Evolution, that all are the descendants of one or a few originally created simpler forms. The first doctrine is purely speculative, incapable from its very nature of proof; teaching nothing and suggesting nothing, it is the despair of investigators and inquiring minds. The other, whether true wholly or in part only, is gaining adherents rapidly, because most of the phenomena of plant life may be explained by it; because it has taught much that is indisputably proved; because it has suggested a multitude of prolific inquiries, and because it has directed many investigators to the discovery of new facts in all departments of Botany." What Sir Joseph Hooker says of evolution in its relations to botanical science may be more than re-echoed by students of distribution. As already remarked, the science of distribution has been actually created by evolution. Before the idea of the modification of species was ventilated, no science which could account for the diverse relationships of living beings in space was possible, because such explanation, on the theory of special creation, was not required. Only, therefore, on the

hypothesis of evolution can any explanation of the distribution of life be attempted. It may be likewise added that, in the facts of distribution, the evolution hypothesis finds one of its strongest supports.

In 1605 appeared a curious work, entitled "The Restitution of Decayed Intelligence in Antiquities, concerning the most noble and renowned English Nation." The author—one Verstegen—informs his readers in one chapter of the reasons for believing that the "Isle of Albion" had been connected by "firm land with Gallia, now named France, since the Flood of Noe." One passage from this quaint work interests exceedingly the student of distribution. It runs as follows: "Another reason there is that this separation hath been made since the Flood, which is also very considerable, and that is the patriarch Noe, having had with him in the ark all sorts of beasts, these then, after the Flood, being put forth of the ark to increase and multiply, did afterward in time disperse themselves over all parts of the continent or mainland; but long after—it could not be before—the ravenous wolf had made his kind nature known to man; and therefore no man, unless he were mad, would ever transport of that race out of the continent into the isles, no more than men will ever carry foxes (though they be less damageable) out of our continent into the Isle of Wight. But our Isle, as is aforesaid, continuing since the Flood fastened by nature unto the Great Continent, these wicked beasts did of themselves pass over. And if any should object that England hath no wolves on it, they may be answered that Scotland, being therewith conjoined, hath very many; and so England itself some time also had, until such time as King *Edgar* took order for the destroying of these throughout the whole realm."

That which to the contemporaries of Verstegen, as to many persons ignorant of the teachings of geology even in our own day, would seem a wild impossibility—namely, the junction of England and France by land-surface—is known to the tyro in geology to have been a plain reality. Convulsions and disconnections, as well as elevations and connections of land-surfaces, are among the most familiar facts of geological science, which views the land as an ever-shifting quantity amid the factors of physical change.

A brief allusion to some of the more familiar instances in which the association or connection of land-surfaces serves to account for a likeness of the contained life, may demonstrate that the author of "The Restitution of Decayed Intelligence in Antiquities" was, in his day and generation, groping successfully enough after the true cause of the likeness between the animals of Albion and Gaul. In the

Neotropical region of the geologist, the Island of Trinidad presents us with an excellent example of the bearing of geological change over the distribution of life. Geographically, Trinidad is one of the West Indian Islands; zoologically, Trinidad is a part of South America. Whilst the animals of the West Indian Islands are highly peculiar, as we have seen, those of Trinidad resemble the animals found in the neighbouring American area; and along with Trinidad we may class the islands of Tobago, Margarita, and Curaçoa as zoologically belonging to the South American Continent, and not to the Antilles. Close to Trinidad lie Grenada, Barbadoes, and St. Vincent; yet the geographical nearness of these three latter islands to Trinidad is completely overturned by the facts of distribution. What theory of the constitution of living beings and of the earth at large is competent to explain the immense differences which separate Trinidad and neighbouring islets in a zoological sense from the Antilles? On the theory of special creation, no explanation is possible. On the hypothesis of evolution, the main outlines of the problem and its solution are clear enough. The relations of Trinidad and South America are in reality the counterpart of those which Verstegen assumed existed between the "Isle of Albion" and Gaul. At a relatively and geologically "recent" date, there was land connection between Trinidad and the American Continent—such is the geological phase of the question. The biological aspect shows us a sufficient reason for the likeness of the fauna of Trinidad to South American life, by assuming that the processes of variation and change in its species have not yet had time sufficient at their disposal to establish differences of importance. Conversely, the Antilles form, as we have seen, a highly peculiar region for the opposite reason—namely, that these islands, once united to Central America, became detached at a remote period. This ancient separation prevented the inroad of the higher and later forms of life, whilst it would specialise and intensify the characters of the forms which these islands originally claimed as their own.

The case of other islands presents equally and in some cases even more notable and characteristic examples of the influence of isolation from or, conversely, of long-continued connection with continents upon the included life. Very interesting is it to note the extreme differences which prevail between the islands of Bali and Lombok in the Eastern Archipelago, each island being as large as Corsica. They are separated by the Straits of Lombok, which are about fifteen miles in width at their narrowest part. Despite the narrowness of this channel—which, however, bears evidence of its

antiquity in its great depth—these islands differ far more widely in the character of their animals and plants than do Britain and Japan. On the Australian side of the Straits we find Lombok, the outpost, so to speak, of the strange Australian land that lies beyond. On the Indian side lies Bali, essentially identical with the other islands of the Archipelago in the life which has already been described. Does the theory of special creation give any rational explanation amongst its tenets for this extraordinary dissimilarity between two apparently adjacent islands? Or, if we look in vain for such explanation from the side of special creation, does the theory of evolution, which postulates the long separation of Bali from Lombok as the primary cause of the divergence of their respective fauna, offer a satisfactory solution of the problem? There can be no hesitation in our choice of explanations; since, whilst the former hypothesis presents only a speculative faith as the reason of its being, the latter is founded upon geological facts, and upon evidence derived from the distribution of life at large.

Again, in the Oriental region, and within the limits of the Eastern Archipelago itself, we may meet with abundant instances of the same great truth, that the long isolation and separation of any land, however limited or however extended its area, must entail a corresponding divergence and specialisation of its included animals and plants. The history of islands becomes, in this view of matters, especially instructive to the naturalist. Java, Borneo, and Sumatra are thus regarded in a geographical sense as being nearly connected. Java and Sumatra are geographically near, whilst Borneo is more remote from the two former islands. But, curiously enough, whilst Borneo is thus removed from the vicinity of Sumatra, its included life resembles that of Sumatra, whilst the animals and plants of these two islands taken together, differ materially from those of Java. Thus, whilst at least 13 genera of quadrupeds are known to inhabit two or often three of the other Oriental areas—Borneo, Sumatra, and the Malay Peninsula—these genera are absent from Java, and they include, as Mr. Wallace remarks, such typical forms as the elephant, tapir, and Malayan bear. There are 25 genera of birds found as a rule in Sumatra, Borneo, and the Malayan peninsula, which are yet absent from Java; these birds including the jays, gapers, hornbills, cuckoos, pheasants, partridges, and other equally familiar forms. A second fact of importance in considering the relations of Java to its neighbour islands consists in certain marked similarities, which its animals are known to present to the Asiatic Continent. The mammals and birds of Java, in a word, "when not Malayan,

are almost all Indian or Siamese." How, then, are these two series of facts to be accounted for? How are we to explain, firstly, the dissimilarity of Java from Sumatra and Borneo, and its likeness to Indian and Siamese in respect of its included life? Again we appeal to the facts of geological change for a solution of the difficulties in question. If we suppose, firstly, that Himalayan species, driven southwards by climatal or other changes, found a home in Java; and, secondly, that the separation of Java from the adjoining lands took place long prior to the isolation of Borneo and Sumatra from the Malay peninsula, we may fully account at once for the persistence of Asiatic animals in Java, and for its differences from Borneo on the one hand and Sumatra on the other. In such an explanation, let us note, we must likewise take the facts of organic variation, producing change and modification of species, into account. The peculiarities of the Philippine Islands, which were separated in their turn earlier than Java from the mainland, can be accounted for on the same principle of isolation, entailing a corresponding modification of the life of any area.

No less interesting is the history of such islands as the Azores, and Galapagos, which represent "oceanic" islands, never connected with a continent or large land area; or the history of such isolated lands as the British islands, which are clearly of "continental" origin, and which once formed part of the larger land area to the south and west: whilst such islands as Madagascar or New Zealand present us with an instance of specialised land-surfaces, whose connection with continents is a thing of the very remote past. A reference to each of these islands will serve to establish more firmly and clearly in the mind the high importance of physical change as a paramount condition in determining the distribution of life on the globe.

The Azores and Galapagos islands are typically "oceanic." San Miguel, in the Azores, is 900 miles from the coast of Portugal as the nearest continental area; whilst the Galapagos are about 600 miles from the west coast of South America. In these islands we see exemplified the characters of "oceanic" islands. They are volcanic in nature, and represent rock masses upheaved from the sea-depths. As in oceanic islands, at large, there are no native quadrupeds, and none of the frog or toad class (*Amphibia*). In the Azores there is not a single native, terrestrial Vertebrate animal—no snake or lizard being found in addition to the already specified omissions; and no fresh-water fishes exist. The rabbits, weasels, rats, and mice of the Azores, and a single lizard, occurring in Madeira and Teneriffe likewise, are all importations; and of the eels and gold fish in the lakes

of the Azores, the same opinion may be expressed. Birds, land-shells, and insects constitute the animal population of these islands. Of 53 species of birds, 31 are waders or swimmers; and whilst 20 aquatic birds are residents, 18 of the land birds are permanent tenants. With three exceptions, the 18 land-birds, however (including the quail, robin, barn-owl, starling, wood-pigeon, etc.), are common in Europe and North Africa; the exceptions being the Atlantic chaffinch and the canary of the Madeira and the Canary Islands, and the peculiar Azorean bullfinch. There are no difficulties in the way of accounting satisfactorily for the existence even of these latter species. The bird-population of the Azores, as a whole, originated in the storm-driven or chance stragglers from other lands. The oriole, snow-bunting, and hoopoe even now are occasionally found in the Azores; and as the birds are most numerous in the Eastern islands of the Azores, Europe and Africa may be assumed to be the chief sources of supply of the bird-emigrants. The bullfinch of the Azores is, however, peculiar as well as interesting in its history. This bullfinch is a marked variety of the European species, just as other Azorean birds exhibit slight divergences from our own species. We see in this bird, in fact, the beginning of that work of modification, induced by the influence of new locality on the species, to which is due the endless variety of the earth's population as a whole. The insects and land-shells of these islands present clear traces of European relationship; and the botany of the Azores, showing us 480 various species of flowering-plants and ferns, also declares that 440 of these species occur in Europe. Even of the forty peculiar species of plants, all, save six, find a near relationship in European plants; and these six are related to the plants of the Canaries and Madeira. Like the birds, the land-shells, insects, and plants have reached the Azores as emigrants from the adjacent continents and islands. Means of dispersal and conveyance are abundant; and Darwin has shown how common are the methods whereby the lower and occasionally the higher forms of animals and plants can be distributed often to vast distances from their original home. Let us for a moment consider some of these casual or accidental means of dispersal.

Many seeds will, for example, resist for lengthened periods the action of sea-water. Out of 87 kinds of seeds, 64 germinated in Mr. Darwin's hands after twenty-eight days' immersion; and a few survived after 137 days' immersion. Ripe hazel nuts, when dried, floated for ninety days, and then germinated; and "an asparagus-plant with ripe berries floated for twenty-three days;

when dried, it floated for eighty-five days, and the seeds afterwards germinated." There is thus ample time and opportunity, so far as the vitality of many seeds is concerned, to enable them to be transported safely by ocean-currents to far-distant shores. Seeds are, again, often carried, impacted in the earth of floating roots of trees; and, as Darwin remarks, even the seeds of plants taken from the crops of dead birds floating on the surface of the sea, germinate when planted. Peas and vetches, "taken out of the crop of a pigeon, which had floated on artificial sea-water for thirty days, to my surprise," says Darwin, "nearly all germinated." Living birds, next, act as efficient transporters of seeds. The hard seeds of many fruits pass uninjured through the digestive system of birds, and germinate thereafter. Even when a bird, containing seeds in its digestive system, has been swallowed by a hawk or other bird of prey, the seeds may be preserved intact during this double intussusception, and, on being disgorged by the flesh-eater, may germinate. "Seeds of the oat, wheat, millet, canary, hemp, clover, and beet, germinated after having been from twelve to twenty-one hours in the stomachs of different birds of prey; and two seeds of beet grew after having been thus retained for two days and fourteen hours. As regards insects, locusts, says Darwin, may be "blown to great distances from the land." A locust was caught 370 miles from the coast of Africa. In November 1844, a swarm of locusts visited Madeira, and Darwin remarks that, as from locust-dung he extracted the seeds of seven grass plants, "A swarm of locusts such as that which visited Madeira, might readily be the means of introducing several kinds of plants into an island lying far from the mainland." More curious still is it to discover a means of plant-dispersal in the earth which adheres to the beak and feet of birds. From the leg of a woodcock, a little cake of dry earth weighing nine grains was removed by Mr. Darwin. In this earth a seed of the toad-rush was contained, and this seed germinated. From the seeds contained in the earth adhering to the leg of a partridge, which had been kept for three years, Mr. Darwin obtained 82 plants. "With such facts before us," says Mr. Darwin, "can we doubt that the many birds which are annually blown by gales across great spaces of ocean, and which annually migrate—for instance, the millions of quails across the Mediterranean—must occasionally transport a few seeds imbedded in dirt adhering to their feet or beaks?" The agency of icefloes and icebergs, which are frequently laden with earth, and which have been known even to transport the nest of a land bird, must likewise be considered as a means whereby transport of arctic

and antarctic species may have occurred. We must lastly add to these artificial methods of plant-dispersal, the natural means which exist in many plants for the diffusion of their offspring. Winged seeds and fruits are by no means uncommon; the *pappus* or down of the Dandelion and other *Compositæ* present familiar examples of natural contrivances for securing a wide distribution of their seeds; there are some flower-heads (*Acæna*) which adhere to the fur of animals or to the feathers of birds, like our familiar "burrs"; and other plants, again, possess more special contrivances still, for securing their adhesion to the animal integument.

The dispersal of animals in the same way is accomplished by natural and casual means. The power of flight and of swimming illustrate the former; whilst the conveyance of an animal on drift-wood, or the chance dispersal of their eggs by other animals or upon plants, exemplify the accidental methods of diffusion. The minute eggs of fishes have been known to adhere to the plumage of aquatic birds; even water-insects may transport fish-ova. The young of shell-fish, like the cockle and oyster, at first swim freely in the sea, and may migrate to vast distances; and certain shell-fish (*e.g.* fresh-water snails) deposit their eggs upon aquatic plants, which may likewise be conveyed for many miles by currents. That the feet of aquatic birds may convey minute or embryonic shell-fish to great distances is rendered probable by observations of Mr. Darwin; and the same high authority remarks on the agency of aquatic birds in conveying seeds which are contained in the mud of ponds adhering to their feet. With regard to the dispersal of insects, the power of flight is seen to confer obvious advantages upon this class of animals. Even quadrupeds appear to possess occasional powers of dispersal, which may account for their presence in situations that at first sight would seem inaccessible to the race. The tiger is known to be a powerful swimmer; and the pig, popularly credited with being inefficient in the water, has been proved to be a swift swimmer likewise. Quadrupeds may also be conveyed long distances on driftwood, and may thus chance to be deposited in localities far removed from their original habitat.

There is little difficulty in accounting for the mechanical means and conditions whereby the dispersal of animals and plants is secured. Hence returning to the question of island-population, we find in the Azores a collection of animals and plants, obviously derived from adjoining areas, and which has as yet had but little time to develop, through variation, a general distinctness of its own.

The Galapagos Islands present, as we have seen, the common

features of "oceanic" islands, in the absence of native quadrupeds and amphibians, and in the fact that they are of volcanic origin. They differ from the Azores, however, in that they possess two species of snakes, lizards, and land-tortoises—the latter being of large size. A single mouse exists in these islands; but this quadruped belongs to an American genus, and was probably introduced, since these islands have been largely visited for 300 years back by sailors. The tortoises are regarded as having been derived from the American continent, and the lizards, of which there are five, are likewise typically American in their character. That tortoises and lizards can travel for long distances by water cannot be doubted; and the fact that snakes occur in the Galapagos, and may have reached these islands by swimming—seeing that they are related to South American serpents—is explained by the knowledge that snakes may swim for long distances. A boa constrictor has been known to swim to St. Vincent from the South American coast, a distance of at least 200 miles. The birds of the Galapagos number 57 species—38 species being peculiar to the islands. But the study of the birds is rendered extremely interesting by the fact that we notice amidst their ranks all shades of likeness and divergence from continental forms. Some species are identical with American birds, whilst others are different from well-nigh all other bird forms. Thus there is the rice bird of Canada and the United States remaining unchanged in the Galapagos Islands; whilst the short-eared owl, which, as Mr. Wallace says, "ranges from China to Ireland," evinces a slight variation in its Galapagos form from the familiar home bird. The finches and sugar birds of the Galapagos exist as distinct genera, and represent forms which, restricted in range even in South America, have kept their chief peculiarities intact, and have developed others sufficiently distinct to render their race peculiar to these islands. Casual migration, along with a comparatively undisturbed residence in these islands, together explain the distinct character of the bird population, as well as of the lower denizens of the Galapagos.

If the effects of land-separation and isolation are typically witnessed in the case of the "oceanic" islands, the opposite results of recent land-connections with continental areas are seen in the history of the "continental" islands. Of these islands Great Britain and Ireland form typical examples, as likewise do Japan, Borneo, Java, and other areas. The "continental" islands evince a close connection with the motherland in the usually shallow sea—not as a rule exceeding 100 fathoms in depth—which separates them from the continent. They possess quadrupeds and reptiles, and these animals,

along with the remaining fauna, exhibit, as a rule, a close likeness to the life of the larger area. All around the British Isles the 100-fathom line persists, and joins Britain to Denmark, Holland, Belgium, and France, as well as to Ireland on the west. The geological proofs of our "recent" union with the continent are numerous and indisputable. Probably after the greatest intensity of the glacial epoch, Britain joined the continent for the last time; and as our quadrupeds are identical for the most part with those of France and the continent, there can be little hesitation in endorsing the geological opinion from the zoological standpoint. Possibly submergence after Britain received its continental migrants, may account for our paucity of species, when compared with continental life; this subsidence destroying and limiting what would otherwise have been an abundant fauna. For we discover that whilst Belgium has 22 species of reptiles and amphibia, Britain possesses but 13, whilst Ireland has but 4 species—this latter result being due to the depth of the Irish Sea, which is greater than that of the German Ocean: a fact pointing to the more remote separation of Ireland, as compared with the continental connections of Britain. Our islands possess, it must be remarked, certain peculiar birds; they are rich in peculiar fishes, and probably in mosses of special kinds as well. But whilst these peculiarities point to the existence of conditions which favour specialisation of form, they do not in any sense oppose the idea—strengthened into absolute fact by all the considerations of geology and biology—namely, that at no remote date, but "recently" in a geological sense, the "land of the free" itself had no special identity of its own, and that all its future individuality was merged in its continuity with the great continental area around.

A brief reference to the peculiarities of Madagascar and New Zealand may serve to conclude our reflections on islands and detached land areas, as illustrative of the geological factors which regulate the distribution of life on the earth's surface. The peculiarities of New Zealand as a biological province have already been discussed. Its want of native mammals and snakes, its single frog, its peculiar lizard, and its living and extinct wingless birds, as well as certain characters of its plant-life, mark it out as especially peculiar. No less specialised and peculiar, on the other hand, is Madagascar, the zoology of which has likewise been described. The differences of its animals from those of the African continent; its peculiar lemurs; its special insectivora and carnivora, and rodents; and its other biological features, render this great island a highly specialised part of the world's surface. New Zealand and

Madagascar stand out prominently before us as examples of "ancient continental islands." That "once upon a time" they formed part of a continental area, no one may doubt; but that their separation has been so remote as well-nigh to justify the appellation of "oceanic" islands, is also a logical deduction from their biological history. In Madagascar and New Zealand are beheld, in a word, the effects of isolation, which, depending in turn upon geological changes and the submergence of land, gives to the latter agencies their great power in modifying the life of the globe. "Such islands," says Mr. Wallace, "preserve to us the record of a bye-gone world—of a period when many of the higher types had not yet come into existence, and when the distribution of others was very different from what prevails at the present day." It is in islands such as Madagascar and New Zealand, that we see preserved to us the remnants of a fauna that may once have been of world-wide extent. Mr. Wallace, again, remarks that "A partial subsidence will have led to the extinction of some of the types that were originally preserved, and may leave the ancient fauna in a very fragmentary state; while subsequent elevations may have brought it so near to the continent that some immigration, even of mammalia, may have taken place. If these elevations and subsidences occurred several times over, though never to such an extent as again to unite the island with the continent, it is evident that a very complex result might be produced; for, besides the relics of the ancient fauna, we might have successive immigrations from surrounding lands, reaching down to the era of existing species." Thus, in the life of Madagascar, we see the results of isolation interrupted by periods of connection with large continental areas. The fact that the lemurs of Madagascar exist likewise in West Africa, in the Indian region, Ceylon, and the Malay Archipelago, is explicable—not by supposing a direct land connection occupying the site of the Indian Ocean—but by regarding these animals as presenting us, in Madagascar, with the remnants, secured from harm by isolation, of a once widely distributed lemur-population. This group of animals, doubtfully classified to-day as the lowest order of the monkey-tribe, as we know from the evidence of fossils, overran Europe in the Eocene period of geology. We know that Africa was separated from Europe and Asia in the Tertiary period by a large sea-area. Thus, late in its history, were outlined the bounds of the Ethiopia which the biologist has defined, and which, as we have seen, has the desert region as its northern and natural boundary. Joined to Africa in its earlier phases as an island, Madagascar doubtless

received from Africa the lower quadrupeds, reptiles, insects, and other forms bearing evidence of a distant Australian or New World relationship. Then came the separation of Madagascar from the African continent—a phase of its history which left that island to mature and develop the modified and peculiar species we see within its limits to-day. At the same time this separation protected it from the inroads of the higher animals coming from the north, which we now find amongst the existing African fauna.

Similarly, the problem of the likenesses and differences between the life of New Zealand and Australia are explicable only upon the idea—supported by strong geological evidence—of land changes of curious and complex character. Thus East Australia must have been separated from Western Australia in the Chalk period; and whilst New Zealand was connected by shallow water with tropical Australia, it was sharply demarcated from temperate Australia by a deep sea. Thus is explained the fact of the plants which are common to Australia and New Zealand being tropical and sub-tropical in their nature. Direct land-connection between the two countries, but a connection which at the same time was anything but equivalent to continuity with existing Australia—seeing that the latter was practically halved in the Chalk period—explains the means whereby the underlying likeness between the life of these islands was established.

By way of establishing still more firmly the truth of the axiom that physical change forms one of the two main factors involved in the regulation of life and its distribution, we may lastly glance at the history of that peculiar race of quadrupeds, the *Marsupials*, or "pouched" mammals, in their relations to Australia as their head-quarters and home. These animals, possessing the kangaroo as their most familiar representative, are, with one exception, confined to Australia, along with certain other and lower quadrupeds, such as the *Ornithorhynchus* and *Echidna*. The exception to the rule that the two lowest orders of quadrupeds are confined to the Australian region is the opossum family (*Didelphidæ*), which occurs in the New World. Bearing in mind the facts that, firstly, save a few recently introduced bats and a rodent or two, Australia has no native mammals of higher grade; that, secondly, the kangaroo and its neighbours represent in that land the fulness of quadruped-life elsewhere; and that, thirdly, save the opossums, those animals are absolutely confined to Australia,—how, it may be asked, are these peculiarities to be accounted for? If the theory of special creation be appealed to, it would find it necessary to insist, in

virtue of its own terms, that the marsupials were created where we now find them. Such a theory, however, supplies no intellectual reason why the opossum, a typical enough marsupial, should have been created in the New World, and thus have been left mysteriously and arbitrarily outside the limits of the Marsupial or Australian territory. Let us endeavour to ascertain what explanation of these apparently anomalous facts the science of distribution can afford.

Firstly, from the geological side comes the evidence that Australia has never possessed, at any time, any native quadrupeds of higher type. All the fossil remains of the Tertiary and Post-Tertiary Age discovered in Australia are those of Marsupials, often of giant size, but still allied to the existing quadrupeds of the region. But geology opens up a new vista of thought before us when it reveals the fact that in the earliest Tertiary period Marsupials occurred in Europe, these being the remains of opossums. In older deposits—that is, in the Oolite and Trias—of Europe, occur the remains of Marsupials, some of which are well-nigh identical with the little banded anteater (*Myrmecobius*) occurring in the Australia of to-day. Passing to North America, we discover in the Triassic rocks of that continent the *Dromatherium*, likewise an ally of the living anteater of Australia. So far, therefore, from Marsupials having mysteriously sprung into being in Australia, we discover that in Triassic times they existed not only in Europe but in North America, and that, in fact, they may be regarded as having possessed a wide Palæarctic range in that period and in its succeeding Oolitic epoch likewise.

Let us note, again, that the marsupial and allied quadrupeds resembling the ornithorhynchus were the oldest and earliest in time, as well as the lowest in structure. The problem of the origin of the Australian quadrupeds and of their distribution is not now difficult of solution. We pass backwards in imagination to the Triassic and Oolitic times to behold, then, the dawn of mammalian life. We see the Marsupial tribes representing, in the ancient Palæarctic region, the fulness of the quadruped life that was afterwards to dawn. No higher form of mammalian existence was then to be seen. The carnivora and rodents, the bats and apes, the hoofed quadrupeds, and the variety of mammalian life that marks our day, was as yet unknown. But Australia at this period is in geographical connection with the Asiatic continent. Over a continuous land-surface, these earliest quadrupeds pass to people the Australian territory. Next comes the separation of Australia from Asia. The Malay Archipelago represents the broken and divided land-connection, first severed probably at the Straits of Lombok. The higher tribes of quadrupeds are

evolved from the lower tribes in the ancient Europeo-Asiatic continent. The defenceless lower Marsupials are worsted in the "struggle for existence" that ensues. The higher "tooth and claw" exterminate the lower races in the Palæarctic region; but in Australia the isolated, these Marsupials, free from the irruption of later carnivores with tooth and claw, and protected by the intervening sea from the inroad of the higher quadruped-races, flourish and grow. As time passes, the original species of Marsupials—that is, the first emigrants to Australia—vary, and, through variation, produce new races and species of these quadrupeds. Australia in due time developes a quadruped population of its own, which repeats the varied features of mammalian existence elsewhere. Thus again there is presented to our view an illustration of the double work of land alteration and specific or biological change, in developing a strange and wondrous population on the surface of the earth.

Last of all, the history of the opossums and their distribution, now limited to the New World, falls under the sway of the same efficient explanation, supported by every fact of life and by all the details of geological science.

Commencing their existence in the Palæarctic region—their fossil remains occurring, for example, in the Eocene rocks of France—the opossums represent a race which never at any period of their existence have dwelt in Australian territory. Their occurrence in America is explicable, not on any theory of possible connection between America and Australia, but on the plain hypothesis of their migration to the New World by a continuous land-surface in the middle or towards the end of the Tertiary period, from Europe or from Northern Asia as a centre. Their earliest fossils, in the New World, occur in the American Post-Pliocene—that is, long after their first appearance in European formations. Passing thus to the New World, the opossums migrated southwards, where they flourished and grew apace, comparatively unmolested by carnivora or other enemies. Again extending their range northwards, they are found in North America; and they thus represent in the Western Hemisphere a flourishing remnant of a race killed off from the Old World, and driven, by stress of outward circumstances, to seek refuge in the New.

Not less interesting is it to find that the existing life of Australia at large fully endorses the biological dictum that in this island territory we find still represented the life which was once world-wide in its extent in the Triassic and Oolitic period, in which period Australia severed its connection with the Asiatic continent. As the Marsupial

quadrupeds of the Oolite overran the existing land area of that day, so they flourish, and flourish alone, in the Australia we ourselves know. As the spine-bearing Port Jackson shark swims in the Australian seas to-day, so the spiny fishes *Acrodus* and *Strophodus* swam in the Oolitic seas that washed Palæarctic and other coasts. As the shell-fish *Trigonia* lived in the seas of the Stonesfield Slate period around our shores, so that *Trigonia* still persists on the Australian coasts alone. And, lastly, as the Araucarian pines and cycads grew in Oolitic times in our own area, so they grow now in Australian territory—a remnant, like the quadrupeds and fishes, of a flora and fauna once well-nigh universal, but now limited to the region of the earth wherein alone the original conditions of their life are truly represented.

If geological change isolating or uniting land areas, and the variation and modification of species consequent upon such separation or union, be thus credited with constituting the great factors and powers which have produced the existing distribution of animals and plants, and which have regulated that distribution in all time past, we may now briefly glance at the main features which the great biological regions of the world have exhibited in relation to the changes and alterations of their boundaries they have from time to time undergone.

Whilst the late Sir Charles Lyell and other geologists were found not so long ago to declare that the great continents of the world "shift their positions entirely in the course of ages," a clearer understanding of geological evidence has completely established the doctrine of the permanence of the great continental areas, and of the general stability in time of the main masses of the land. It is needful to make ourselves acquainted with this fact, inasmuch as, if the distribution of life depends primarily on the distribution of land and sea, a clear understanding of the agencies regulating the development of animals and plants on the globe will be gained only when the physical changes in question are duly appreciated. The geological evidence, then, goes to prove that, whilst the general mass of the continents has remained unchanged, their minor features and more intimate details have been subjected to frequent disturbance. Thus in the past, as at present, the uniformity of geological action postulates the work of rivers in eroding the land, of the sea in defacing the coasts, of ice in carving the land surface, and of volcanic action in depressing this area or elevating that, and in causing the sea to flow here, or to repress its march there. Professor A. Geikie maintains that the stratified rocks, instead of being formed in the beds of deep

oceans, "have all been deposited in comparatively shallow water." And, again, this eminent geologist remarks of the manner in which this earth's materials have been formed, that "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," adds Professor Geikie, "are the deposits of comparatively shallow water."

Thus with the proofs of the general permanence and stability of our great continents at hand, we can completely account for all the plainer facts, and for many of the difficulties, of distribution. For example, we infer that about the middle of the Tertiary period, Europe and Asia, as at present, formed one continuous land surface, which contained as its inhabitants the elephants, rhinoceroses, giraffes, apes, and other forms now found only in the Oriental and Ethiopian regions. Antelopes were then found in Southern Europe, and the giraffes extended from the South of Europe to the North of India. But we must likewise take account of those more intimate changes of land and sea which accompanied the general permanence of the continents. At the time we are considering, Africa south of the desert was a large island; India and Ceylon were isolated by sea from Asia; Northern Africa was united to the South of Europe; Asia Minor was joined to Greece;—the outlines of the great zoological regions of the Old World were, in short, actually mapped out in the middle of the Tertiary period in the then existing lands and seas. But neither the detached India nor the isolated Africa possessed the abundant quadruped life of Europe and Asia. They possessed only the lower life of the Eocene time. When, however, the next series of physical alterations took place, when land passages arose between Europe and Asia together on the one hand, and Africa and India on the other, the higher quadrupeds migrated to these areas. There some adapted themselves to their new conditions, and flourished in their new localities, whilst others succumbed to the more rigorous surroundings which faced them. The antelopes, for instance, migrating to Africa, flourished in Ethiopia, because there they found a plentiful vegetation and the other conditions of life calculated to produce the development of new species by the modification of the old. The bears and deer are unknown in Africa, on the contrary, since they were later comers in European territory, and because they found migration a difficult or impossible task. The fauna which Europe then gave to Ethiopia was killed off in the former by the climatal changes which succeeded these

Miocene times, and which left the region to be peopled after the glacial cold, by the hardier forms which we now call our representative animals. Similarly, India as the Oriental province possessed when detached from Asia its own lower Edentates, and its lemurs; but when it became united with the Asiatic continent, it received from the north, like Africa, its new complement of animals—its monkeys, tigers, elephants, and other forms—these animals arising in the ancient Palæarctic land, whence, as we have seen, the earlier marsupials themselves migrated to people the other quarters of the globe.

The history of the New World is equally instructive, both as regards the proofs it supplies of the permanence of the continents, along with the evidences of the same laws of dispersal and migration of life which the consideration of the Old World areas affords. The first fact of importance in the scientific history of the New World areas consists in the knowledge that in the Post-Pliocene times the life of the Nearctic region approached very closely to that of the Palæarctic province. In the Post-Pliocene formations of America, we find the fossil remains of numerous carnivora, horses, camels, bisons, and elephants. Of the living elephants, as we have seen, the existing New World knows nothing. The horses were reintroduced by man; whilst the buffalo certainly represents the bisons, and the llamas similarly represent the camels. Before the Post-Pliocene time, geology reveals that America possessed rhinoceroses, special forms of ruminants, and a porcupine decidedly of Old World type. In the still earlier Miocene period, North America had its lemurs—now limited to India, Africa, and Madagascar—many carnivora, camels, deer, and tapirs. Earlier still, that is, in the Eocene period, there lived in North America animals unlike any forms now existent. There were the Tillodonts and Dinoceratidæ of Professor Marsh, which appear to have united in themselves the characters of several distinct orders of quadrupeds. There is thus every reason to believe that in the Post-Pliocene period, at least, and in earlier times likewise, there was free land communication between the Palæarctic and Nearctic areas. So that it requires no stretch of hypothesis to assume that the horses, camels, elephants, and other quadrupeds of America—proved to be near allies of European fossil forms—must have freely intermingled with those of Europe. That Europe, or, more properly, the Palæarctic region, must have been the original source whence the Nearctic land obtained its mastodons, porcupines, deer, and other quadrupeds, is proved by the fact that these animals are known to have lived and flourished in Europe long

before they occurred in America. So that, as Mr. Wallace puts it, "As the theory of evolution does not admit the independent development of the same group in two disconnected regions to be possible, we are forced to conclude that these animals have migrated from one continent to the other. Camels, and perhaps ancestral horses," adds Mr. Wallace, "on the other hand, were more abundant and more ancient in America, and may have migrated thence into Northern Asia." The physical difficulties of such a land connection at Behring's Straits or across Baffin's Bay, are not, it may be remarked, by any means insuperable.

Then, likewise, we must take into account the share which South America, or the Neotropical region, has had in influencing the distribution of life in the New World at large. North America seems in the Post-Pliocene epoch to have been a literal focus wherein Palæarctic life commingled with life from the South. Thus the North American Post-Pliocene deposits give us sloths and other forms of Edentate mammals, llamas, tapirs, and peccaries, all of which are typically South American; whilst some are identical with living Neotropical species. The bone-caves of South America show us that this region, like Australia, possessed in Post-Pliocene times the same description of quadruped life that now distinguishes it. As giant kangaroos lived in Australia, so gigantic sloths and armadillos lived in South America; and its chinchillas, spiny rats, bats, and peculiar monkeys were likewise existent then as now. In addition, we find that, as North America possessed its peculiar groups of lower quadrupeds in its tillodonts and other forms, so South America likewise had its special types of life, such as the *Macrauchenia*, resembling the tapirs, and the *Toxodonts*, related at once to the hoofed quadrupeds and to other groups. But, whilst the quadruped immigrations into North America likewise affected South America, it must be borne in mind that the isolation and separation of South America from the northern part of the continent, as indicated by its regional distinctness, must have largely influenced the development of its own peculiar life—just, indeed, as the peculiarities of North America are due to its separation, in turn, from the Palæarctic area. And when we further discover the all-important fact that the fishes on each side of the Isthmus of Panama are identical, the theory of the relatively recent continuity of sea at this point, and the consequent separation of Neotropical from Nearctic land, rises into the domain of fact. Thus we see in North America a region which has repeatedly received and exchanged tenants with the great Europeo-Asiatic continent; which has, in consequence, developed a

close resemblance to the life of the Palæarctic region; and which has, likewise, been to a slight extent modified by the migration northwards of southern forms. In the life of South America we perceive, on the other hand, the results of longer isolation and greater specialisation. There the development of special forms of life has accordingly progressed to a much greater extent than in North America; and the effect of a commingling of types has been largely prevented by its relatively recent junction with Nearctic land. As in Australia, the lower types of quadruped life have been preserved by the isolation of that area, so in South America, the preservation of the sloths, armadillos, and anteaters, and the development of special forms of monkeys and other quadrupeds are to be regarded as the fruits of that separation which secures protection to lower and comparatively defenceless life.

A glance at some of the difficulties of distribution, and a reference to the influence of migration upon the distribution of life, may draw our consideration of this topic to a close. The progress of any science from the stage wherein it formulates its beliefs in theory, to that when its theories rise through cumulative proof into the higher region of fact, is not accomplished without trial and tribulation. Criticism, destructive and constructive, is the lot of every scientific theory. But the earnest and unbiassed mind welcomes the criticism wherein the trial of its beliefs is contained, as the honest mind gauges the tenability of its beliefs by the residue, large or small, of solid fact which it is able to collect after the critical assault upon its stronghold is overpast. Of the science of distribution it may be said that its evil days are fairly past. Critics it has had, and biological opinions may even now be found to differ regarding the minor details of its constitution. But the larger and more fundamental propositions of distributional science remain untouched. They have passed out of the sphere of discussion, and have taken their place amongst the stable facts of the scientific system. It is necessary, however, to detail one or two examples of the difficulties which may still disturb the complexion of the scientific mind, and which are ever welcome to the devotees of a science, since they afford the means whereby the weak points and the unsettled problems of the science may be strengthened and solved.

Of such difficulties, then, let us specify a few instances, by way of showing how readily their solution may, through careful consideration, be obtained. Mr. Sclater has specified in a highly distinct manner, a few of the knotty points that await the student of distribution, and has thus afforded opportunity for the discussion of the

subject, and for their explanation or modification by the exercise of scientific acumen and research. Taking the case of the lemurs—those curious quadrupeds usually classified as lower monkeys—we are presented with certain apparent anomalies in their distribution over the surface of the globe. Thus the lemurs have their head-quarters in Madagascar, as already remarked, but they also occur in the Eastern Archipelago. They are scattered, to use the words of Mr. Wallace, "from Sierra Leone to Celebes, and from Natal to Eastern Bengal and South China." How, it may be asked, can the apparently erratic nature of the distribution of these animals be accounted for? and how can the facts of such a straggling population be harmonised with those conceptions of orderly biological and physical laws on which the science of distribution bases its existence?

Mr. Sclater himself, in 1864, postulated the former existence of a continent occupying the site of the existing Indian Ocean. This continent, named *Lemuria*, he conceived might have formed the head-quarters of the lemur group, whence they became radiated and dispersed east and west. Such a hypothesis is no longer required, however, to account for the curious distribution of the lemurs. In the light of new facts, and especially in the face of geological evidence, the existence of the theoretical "Lemuria" is rendered unnecessary. Mr. Sclater's perfectly justifiable supposition has simply been superseded by more natural explanations of the distribution of the lemurs, whilst the views entertained regarding the permanence of the great ocean basins and of the continental land areas are likewise opposed to the theory of a former land-connection between the Ethiopian and Oriental territories. For what are the geological facts concerning the range of the lemurs in the past? Their fossil remains occur in the Eocene rocks of France—that is, in the lowest and oldest of the Tertiary deposits—the remains in question being those of a form allied to the existing "potto" of West Africa; and in North America, where the lemurs exist to-day, the Lower Eocene rocks afford evidence of their existence in the past of the New World. So that we find at the outset our difficulties largely resolved by the bare mention of the idea that the existing anomalies in the range of the lemurs really depend upon their past history. In a word, as the "Marsupial" population of Australia is to be regarded as a survival, owing to land separation, of an animal class once world-wide in its range, so the lemurs now found at distant points in Africa and Asia, are merely the survivals of a lemurine family circle once represented both in the Old World and in the New. We know of their existence in

Eocene times in Europe, and thence they probably spread in all directions—to Africa, Madagascar, Asia, and elsewhere. Killed off over the general area inhabited by their race, the lemurs have remained in the environs of the earth, so to speak, because there, to this day, the competition with higher forms is not too severe. Like the American opossums, the lemurs represent to-day the mere remnants of a once world-wide class. Their distribution has not been one from Asia to Africa, or *vice versâ*, through a once existent "Lemuria," but has really been a diffusion from Europe, or the Palæarctic region probably, to the adjoining regions and to the New World.

A second case of difficulty in connection with the distribution of quadrupeds is that of the peculiar animals forming the order *Insectivora*, a group familiarly represented by the moles, shrews, and hedgehogs. This order of quadrupeds is highly singular in its range and distribution. It is entirely unrepresented in Australia and South America, and its representative species occur in the Palæarctic, Oriental, and Ethiopian regions; whilst North America also possesses moles and shrews, probably of very recent introduction into that continent. But more curious still is the fact that the Insectivora include certain peculiar and isolated animals, which inhabit detached regions, and which present problems for solution in the way of an explanation of the how and why of their existence on the earth's surface. For example, a curious animal (*Solenodon*) is found only in two West Indian Islands, namely, in Cuba and Hayti. Again, the nearest relations of *Solenodon* occur in Madagascar, where, under the name of the *Centetidæ* or "Madagascar hedgehogs," they flourish in numbers. Thus we are required to explain the following facts: Firstly, the detached existence of *Solenodon* in the Antilles; secondly, the similarly isolated distribution of the species of *Centetes* in Madagascar; and thirdly, the absence of any species of *Centetes* in the intervening African continent.

In attempting to solve these problems we find that the way of investigation lies along the same lines as those which lead to a solution of the case of the lemurs. The existing Insectivora are small animals, mostly living in areas where they are removed from the direct effects of competition with other and stronger forms. Their fossil history is fragmentary but important; for we discover a link that connects *Solenodon* of the New World with *Centetes* of the Old World, in the fossil *Centetidæ* which occur in European deposits of Lower Miocene age. With even this solitary fact at hand, we begin to discover that the problem before us is not the bridging of the gulf between the West Indies and Madagascar, but the simpler

task of accounting for the survival in out-of-the-way corners of the earth of a group once far more widely distributed. Thus Madagascar obtained its species of *Centetes* just as the West Indies obtained their *Solenodon*, namely, at a time when land-connection with a larger land-area permitted these insectivores to gain admittance to what was shortly to become a detached island-area. As has been pointed out, the conditions of life which exist in Madagascar closely resemble those of the Antilles, and both differ in turn from the conditions that prevail on the adjacent continents. There is an absence of large quadrupeds, a lack of carnivores, a complete separation from larger areas by deep sea, and, in fact, a full representation of all the conditions which suit these insectivores, just as conversely on the continents the conditions are unfavourable to the prosperity and increase of their race. We do not require to connect the Antilles and Madagascar on account of these animals, any more than we need to postulate the existence of a former Pacific land-connection between Asia and America because the camels of the former continent are related to the llamas of the latter. And when we further reflect that Madagascar preserves a mouse nearly related to a New World type, and snakes belonging to a typical American group, we at once note how the principle of seeking to prove the former wide distribution of a race of animals and its modern limitation by geological and biological changes forms the best clue to many of the difficulties of this science. It is a clue, moreover, which is at once originated and supported by the fossil histories of the animals whose distribution is the subject of remark.

A third case which has excited the attention of students of distribution is that concerning the past history of the giant tortoises found in the Mascarene and Galapagos Islands—the former belonging to the Madagascar group, and the latter being situated 600 miles from the South American coast. Of these tortoises, as Dr. Günther has shown us, three chief groups exist. One of these inhabits the Galapagos, a second occurs on the coral island of Aldabra to the north of Madagascar, and a third, which has become extinct, inhabited the Mascarene group of islands. But our difficulties are lessened in this case—which demands the explanation of the existence of apparently similar forms in widely-removed areas—by the knowledge that these tortoises, though apparently related, in reality belong to distinct types, and that, therefore, the necessity for presuming a connection between their distribution thus disappears. The Galapagos tortoises may be presumed to have come from the American continent; and as these animals can survive long exposure to sea, and are tenacious of

life, their own conveyance or that of their eggs, on driftwood for example, is a hypothesis involving no great demands upon a scientific imagination. The Mascarene tortoises may have similarly been conveyed from Africa; and there is no greater difficulty, therefore, in accounting for the detached existence of these great reptiles, than in explaining how their more diminutive kith and kin, belonging, like the giant tortoises, to different groups, have acquired such an extensive range over the earth's surface. Indeed, the case of the tortoises may serve to remind us of that of *Bassaris*, an animal formerly regarded as a kind of weasel or civet, but shown conclusively by Professor Flower to belong to the racoons of the New World. Bassaris, however, inhabits California, Texas, and Upper Mexico, and when it was regarded as a "civet" (*Viverridæ*), an anomaly at once arose, since all known "civets" inhabit the Old World. But when the supposed "civet" was proved to be a member of the racoon group, all the difficulties of the case vanished; inasmuch as, being one of the *Procyonidæ* or racoons, it fell naturally into its habitat, since all the members of this family are limited in their distribution to the New World. An error in classification may thus generate anomalies in distribution which further research proves to have no real existence.

These illustrations of the manner in which the difficulties of distribution are resolved may serve to show besides the wide demands which this science makes upon well-nigh every department of natural science. The issues of distribution, in fact, involve an acquaintance with the entire range of not merely biological study but of geological investigation as well; whilst the deductions of distributional science, more perhaps than those of any other department of biology, open up before us the widest possible vista of human knowledge, and link together the varied interests of workers in every field of natural-science study. Nor is it in the grander aspects of this science that its far-reaching extent is alone to be seen. Even the apparently trivial details that constitute the story of the life existing on a barren and desolate islet may play an important part in the solution of questions dealing with the nature of life in its highest grades. And thus availing itself of knowledge from every source, this department of biology, more forcibly perhaps, as a whole, than any other branch of life-science, demonstrates how the true history of the existing universe is a history of variation and change—a chronicle, whereof the materials for each fresh chapter are derived from the lessons and the teachings of both the remote and the recent past.

ANDREW WILSON.