CHAPTER XIV.

Distribution — Nature of the Subject — Distribution in "Space and in "Time" — "Geographical" Distribution: its Division and Aspects—"Zoological Provinces"—Conditions affecting the Distribution of Forms in Space—Law of "Geographical Succession"—Homomorphism and Distribution—"Bathymetrical" Distribution — Deep-sea Life—Forbes' "Zones" of Marine Life—History and Progress of Deep-sea Exploration —Conditions of Life in the Depths of the Sea—Influence of Pressure—Light—Temperature—Food-supply, etc.—Distribution in Time—General Considerations—Fossils—Life-Epochs —Imperfection of the Geological Record—Conclusion.

THE last or *Distributional* aspect of biological science has reference to the conditions under which the living organism now exists in the world, and to those under which it may have existed in time past. We have already seen that our examination of the structural and functional relations of a living being places us in possession of full information regarding the organism, both in its young state and in its adult form. But if our survey of the organism is to be complete in the true sense of the term, we have in addition to these points to investigate the relations which the living being bears to the world or medium in which it exists. To such relations, as distinguished from those elicited by the morphological or physiological survey of the being, the term "external" or "objective" relations is not unfrequently applied.

The "distributional" or "objective" relations of living beings admit of being studied from a twofold yet connected aspect. We may firstly direct our attention to the conditions in which the organism exists in the world around us; in what districts or "areas" it is found, and from what localities it may be invariably absent. This first aspect has therefore reference to the "geography"

of living forms; to their "geographical distribution," or, as it is occasionally termed, their "distribution in *space*."

The present history of an organism or series of organisms has generally and inseparably bound up with it the history or record of a past. This latter or past history has reference to the conditions under which the organism or series was represented in certain anterior or past epochs of our world's history, which the researches of the geologist and palæontologist have led us to recognise as possessing a definite existence. To this latter and second aspect of distributional science the names of "geological distribution," or "distribution in *time*," have accordingly been given.

These two aspects of our present subject, it is almost needless to say, are related to each other in the most intimate manner. The circumstances and facts elicited by a study of the one aspect or section, must usually be taken in connection with the generalisations of the other. The distribution of a form in the present may vary greatly, or, on the contrary, may vary but little, from the conditions under which it existed in the past; but in either case the two aspects will generally be found to be mutually explanatory, and in some cases the aid of the one is absolutely necessary to the proper understanding of the other.

The advice of Professor Greene with regard to the study of distribution, "to separate the facts of the science from the various theories which have been devised to explain them," is, I think, an exceedingly wise and useful caution in these speculative days. Since the biological student will not in any case extend his knowledge, or wander very far out of the more beaten tracks, without finding that a special theory has in very many instances been made and adjusted to the "facts of the science," without the slightest regard to the primary conditions or circumstances from which the facts take origin. Thus, as we have before had occasion to remark, and to select a single example, the doctrine of "special creation"

assumes the existence of special or "specific" centres of creation and distribution for the various species of living forms; and that their subsequent distribution radiated from these central points to a greater or less extent, and until it was checked and limited by natural barriers or conditions. Such a theory necessarily involves stated notions as to the distribution and subsequent modification of living forms. And other hypotheses similarly profess to explain the probable causes of distributional variations on grounds consistent enough with the facts as they stand, but which exhibit many flaws and deficiencies when subjected to a careful scrutiny and analysis.

The terms "flora" and "fauna" are respectively used to conveniently and shortly express the vegetable and animal population of a district, zone, or country; and concerning the aspects of the "Geographical" distribution of living forms, to which, in the first place, we may conveniently turn our attention, we have to notice the division of this subject into three sections. Thus we may firstly investigate the relations of the organism to the "medium" in which it lives. The conditions of existence on land, in air, or under water, and the consequent adaptations for that existence, may thus be considered under this first head. Then, secondly, we may direct attention to the "lateral" or "surface" distribution of animal forms; that is, to the purely "geographical" aspect of the subject. In this way we may take cognisance of the extent of surface or of the "area" over which the distribution of a form may extend; or we may note the limits by which its distribution is bounded or confined. And lastly, we may investigate the "vertical" or "bathymetrical" distribution of living organisms; this latter aspect having reference to the distribution of forms relatively to the "depths" or "vertical surfaces" amid which they may be placed. The investigation of the depths of the sea thus falls under the consideration of this third head or aspect of the present subject.

The entire subject of distribution, it is to be noticed, is one which is at present in a somewhat chrysalis-like

state; the rapid extension of our information and ideas bidding fair to place this department of biological science on a footing wholly and entirely different from that in which it now exists, and to evolve new conceptions of the conditions of life, particularly in the lowest organisms. The present sketch can therefore embrace only the most general of considerations; and even these must be made with some reservation in prospect of the new facts which the progress of current research is almost daily bringing to light.

The naturalist, in considering the distribution "in space" of living forms, finds it convenient to divide the surface of the globe into a number of definite "areas" or "provinces," known generally as "zoological" or "botanical provinces." These "provinces" together make up the distributional world, just as continents collectively constitute the world in a purely geographical sense; but concerning the exact limits and extent of these individual provinces naturalists are by no means agreed.

The various "species" of forms which compose the organic whole, vary widely in their general distribution, as also in the more special limits by which the distribution of each individual or single species is bounded or confined. In the same way that a general similarity of appearance serves to reconcile and unite together the various "species" found in a "genus," so the various forms included in a distributional "province" are generally united to each other by certain relations of a more or less intimate and definite kind. These relations, it must however be borne in mind, are not *necessarily* of a structural character, or dependent upon the presence of a true specific relationship between the forms which inhabit the province. Although, therefore, closely-allied "species" may be situated within the same area or portion of an "area," the intimate nature of their distributional relations does not necessarily indicate any other association than that which may be said to depend or follow upon an exposure to surrounding and similar conditions.

The conditions and circumstances which regulate the

"lateral" or surface distribution of living beings, and from which extensions or limitations of distribution have taken origin, may be regarded as chiefly dependent on physical causes, which affect to a greater or less degree the life and habits of the forms included within a given area. The influence of physical conditions upon the organisms inhabiting the globe, has formed the basis of not a few of the theories relative to the specific origin of, and to the differences between, the forms that people the universe. And although we may not assume that these conditions are capable of affecting the living organism to the extent demanded and advocated by such theories, there can be no doubt of the very definite influence which surrounding conditions exert upon a living being placed and situated in their midst.

The study of physical geography aids us in framing correct generalisations with regard to the geographical distribution of living forms; and serves at the same time to impress upon us the due influence upon animal and plant life of the conformation of the earth's surface, and of the conditions which follow or depend upon any particular disposition of physical agencies.

Thus the existence of a mountain-chain may produce visible and apparent effects in the distributional aspects of a zone or territory. The intervention of a chain of mountains may divide closely-allied, or even a single species, and necessitate their classification in distinct and separate "zoological provinces." And the same condition which prevents the union of such species may similarly tend to limit the migratory or spreading tendencies assumed to be inherent in most forms. The separation of tracts or lands by rivers, seas, or oceans, has a corresponding and definite influence in the division of species or groups, and in the localisation of forms.

Other conditions, however, must also be included in the list of physical agencies affecting the distribution of animals or plants. The influence of food and climate tends to alter the conditions of life and habitat of forms, just as we have observed these agencies to be instru-

mental in changing "specific" into "varietal" characters. The food-supply of animals has thus a most powerful influence upon their distribution. The aggregation of forms where food is plentiful, and their absence from those districts where food is scarce, constitute the most obvious of generalisations and laws induced by the state of the food-supply.

And similarly with climate; the influence of this latter condition being even more visible and ascertained than that of the food-supply. The influence of a rigorous climate, as tending to disperse animal forms from a given area, or that of a genial climate in fostering their aggregation, will be readily estimated; whilst to the alteration and succession of the seasons, inducing a colder climate or the reverse, is due the temporary change of province or area, which, in birds, we familiarly term "migration."

The relations of distribution in "space" to distribution in "time," have an intimate bearing on the comparative duration of "species" and groups of forms in a given locality or "area," and also on the relative stability of a "zoological province." We may thus find the constitution and limits of a zoological province to remain in the present, much, or exactly the same, as they appear to have been in the past; the *specific* nature of the included forms, however, having been materially altered and changed. In other words, a zoological province may be occupied in the present day by species and genera different from, but still allied to, those which inhabited it in the past.

These conditions and phenomena are included to form a law, known as that of the "geographical succession of organic forms," which, according to Owen, is embodied in the expression, "that with extinct as with existing Mammalia, particular forms were assigned to particular provinces; and that the same forms were restricted to the same provinces at a former geological period as they are at the present day." The "former geological period" here referred to, it must however be remarked, was "the more recent tertiary one."

At a very recent period, geologically speaking, we may thus observe that the fauna of a particular region exhibited certain peculiar and distinctive characters. And, as expressed by the "law of organic succession," these special characteristics of the fauna may, in the present day, still be found within the same province, but represented and perpetuated by entirely new and different *species* of animals. The characters peculiar to the whole fauna still remain, but the representative *species* are widely different from the species of the past.

Thus, to quote the familiar example of the distribution and relations of the South American *Edentata*, we observe the characteristics of the extinct and gigantic Sloths, and of the armour-plated *Glyptodon*, to be embodied and perpetuated in the modern species of Sloths, and in the existing Armadillos respectively. And similarly with the monkeys, llamas, tapirs, and peccaries of South America. The fossil "species" of these latter forms differ from existing species, but the distinctive peculiarities of each "group" are perpetuated in the living representatives. The fossil monkeys were thus of the *Platyrhine* kind, just as the living *Quadrumana* of South America belong exclusively to that group. And the extinct tapirs, llamas, and peccaries, although *specifically* distinct from their living representatives, nevertheless presented the same characters by which these forms, as distinct "groups," are now recognised.

The extinct mammals of Australia were also of a kind similar to those which now render that region so peculiar among the zoological provinces of the world. The recent deposits of Australia give evidence of as great an abundance of *Marsupial* life in the past, as now exists in that region. These extinct *Marsupials* were of different *species* from existing kangaroos, etc., but they formed in their period a no less distinctive fauna than that which characterises the Australia of to-day.

And the examples of "organic succession" thus given, might be repeated with reference to almost every region of the globe in which palæontological research has made even

limited progress. It is, however, important to bear in mind the observation already noticed—namely, that this law of "geographical succession" is applicable only to the later tertiary period of geology; and that it thus deals with superficial formations and with comparatively recent times. The zoological provinces of the present day are, however, thus proved to be generally of earlier date than the species or forms by which they are populated.

In connection with the "surface" distribution of animal forms, we may lastly notice the presence of certain features of correspondence between the fauna of widely-separated areas or provinces, whereby certain representative forms of one area are represented in another and widely removed province by analogous species, which latter, apart from all structural affinities, appear to fill the same place in their particular province as their neighbours in the other area. "Thus," to use the words of Professor Phillips, "the Platyrhine Monkeys of the new world are balanced by the Catarhine Quadrumana of the old world; the Feline races of Asia and Africa, the Lion and Leopard, are copied, so to speak, by the Puma and Jaguar of tropical America; the Tapir of Mexico mimics the congeneric animal of Sumatra; the Sloth, Armadillo, and Myrmecophaga of Brazil, find relatives in the Manis and Orycteropus of Asia and Africa."

And to these we might add the representation in South America by the llamas and alpacas, of the camels of Asia and Africa; or the balancing of the entire mammalia of other provinces by the single marsupial order of Australia. Whilst amongst birds, reptiles, fishes, and many invertebrate orders, many other examples of this distributional correspondence between forms might be found.

This subject has already been referred to in treating of Homomorphism, when we noticed the theories and views which had arisen from the fact of such widely-removed forms frequently exhibiting a striking resemblance to each other; and from the supposition that such a resemblance depended upon a common origin, upon the performance of similar functions, and upon the subjection

to like external conditions. These ingenious views cannot, however, be regarded as wholly satisfactory, or even as explanatory of facts as they stand; and, as already pointed out, the views of Forbes—who regarded special creations in similar areas as serving to explain these "homomorphic" resemblances—leave many points of the subject as inexplicable as before.

The consideration of the "vertical" or "bathymetrical" distribution of living forms exemplifies in a striking manner the sweeping changes, which even the limited progress of research has wrought in our ideas of the distribution of life throughout various areas or provinces. And the older belief in the limitation of the life-fields to certain depths, in the case of the marine "zones of distribution," has now been swept away by the better investigation of the deep-sea bed.

The researches and explorations of the late Professor Edward Forbes, chiefly led naturalists to classify marine forms, with reference to their "vertical" distribution, into five great classes or "zones." These "zones" or "bathymetrical areas" were arranged as follows:—

1*stly*. The "littoral" zone, extending between high and low water marks, and including forms which are not affected by a temporary withdrawal from their native element. The crustacea generally, and many mollusca, exemplify such forms.

2*dly*. The "circumlittoral" or "laminarian" zone, extending from low-water mark to a depth of fifteen fathoms.

3*dly*. The "median" or "coralline" zone, distinguished principally as the chief habitat and sphere of coral life, and which extended from fifteen to fifty fathoms.

4*thly*. The "Infra-median," or "Deep-sea Coral" zone, extending from fifty to one hundred fathoms; and,

5*thly*. The "Abyssal" zone, extending from one hundred to about three hundred fathoms, beyond which depths but few living forms were supposed to exist.

These ideas thus limited the distribution of life in the ocean to a depth of about 1800 feet, or even to a less extent; the depth of 300 fathoms constituting, according to Forbes, a kind of "zero" in the bathymetrical distribution of marine life. Or, to use Forbes' own words, when speaking of the "Deep-sea Coral Zone:"—"As we descend deeper and deeper in this region, its inhabitants become more and more modified, and fewer and fewer, indicating our approach towards an abyss where life is either extinguished, or exhibits but few sparks to mark its lingering presence."

Recent deep-sea dredging expeditions, in which the names of Drs. Wyville Thomson and Carpenter, and Mr. Gwyn Jeffreys, stand conspicuous, have, however, demonstrated the presence, in the very lowest sea-depths, not only of vast fields of animal life of a low type of existence, but have also brought to light, from enormous depths, creatures of a high type of organisation, such as Echinodermata, Crustaceans, Molluscs, and even Fishes. These and concomitant facts, which further and daily research is bringing to light, tend at once to revolutionise and alter all our previous ideas of "bathymetrical" distribution, and to render the generalisations of Professor Forbes altogether inadequate to correctly express the conditions of life among the oceanic fauna as a whole.

Prior to the announcement of Forbes' ideas in 1843, however, living forms of animal life had been obtained from a depth of nearly 1000 fathoms. These living forms consisted of several tube-dwelling worms, together with a large specimen of the "Medusa-head" Starfish (*Astrophyton linckii*). These organisms were found in the mud of the sounding-lead, and attached to the sounding-line of the Arctic Expedition of 1818, which was conducted by Sir John Ross. This incident constitutes the first undoubted and verified instance of animals of a comparatively high grade of organisation being obtained from a very great depth of sea.

Then, in 1855, the late Professor Bailey of the United States, published the fact that the fine ooze or mud of

the North Atlantic sea-bed consisted in greater part of minute *Foraminifera*, both in a living state and as dead or disintegrated organisms. These organisms were obtained from depths varying from 1000 to 2000 fathoms; and Professor Bailey gave it as his opinion that these *Foraminifera* were inhabitants of the upper strata of water, and that they had been conveyed to the lower depths by currents, or as the result of their death and disintegration. Ehrenberg, on the other hand, more correctly concluded that these *Foraminifera* were to be considered as deep-sea organisms in every sense of the term; and that they lived in the lowest depths of the ocean, and thus constituted vast fields of life in a region formerly thought to be entirely destitute of the presence of vitality.

The observations of Dr. Wallich in 1860, and the remarks of Professor Huxley on the ooze obtained in the soundings of 1857 for the route of an Atlantic cable, tended to confirm the supposition of Ehrenberg with regard to the habitat of the *Foraminifera*, and thus opened up a new era of thought with regard to the life of the sea-depths.

In the "Bulldog" Sounding Expedition, commanded by Sir Leopold M'Clintock, which was undertaken in 1860, with a view to determine the feasibility of a new route for an Atlantic cable, and which Dr. Wallich accompanied as naturalist, several "Brittle-stars" (*Ophiocomæ*) were brought up on the sounding-line from a bottom-depth of over 1200 fathoms. And the stomachs of these *Ophiocomæ* were found to contain *Globigerinæ*—those *Foraminifera* of which the oceanic ooze of the ocean beds is in greater part composed—this fact serving to show that these Brittle-stars normally existed at this great depth, and that the *Globigerinæ* of the sea-bed constituted their usual and ordinary food. The "Bulldog" expedition further procured various *Annelids*, some lower *Mollusca* (*Polyzoa*), and even *Crustaceans*,—all of which were obtained from depths which were formerly accounted absolutely unsuited for the growth and development of living organisms.

The results of subsequent and comparatively recent dredging expeditions, together with the progress of current research, have demonstrated the error of the ideas formerly entertained with regard to the vertical distribution of marine life ; and have shown us that the depths of the sea constitute an entirely novel field for biological exploration, and one which is now being thoroughly worked and investigated under qualified guidance, and by the aid of efficient and improved apparatus.

Any system or tabulated scheme of the vertical or bathymetrical distribution of marine life, professing to meet the exigencies of our increasing knowledge, would have therefore to include the entire depth of the ocean, from the "littoral zone" to the lowest bed or sea-depth. Or, recognising the utility of the first four zones of Forbes, we should have to extend the limits of his fifth zone to include the depths from 300 fathoms to the bed of the ocean ; the constitution and life of this latter area or zone presenting, in all probability, characters of a kind exceedingly varied from those which distinguish the fauna of the other and more superficial zones.

Without entering, in the present instance, into the details and classification of the forms which are ascertained to make up in part the population of the lower sea-depths, we may very briefly glance at the probable conditions under which life exists in these depths. These conditions of life have been chiefly included under the considerations relating to the pressure, light, temperature, and food-supply of the organisms which exist at such enormous depths in the ocean. A few words on each of these latter points will not be out of place in concluding our remarks on the aspects of geographical distribution.

The question of *Pressure*, as constituting a condition pre-eminently unfavourable to animal existence in great depths of sea, has, until recently, influenced discussions on the subject to a greater or less extent. It has, however, been pointed out, that in accordance with the most familiar of the laws of natural philosophy, the pressure upon the outer surface of an organism living in the

greatest depths of sea, would be perfectly counterbalanced by an equal pressure of water from within the organism. The law of the equal pressure of fluids in all directions, and its application to the case of these animal organisms, thus removes a stumblingblock which long impeded the correct appreciation of this important modification of what would otherwise appear to be a thoroughly unfavourable condition to the maintenance of life in the sea-depths. And although we know that at a depth of 2400 fathoms the pressure upon an animal organism must amount to about three tons on each square inch of its surface, yet the equal distribution of fluid pressure constitutes a perfect provision and natural safeguard against any deleterious effects. The condition of the lower organism without air-cavities of any kind, and under such circumstances, is thus maintained in perfect equilibrium, and has been compared in some degree, by Dr. Carpenter, to the similar and perfectly-balanced condition of land-animals, which exist under enormous atmospheric pressure, and under variations in that pressure, without experiencing any effects, or indeed without necessarily being aware of such pressure being at all exerted.

That this purely physical condition, therefore, is fulfilled in greater or less degree by marine forms, in whatever zone or depth they may reside, there can be no doubt. The law which applies to the surface-living form is also applicable to its deeper neighbour. The latter form, however, submits to more rigorous conditions than the surface-form, simply and in virtue of the greater pressure which exists and operates at a greater depth.

The absence of *Light* in the depths of the sea has, similarly to the consideration of pressure, proved a somewhat awkward fact to the supposition that the necessary conditions for vitality are or can be present at great oceanic depths. We have already referred to the importance of light as a subsidiary condition for the manifestation and maintenance of vitality and of vital functions. Yet the ascertained absence of light at but a very short distance from the surface of the ocean, does not

appear to affect the growth and development of many animals which pass their existence in moderate but entirely darkened depths. Nor does this absence of light appear to be attended, in the case of deep-sea organisms, with the results which we naturally expect to follow non-exposure to the solar rays. The coloration of certain forms, brought up from depths of from 500 to 600 fathoms in deep-sea dredging expeditions, was found to be as brilliant as that of their ordinary "littoral" or shore representatives (Carpenter.) The explanation of these anomalous circumstances, and the determination of the causes why absence of colour should follow non-exposure to light in one case, and not in another, have yet to be framed and suggested; but two thoughts or suggestions are admissible in the present state of our knowledge. We may thus either suppose that the vital functions may, from adaptative conditions, be carried on in these organisms in the absence of light; or, on the other hand, that special means may be afforded whereby the influence of the surrounding darkness may be counterbalanced or neutralised. And to these considerations we may not inappropriately add the third, of the possible adaptation of chemical laws and conditions which may influence the development of colour in these organisms, and under the special circumstances of their life, position, and habits.

Throughout the higher groups of the organic series the presence of light appears to be almost absolutely essential to the perfect performance of vital functions. Where we find forms of a high degree of organisation living in darkness, a general absence of colour, together with non-development or a rudimentary condition of the visual organs, are generally to be perceived. Yet, in the case of certain forms brought up by the dredge from enormous depths of sea, and which, from a careful consideration of their habits, appear to normally exist in the lowest depths of the ocean, the eyes appear as perfect in every way as those of nearly-related organisms living and existing in the light.

Such facts constitute most intricate and difficult points in the consideration of the conditions of life in the sea-depths, and more perfect knowledge is requisite and necessary before further attempts to account for or explain these anomalies can be warranted. But the consideration of such phenomena, and the solution of the difficulties which attend them, have not been neglected by naturalists and physiologists in the past.

Dr. Coldstream, in the *Cyclopædia of Anatomy and Physiology*, together with Ehrenberg, De Quatrefages, and others, have of old directed attention to the hypothesis or suggestion that the deep-sea forms may be capable of seeing by aid of the phosphorescent light which themselves or their neighbours are capable of producing. Thus Coldstream quotes the remark by Macculloch, from the *Edinburgh Encyclopædia*, that "in marine animals their luminousness may be 'a substitute for the light of the sun,' and may be the means of enabling them to discover one another, as well as their prey."

This hypothesis, which deserves mention if from no other consideration than its ingenious nature, has been repeatedly referred to and reproduced in discussions on the conditions of life in deep-sea or in ordinary marine organisms. Objections to this supposition have been founded on the fact that the power of producing this phosphorescent light is not possessed by all the forms inhabiting the sea-depths, nor by those dwelling in shallower but still darkened water; the surface of the sea, indeed, being the particular region or tract where the luminosity is most to be perceived. Then, also, it has been shown that forms which apparently would most benefit from the possession of this property are destitute of it; whilst other animals, the habits of which do not appear to necessitate such a provision, possess the phosphorescent property in fullest vigour.

These and allied considerations certainly militate against the validity of this supposition; although, from the nature of the case, and from the present state of our knowledge, we cannot satisfactorily either support or

reject a suggestion offered and propounded after a due consideration of facts as they stand.

The subject of *Temperature*, as affecting the conditions of life in deep-sea organisms, is not surrounded by such difficulties as beset the question and relations of light. The due observation and investigation, by aid of improved apparatus, of the temperature of the ocean at various depths, has led to the well-founded belief that the temperature of the sea is regulated by the distribution and direction of the currents which at all depths affect its mass. By the agency of these moving streams the degrees of heat and cold in the sea-depths are duly regulated; and it has been found that the distribution of hot and cold areas in the ocean has a very important, if not the most important, effect in determining the range and distribution of life throughout the wide domain and depth of sea.

The ideas formerly entertained concerning the relative temperature of various sea-depths have been greatly modified, and in some cases completely superseded, by the results of recent investigations. And although the consideration of such a question belongs more properly to the department of physical geography, yet the recognition of the influence of temperature on the bathymetrical distribution of life may warrant us in briefly stating the conclusions to which late investigations have led.

Formerly it was believed that the temperature of the ocean at certain depths was of a permanent and stable character, and corresponded to about 4° C. The surface temperature, on the other hand, was believed to vary greatly under the influence of the heat of the sun, from the effect of currents and of winds, and from other causes. The results of recent investigations tend to show, as expressed by Professor Wyville Thomson, "that instead of there being a permanent deep layer of water at 4° C., the average temperature of the bottom of the deep sea in temperate and tropical regions is about 0° C., the freezing-point of fresh water; and that there is a general surface movement of warm water, produced pro-

bably by a combination of various causes, from the equatorial regions towards the poles, and a slow under-current or rather indraught of cold water from the poles towards the equator."

In the conditions which affect the distribution of marine forms, therefore, we may assign to temperature the first place of importance. "The nature of the ground," to use Professor Thomson's words, "can have little to say to it, for on every line of coast, of any extent, almost every condition and every kind of sediment is usually represented."

Finally, the question of *Food-supply* has also been regarded as forming one of the knotty points in the consideration of the distribution and maintenance of deep-sea existence. The existence of a food-supply to the animal bears, as has already been shown, an important relation to the presence of light; since the plants necessary for the maintenance of animal-life require the presence of sunlight for the due operation of their vital chemistry. The absence in the sea-depths of any but a few of the lowest, and generally microscopic plant-organisms, forms, therefore, a notable feature in the consideration of the present subject; since, in the absence of the solar-beam, the higher plants cannot exist, and with them disappears the chief support and stay of animal existence.

From the contemplation of such a difficulty arose the suggestion that the lower animals in the sea-depths might assume the functions of plants, in that they might be conceived to be capable of availing themselves of the inorganic materials by which they were surrounded, and of elaborating from such matter a nutritive supply. This supposition, however, has been abandoned in favour of a second theory, which, whilst it offers a more feasible explanation of the mode in which the nutrition of these organisms may be provided for, is not wholly free from objections to its favourable reception. This latter idea maintains the existence, in the great quantity of organic matter held suspended in the water of the sea, of a

supply of nutrient material, sufficiently and physiologically adapted for the sustenance of these lower organisms.

The actual presence of such organic matter in great depths of sea has been fully demonstrated, and this material has been supposed to be derived from the "surface-life" of the ocean, and from marine vegetation, together with the matter derived from the disintegration of the dead bodies of organisms of every grade and kind. Such organic material, thus widely diffused throughout the water of the ocean, and consisting of "dilute protoplasm," is therefore believed to afford food for organisms, the resources of which, from habits or distribution, appear of the most feeble and contracted kind. And the theory, which thus accounts for the food-supply of these deep-sea forms, is generally known as that of the "Protozoic-absorption theory."

Whilst this hypothesis appears sufficiently tenable and worthy of belief, until the question be more thoroughly worked out, there are a few points which may be suggested as militating against the theory. Thus the question of the actual necessity for recognising a food-supply in this "decomposable organic material" may not inaptly be raised. We are familiar with very many organisms, from all classes of the animal kingdom, up to and including the fishes, which may be preserved in a living and healthy condition, and for an indefinite period, without being furnished with any solid nutrient material. And the supposition that these deep-sea organisms may, like other and higher forms, find in the microscopic organisms and particles which are contained in even the clearest water, a source of food-supply, somewhat invalidates the necessity for our looking beyond the ordinary medium and conditions in which they live for the presence of nutrient matter.

The respiration of deep-sea forms, and the renewal of the gases concerned in the aërating-processes, in the absence of plants, are effected under the most admirable conditions. "Surface-waters" were found to contain a large percentage of oxygen, and comparatively little

carbonic acid; whilst "bottom-waters" contain a large amount of carbonic acid, and comparatively little oxygen. These conditions, and the relative preponderance of these gases, depend upon the interchange of oxygen and carbonic acid which takes place in the functional life and respiratory processes of deep-sea forms; the carbonic acid emitted by the organisms being consequently in greater preponderance in the lower depths, whilst the renewed oxygen is present in greater quantity in the upper strata of water. The renewal of the oxygen, and disposal of the carbonic acid, is effected by the downward diffusion of the former and the upward diffusion of the latter gas. A second interchange between the gases of the atmosphere and the gases of the sea thus takes place at the surface of the ocean; and the diffusion and renewal of oxygen is amply provided for by the currents of air and ocean, which together ceaselessly agitate the sea-depths, and so provide for the due purification of the great mass of waters.

Lastly, the presence of diffused mud-particles throughout certain areas (*e.g.*, the deeper parts of the Mediterranean Sea) has been credited with causing an almost entire absence of life, and of thus affecting in an important degree the distribution of deep-sea organisms. But, as has been ably pointed out by M'Intosh, the consideration that very many animals — Molluscs, Annelids, together with Sponges, and other and lower forms of marine life — normally live and thrive in very muddy waters, presents an antagonistic aspect to this theory. Indeed, as has been pointed out, the muddy districts of "littoral" areas present a marked contrast in respect of their abundant life, to those districts where the water is clear and undisturbed. And even amongst the thickest chalk-ooze and putrid mud, many characteristic Molluscs and Annelids are found to flourish in all their vigour and beauty. Thus the conditions of presumed unfavourable aspect to the development of life in one case, become in another case, and unaccountably, a normal habitat for organisms of a higher grade of organisation.

But in conformity with the current progress of research, we may reasonably hesitate to express any decided or further opinion as to the tenability of theories or opinions which may be entertained with regard to the "bathymetrical" distribution and conditions of deep-sea life.

The subject of "Distribution in Time" admits, in the present instance, of only a few considerations, and these must be of the most general description; since the due appreciation of the facts and conclusions to be derived from a study of the palæontological record is dependent to a very great extent upon a certain knowledge of geological science.

The "geological" distribution of living beings, in its fullest sense, thus implies, firstly, the investigation of the past history of our earth, with regard to the physical and other conditions under which the life of the past existed; secondly, the determination of the conditions under which the remains of animals and plants have become preserved to us in the rock-systems of our globe; and, thirdly, the examination of such "fossil" forms, and their comparison in the details of structure and function with the living forms now existent.

The department of science which deals with the relation and structure of living forms in the past is known as that of "Palæontology;" and this branch of inquiry is in turn generally regarded as subsidiary in nature to the wider science of "Geology." The last-mentioned department thus investigates the past history of our earth, in the most extended sense in which such an investigation may be pursued.

The more general considerations which concern our present purpose and subject, are limited to those which may suitably preface a full and complete inquiry into the past history of living forms. We thus become aware, firstly, that many species of animals and plants have been represented in periods of our earth's history anterior to that in which we ourselves exist. These species are principally those of forms which have completely passed out of existence; in other words, they have become

"extinct," and are not identical with, or cannot be referred to, existing "species" of animals and plants. In addition to these "extinct" species, however, we find many species to be represented in the past which are still in existence.

These forms, belonging thus chiefly to extinct, but also to existent species, represent the past population of our globe, and with the more general relations of these organisms it is the province of our present subject to deal. They become known to us from the presence in the rock-formations which compose the "crust" of the earth, of the remains of animals and plants, preserved to us mostly in a petrified state, and known as "fossils," or as "fossil organisms."

A further examination of the distributional aspects of the past population of our globe, evinces the fact that it is possible to determine a certain arrangement and order in their existence; and, necessarily, in that of the rocks or material, in the substance of which they are imbedded. In this way we can trace the existence of certain definite epochs or periods in the history of our earth, and we can also determine that certain forms or groups of forms were characteristic of or represented the life of these periods. And the palæontologist is thus enabled to construct a tolerably correct scheme, exhibiting the development and distribution of life at various epochs in the past, and also to form some idea of the conditions under and through which that life was maintained.

It is, however, to be borne in mind as a primary and most important consideration, that whilst the majority of fossil organisms are "extinct," that is, have entirely passed out of existence; and whilst other fossil forms do not differ from existing species of animals and plants, there is, at the same time, no fossil form which cannot be referred to one or other of the great groups or sub-kingdoms into which both animal and plant series are divided. Then, in addition to the above fact, it must also be remembered that the extinction of a species is essentially and for ever final; in other words, when a

species has died or passed out of existence it never again appears.

The difference between the forms of the past and those of the present is therefore, one, comparatively speaking, of time and not of primary structural detail. And this difference in point of time and general resemblance is exhibited in a defined order; those fossil forms which occur in the first-formed or oldest rocks differing in greatest degree from those at present in existence; whilst the fossils occurring in the newer or last-formed rocks do not, as a rule, differ from existing species of animals and plants.

The successive and gradual formation of the "fossil-bearing" rock systems, which chiefly compose the crust of the globe, was thus accompanied by a correspondingly gradual development of life, this development beginning in order with the least highly-organised, and terminating with the production of the highest being. From the wider differences observable in the distribution and relations of the forms which existed in the past, palæontologists have classified the rock formations of the earth to form three great "epochs" or "life periods." In other words, these epochs are distinguished by the broad characters and wide relations of their contained fossils.

Each period, therefore, contains an assemblage or aggregation of fossil forms, which evince among themselves a certain relationship, chiefly and primarily represented by the time and circumstances of their formation and deposition to form fossil organisms. The fossils of each epoch, and, in many cases, of each rock formation, exhibit thus a comparative contemporaneity of development, and very often of extinction also; whilst the relationship between the fossils of a period or rock formation, so far as structural identity is concerned, may either be of a close description, or of a less intimate or entirely unconnected kind.

The first and oldest of the epochs or life-periods into which the entire series of rock-formations may be divided is known as the *Palæozoic*, *Primary*, or "Ancient-life"

period. This epoch includes the Laurentian ; Cambrian ; Silurian ; Devonian or old Red Sandstone ; Carboniferous (Coal-measures) ; and Permian systems of rock-formations. The fossil organisms included in this period exhibit, as a whole, very distinct and essential differences from existing species of animals and plants.

The *Mesozoic*, *Secondary*, or "Middle-life" period, forms the second epoch, and includes the Triassic, Oolitic, or Jurassic, and the Cretaceous or Chalk systems of rocks. This second epoch is characterised, like the Palæozoic period, by the specifically distinct nature of its included fossils from existing forms of life ; a few exceptions to this rule, however, being found. The fossil flora and fauna of the Mesozoic period, however, approach more nearly than those of the Palæozoic epoch to existent species ; and the term "Middle-life" period has been applied to this epoch, from the somewhat intermediate nature of its position between the older and newer periods.

The *Kainozoic*, *Tertiary*, or "New-life" period, forms the last of the life-epochs. It includes the more superficial rocks, beginning with the Eocene formations, and including the Miocene and Pliocene, and finally ending the entire series with the Pleistocene, and Post-Tertiary, or Recent deposits, which latter bring us to the formations of our own day. The contained fossils of the Kainozoic period evince, for the most part, a decided relationship with the existent species of animals and plants ; many of the Kainozoic fossils being specifically identical with living forms, and the more recent or newest deposits exhibiting, as might be expected, the closest relationship to the existing flora and fauna.

The general considerations thus brought forward may suffice to give a broad or elementary idea of those more important generalisations with regard to geological distribution, which an acquaintance with the principles of geology and palæontology is alone calculated to perfectly convey. It may, however, be impressed, as a closing and final thought, that the geological or palæontological record is

by no means of a uniform, complete, or unbroken nature. The labours of the palæontologist have not resulted in the formation and demonstration of a continuous series of forms, leading us by gradual and successive stages from the era of creation to the present order of existence.

There exist, on the contrary, many and great gaps in the geological record; the ingenuity of theorists having been greatly exercised to account for, and fill up, the breaks in the palæontological chain. These deficiencies have resulted from various causes, with the operation of which the geologist is well acquainted. Two conditions may be enumerated as having tended to produce these imperfections. The first condition is included in the fact, that the destructive nature of many physical or geological actions has undoubtedly caused the obliteration of the fossil-remains of many rock-formations. And, secondly, the absence of many animal and plant forms, which, from surrounding circumstances, or from their habits, would not tend to become fossilised, has left the "record of the rocks" necessarily in an imperfect and interrupted condition. Without, therefore, expressing dogmatically that the progress of research will disclose no new facts, or result in the discovery of no further or more extended generalisations regarding life in the past, we may safely assume that the imperfections and deficiencies alluded to are of a thoroughly permanent nature; and are such, that no succeeding phases of knowledge can ever suffice to render the record of life in the past any the more perfect, or to enable us, with precision and certainty, to fill in all the missing pages in the history of our globe.