The question of the permanence of ocean-basins, to which the remainder of this address will be chiefly devoted, is one that has attained great prominence in this country since the 'Challenger' Expedition. The opinion that the deep parts of the ocean have been the same from the earliest period of which we have any record in the Earth's strata, has received the approval of several eminent geologists and biologists. Nevertheless there are many who feel grave doubts on the subject, and I think the arguments on both sides are worthy of reconsideration.

It will perhaps tend to render my treatment of the subject clearer, if I point out at the outset that there are three possible explanations of the phenomena presented to us by the present and past conditions of the land and by the distribution of terrestrial life; these are:—

1. That the present continental areas, including the shallow seas around them, and the present oceanic tracts with a depth exceeding about 1000 fathoms, have been the same since the original consolidation of the earth's crust.

2. That the continental and oceanic areas are not permanent, but that they are from time to time interchangeable.

3. That the continental and oceanic areas are permanent as a rule, but that portions of them have at times passed from one condition to the other.

I propose to take in order the principal physical, geological, and biological arguments in favour of the permanence of ocean-basins, and to inquire how far they are conclusive, and especially whether any exceptions are probable. I wish also to call your attention to a few facts, mainly referring to the distribution of terrestrial organisms, that I think worthy of the attention of geologists.

The permanence of the land- and sea-areas is no new idea. It would be easy to quote from ancient and modern poets and writers a series of extracts to show the prevalent belief in the fixed limits of the ocean-tracts. It is only of late years, since the teaching of Lyell and other modern geologists has become generally received, that the old belief has been replaced by free speculation on the distribution of land and water in past periods. Under these circumstances, scientific men who revert to the ancient faith suffer from the serious disadvantage of leading an enthusiastic school of followers, who have never renounced the creed of their ancestors, and who hail the convert to orthodoxy with the traditional joy over a repentant sinner. There is always a risk of a sound scientific theory being accepted in a much wider sense than was intended by its original advocates, and the risk is extreme when the theory coincides with the popular taste.

The chief arguments brought forward in favour of the permanence of ocean-basins or deep-sea areas are the following:—

I. The higher specific gravity of the earth's crust beneath the ocean, as inferred from pendulum observations, and the further inference that these areas of greater density have been the same since the original consolidation of the earth.

II. The absence, with a few not very important exceptions, in ocean tracts, of islands formed of stratified rocks such as compose the bulk of the continents, and the fact that nearly all oceanic islands are volcanic, and consequently such as may have been built up from oceanic depths by the accumulation of volcanic discharges.

III. The absence of deep-sea deposits in the rocks of continental areas.

IV. The agreement between the distribution of plant- and animal-life and the present arrangement of land-areas.

I propose to consider each of these arguments in order, though the last is that to which it will be necessary to give the most attention.

I. *Greater Density of Infra-oceanic Crusts.*—The first argument is one to which some importance is attached by Prof. Dana *. But it is only founded on a few observations in India and the neighbouring islands, and was suggested by its author, Archdeacon Pratt, as a probable hypothesis to account for some anomalies in the results of pendulum observations. The principal force of the contention appears to lie in the circumstance that if the crust of the earth now below the ocean had been exposed to denudation, and consequently transport, its exceptional density could not have been preserved, because the action of rivers and currents would in the course of ages have mingled its detritus with that of the present continental areas. It has also been urged that, owing to the contact of cold oceanic waters, the crust beneath the ocean has become thicker and more rigid. This view, however, depends on the hypothesis of a fluid layer beneath the solid crust; and although there is much to be said in favour of such a view, it is impossible to accept it as a proved theory and to use it as a basis for argument. Indeed the next point to be noticed, the presence of volcanic islands in many parts of the ocean, is really antagonistic to the idea of a uniformly thicker and more rigid crust beneath the ocean-bed, because the occurrence of volcanoes indicates areas and lines of weakness. If the infra-oceanic crust were much more rigid and thicker than the infra-continental, volcanoes should be confined to the area occupied by the latter; but this is not the case. That volcanoes should be most numerous near the boundaries between continental and oceanic areas is natural.

II. *The Volcanic Origin of Oceanic Islands.*—This, the second

* Manual of Geology, 3rd ed. p. 815.

argument, is, at present, far more important than the first. Darwin was, I think, the first to call attention to the absence of palæozoic and mesozoic strata in oceanic islands, and his words * which have already been quoted by Mr. Wallace in 'Island Life,' will bear repeating. He says:—

"Looking to the existing oceans, which are thrice as extensive as the land, we see them studded with many islands; but hardly one truly oceanic island (with the exception of New Zealand, if this can be called a truly oceanic island) is as yet known to afford even a remnant of any palæozoic or secondary formation. Hence we may perhaps infer that during the palæozoic and secondary periods, neither continents nor continental islands existed where our oceans now extend; for, had they existed, palæozoic and secondary formations would in all probability have been accumulated from sediment derived from their wear and tear; and these would have been at least partially upheaved by the oscillations of level, which must have intervened during these enormously long periods. If, then, we may infer anything from these facts, we may infer that, where our oceans now extend, oceans have extended from the remotest period of which we have any record; and on the other hand, that where continents now exist, large tracts of land have existed, subjected no doubt to great oscillations of level, since the Cambrian period."

There can be no question as to the force of this argument; but the more fully it is admitted, the more important do any exceptions to the volcanic character of oceanic islands become, and the fact must not be forgotten that the number of oceanic islands in which palæozoic or mesozoic beds have been found has been slightly increased within the last few years. The Falkland Islands, the palæozoic fossiliferous rocks of which were described by Darwin himself †, were not noticed by him in the paragraph quoted, doubtless because he did not regard them as oceanic: although 400 miles distant from the coast of S. America, they are connected with it by a bank of less than 100 fathoms deep, and they have an indigenous land-mammal. But the Archipelago of South Georgia, 800 miles further to the eastward and nearly 1200 miles from the American continent, has now been shown to consist of clay-slate ‡. According to the chart issued with the recently published 'Challenger' narrative,

* Origin of Species, 6th ed. p. 288.

† Q. J. G. S. ii. p. 267.

‡ Geol. Mag. 1884, p. 225; 'Nature,' March 27, 1884, xxix. p. 509.

these islands are surrounded by ocean exceeding 1000 fathoms in depth. Another important island also, isolated by sea exceeding 1000 fathoms in depth, is New Caledonia, where both palæozoic and mesozoic fossiliferous beds are met with *. This, however, is a precisely similar case to that of New Zealand. The Auckland and Campbell Isles † south of New Zealand are said to be separated from it by a sea more than 1000 fathoms deep, but contain ancient sedimentary rocks. The sedimentary deposits of the Fiji Islands, formerly supposed to be ancient, have been shown by Mr. Brady ‡ to be of subrecent formation.

The occurrence of granitic and gneissic formations in islands differs from that of sedimentary beds in this respect, that the former may have consolidated at some depth below the bottom of the ocean. But such rocks, when in place, cannot have formed parts of ordinary submarine volcanic accumulations. A granitic or gneissic island must be part of an ancient land tract, for the rocks could only have been exposed after a long period of denudation. The most important instance of granitic or gneissic rocks occurring in oceanic islands is in the Seychelles §, and these are probably a continuation of the main Madagascar range, which is of similar formation; they are separated from Madagascar and from all other land areas by sea of considerable depth. It should also not be forgotten that granite and schist are said by von Buch to have been thrown out from the volcano of Caldera (I. de Palma) in the Canary Islands ||, that similar rocks have been ejected from the Cape Verde volcanoes ¶, and that hornblendic granite was found by Darwin amongst the fragments thrown out at Ascension **. Granite and gneiss are also said to occur †† on the Marquesas Islands in the Pacific; but there appears to be some uncertainty about this. If confirmed, however, this occurrence would beof the greatest importance.

* Heurteau, 'Ann. Mines' (7), ix. p. 232 (1876).

† Tchihatcheff, 'Considérations sur les Iles Océaniques,' p. 34.

‡ Q. J. G. S. xliv. p. 1.

§ By some mistake, Wallace, in his recent work, 'Darwinism,' p. 342, has stated that the Seychelles are formed of coral rocks. There is, however, no doubt about their geological conformation, as may be seen by referring to the following writers: Velain, Bull. Soc. Géol. France, 1879, sér. 3, vii. p. 278; Perceval Wright, Brit. Assoc. Reports, 1868, sect. p. 143; E. Newton, Ibis, 1867, p. 335. This list of references could easily be increased considerably.

‖ Von Buch, Phys. Beschr. d. Can. Inseln, p. 289.

¶ Dölter, Die Vulkane der Capverden und ihre Producte (Graz, 1882), p. 159.

** Darwin, Volc. Islands, p. 40.

†† Jules Marcou, Expl. 2 éd. Carte Géol. de la terre, p. 185.

It will be seen at once that these examples do not very greatly affect the main argument, because there is still an enormous area of ocean left in which the only islands are volcanic. But still the instances mentioned are worthy of notice, because they show that there are exceptions to the general rule that no palæozoic or mesozoic rocks occur on oceanic islands, and the additions made to our knowledge in this respect of late years render it probable that other instances remain to be discovered. Of course much depends on the definition of an oceanic island; but the accuracy of the term can scarcely be contested in the case of South Georgia. As it is impossible for denudation to hollow out the sea-bottom beyond a few fathoms below the surface, the isolation must in all such cases be due to depression.

There are three other facts that should be remembered with reference to the point under discussion. The first is that our acquaintance with the geology of many oceanic islands is by no means sufficiently complete to justify our being confident that no sedimentary rocks of old date exist. The second is that the rocks of an island may be entirely volcanic, and yet the island may be a remnant of a continental mass. It must not be forgotten that typically volcanic rocks in some continental areas, as in the Western United States of North America, North-eastern Africa, and the Peninsula of India, form vast horizontal or nearly horizontal sheets, and completely cover the surface over areas the diameters of which are measured by hundreds of miles. Such rocks may be of considerable antiquity, and they are typically continental, being all, so far as is known, subaërial. It is, I think, far from clear that some oceanic volcanic islands, such as St. Paul's Rocks, Fernando Noronha, and Kerguelen, are not composed of volcanic formations of the continental type; and rocks of this class are well developed in some ancient continental islands, for instance, New Caledonia. At the same time, this only proves that such islands were formerly of considerable extent, not that they were attached to continents.

The third fact is even more important. This, which has been noticed by Prof. Bonney in one of his notes to the recent edition of Darwin's 'Coral Reefs' (p. 326), is that the occurrence of volcanic islands does not prove that the area in which they occur is not a sunken continent. If Africa south of the Atlas subsided 2000 fathoms, what would remain above water? So far as our present knowledge goes, the remaining islands would consist of four volcanic peaks, Camaroons, Kenia, Kilimanjaro, and Stanley's last discovery,

Ruwenzori, together with an island, or more than one, containing part of the Abyssinian tableland, which, like the others, would be entirely composed of volcanic rocks, but, unlike them, would consist of horizontal or nearly horizontal lava-flows, probably of Mesozoic age. In Southern Africa, too, the peaks of the Stormberg and Drakensberg, though not rising or scarcely rising above 10,000 feet, are the highest in the country and consist of volcanic rocks. The same is the case with the highest peaks in Madagascar, in Mexico, in the Caucasus, in the Elburz Chain south of the Caspian, and in many other parts of the world; though the case of Africa is perhaps the most remarkable.

III. *The Absence of Deep-sea Deposits in Continental Areas.*—This argument is, I think, of far greater importance than either of the preceding. It is perfectly true that the presence or absence of deep-sea deposits in continental areas is only indirectly connected with the condition of the present oceanic areas in past times; because, even if no change whatever has taken place in the former, that does not prove that none has taken place in the latter. Even if no part of the continental area has ever been deep sea, any oceanic area may have been land at one time or another, the necessary compensation having been provided by the deepening of another oceanic tract. But there can be no question that, unless the amount of ocean water on the earth's surface has greatly increased in the later geological epochs, there must have been deep sea over a considerable portion of the earth's surface at all times; and if the continental areas have remained unchanged, the oceanic areas have, in all probability, preserved their original limits. The question for us at present is, whether we have sufficient evidence to justify our belief that the continental areas have remained unchanged.

In this case, even more than in that of the oceanic islands, it appears premature to conclude that our knowledge approaches completion. Because in the extremely small area of the land surface, assuredly not one-twentieth of the whole, that has received close geological examination, no deep-sea deposits have been observed, we have no right to assume that none will ever be discovered in any part of the continental area. The recognition of the character of deep-sea deposits is too recent for geologists in general to have become acquainted with the peculiarities of such formations, so as to be able to recognize them at once. On the other hand if deep-sea deposits were not of exceptional occurrence on continental areas, some would probably have been noticed before this. It has I believe

been suggested that the Graptolite shales of the Silurian system were deposited in deep water, and, so far as the fauna is concerned, the hypothesis appears plausible enough; but the interstratification of coarse sandstones in places seems a fatal objection. The fine slates and interstratified volcanic tuffs of Silurian and Cambrian age are, however, sometimes of great thickness and extent, and are worth further examination to see if any of them are possibly of deep-water origin*.

Throughout a large oceanic area at present it is pretty evident that, practically, no deposits are being formed. The fact that teeth of what are believed, on good grounds, to be extinct forms of Shark have been dredged in a corroded state from the bottom of the ocean shows that such objects have lain for ages where no sediment was deposited to entomb them. There is no ground for surprise therefore if the abyssal red clay is unknown in the older rocks. But the absence of strata corresponding to the Globigerina- and Radiolarian ooze of the present oceans is, so far as our knowledge extends, in favour of the contention that the continental areas have not been depressed beneath the deep sea.

At the same time two recent discoveries of deep-sea deposits, each on the border of the continental area, serve to show how cautious we should be in coming to decided conclusions. These two instances are in the Solomon Islands†, concerning which I shall have some additional remarks to make when dealing with insular faunas, and in Barbadoes ‡. The evidence in the latter case is very remarkable and peculiarly complete, for the deep-sea Radiolarian ooze rests upon sandstones and clays with coal, believed to be of older Tertiary age, and which are evidently littoral, estuarine, or fluviatile in origin. It is clear that the island must have formed part of a continent, that it must have been depressed to a depth of over 1000 fathoms, and then re-elevated; and there is, so far as I understand, no question that these changes have taken place within the Tertiary era and probably within the Miocene and Pliocene periods. Barbadoes is at present surrounded on all sides by seas over 1000

* There is so great a resemblance between some of these remarks and the views on the same subject expressed by Dr. Nicholson in the last edition of his 'Manual of Palæontology,' i. p. 75, that it is necessary to explain that all this part of the address was written before I had seen Prof. Nicholson's work, and, I believe, before it was published.

† Guppy, 'Solomon Islands, Geology,' &c., pp. 77, 81, &c.

‡ Feilden, Ibis, 1889, p. 478; Jukes-Browne and Harrison, 'Nature,' vol. xxxix. pp. 367, 607; Gregory, Q. J. G. S. xlv. p. 640.

fathoms deep. Moreover Barbadoes is said not to be the only West Indian Island in which Radiolarian deposits occur, so that there is a probability, as might have been anticipated, that subsidences and elevations of the character mentioned affected considerable areas.

IV. *Relations between Distribution of Animals and Land-areas.*—The last argument may not be strictly geological, but all who recognize how intimately the story of the earth is bound up with that of its inhabitants will have little doubt that the present distribution of animals and plants is of the highest geological importance, and that the existence of particular forms of living beings in continents and islands is the result and the record of the history of those areas and of their connexions with each other. There can be no doubt, in short, that most important testimony as to the distribution of land and water in past epochs is afforded by the range of living species and genera. The information on the subject of distribution at the present day is considerable, probably more extensive and nearer completion, so far as regards vertebrate animals and phanerogamous plants, than that relating to the geology of the different regions. Moreover the question of zoological distribution has been ably treated by one of the first biologists of the day, Mr. Alfred Wallace, who has in his later works unhesitatingly given his adhesion * to the doctrine of permanent oceanic and continental areas in almost its extreme form. Just twenty years ago the question of distribution was dealt with by Professer Huxley in an address to this Society, and my only excuse for referring to a subject already treated by so high an authority, is that the aspect of the question has entirely changed since 1870, that our knowledge has greatly increased, that the subject has been widely discussed, that the oceans have been better surveyed, and that we are in the presence of an entirely different theory of the distribution of land in past ages from that which prevailed amongst geologists when Professor Huxley's address was written. It is essential to add that, whereas my great predecessor felt called upon to prove the theory of evolution before applying it, we may now regard the doctrine as firmly established.

In all the remarks which follow I shall assume as an accepted fact, not only that all species of a genus, all genera of a family, and all families in an order, class, or subkingdom, are descended from

* 'Island Life,' chap. vi.; 'Darwinism,' pp. 341, &c.

one stock in each case, but that similarity in organic structure is proportional, as a general rule, to the degree of affinity, animals and plants that are like being more nearly related by descent than those which are dissimilar.

As I have already said, I propose to treat the subject of distribution at some length, both because it is, I think, well worthy of the attention of geologists, and because I believe the whole question requires reconsideration. To understand why this is the case, it is essential briefly to recapitulate the history of the inquiry.

Although much had been previously done, the first contribution to which reference is necessary was a paper by Mr. P. L. Sclater, published in 1858 *, "On the General Geographical Distribution of the Members of the Class *Aves*." The terrestrial area of the world was in this paper divided into the following six zoological regions:—

1. *Palæarctic*: Europe, Northern Africa, Northern and Central Asia.
2. *Ethiopian*: Africa south of the Atlas, and Madagascar.
3. *Indian*, renamed *Oriental* by Wallace: India, South-eastern Asia, and part of the Malay Archipelago.
4. *Australian*: Australia, with New Guinea and adjacent islands, New Zealand, and Polynesia.
5. *Nearctic*: America as far south as Mexico.
6. *Neotropical*: Central and South America, with the West Indies.

These regions were founded solely on birds, and mainly on passerine birds (or on passerine and picarian). They were accepted for snakes and Batrachia by Dr. Günther in a paper published in 1858 †; but a far more extended study of the subject, and the great additions made to our knowledge within the last thirty years, have induced Dr. Günther to come to a very different conclusion, as will be shown presently.

The papers just mentioned appeared before the publication of Darwin's 'Origin of Species,' and were, of course, written without any reference to the idea of relationship by descent amongst different genera of a family or different species of a genus. So soon, however, as Darwin's great work had produced its effect, the importance of an inquiry into the distribution of animal- and plant-life was greatly increased.

* Journ. Linn. Soc. Zoology, ii. p. 130.

† P. Z. S. 1858, p. 373.

Various other schemes of regional subdivision have been proposed, but it is unnecessary to notice all. I have already alluded to the most important, that of Professor Huxley, who, on a general survey of terrestrial vertebrates*, proposed four primary distributional provinces, viz.:—

1. *Novo-Zelanian* (New Zealand).
2. *Australian.*
3. *Austro-Columbian* (Neotropical of Sclater, South America).
4. *Arctogæan* (Palæarctic, Ethiopian, Oriental, and Nearctic united).

By far the most important work on the subject yet produced is Wallace's 'Geographical Distribution of Animals' (2 vols., 1876), in which the author adopts Sclater's regions in their entirety for all terrestrial and freshwater forms of animal life. In this work lists of the families of Mammals, Birds, Reptiles, Batrachians (or Amphibia), Freshwater Fishes and diurnal Lepidoptera found in each region are given, and also of the genera of mammals and some birds (Passeres, Picariæ, Psittaci, and Accipitres). Numerous details are added relating to other terrestrial animals, but the regional arrangement is mainly founded on the birds of the orders named, and, as is especially stated, on Mammalia †. With the question whether the mammals quite agree with the classification proposed I shall deal presently; meantime it should be mentioned that Wallace, amongst the reasons given for adopting the regions named, assigns a high rank to the convenience of employing large subequal divisions.

There is one aspect of the whole question to which attention must be drawn. No one doubts that the present form of the great land-tracts extends back with but trivial modification to Pliocene times at least, the only important changes of later date being the opening of Behring's Straits, and severance of America from Asia, the separation from continents of certain continental islands, such as Great Britain and Ireland, Sumatra, Java, and Borneo, Ceylon, &c., and perhaps the reunion of North and South America. The changes since Miocene, and perhaps since Eocene, times have probably been neither very extensive nor very numerous. If, however, the principal divisions of the earth have remained the same or nearly the same for a longer period than the existence of most living genera of Vertebrata, the animals inhabiting those

* P. Z. S. 1868, p. 316; Q. J. G. S. xxvi. p. lv.
† 'Geogr. Distrib.' i. p. 57.

divisions must necessarily, if we accept the ordinary teachings of Evolution, have become materially differentiated, so that each modern natural division has many of its generic types peculiar.

The present distribution of all terrestrial organisms, as has been pointed out already by Huxley, Wallace, and other writers on the subject, is the combined result of several different factors. Of these the original centre of dispersion in the case of each organic unity, such as a family, genus, or species, is one; the distribution of land and water, firstly, at the time of dispersion, secondly, since that time are two others; whilst powers of migration and ability to live under varied conditions are of great importance, and it is notorious that the last two factors are as diverse in different organisms as I shall endeavour to show that the first is.

As regards origin, there is an important point in which mammals and birds, most reptiles and batrachians, probably all insects and arachnida, and all land-plants differ from freshwater fishes and crustacea, and from both freshwater and land-mollusca. The forms in the first category are in all probability derived from terrestrial or freshwater ancestors, differing very widely from them in structure, so widely, indeed, that the ancestral types would have been classed in distinct orders, or even classes. Even when there are marine representatives, such as Cetacea, sea-snakes (*Hydrophidæ*), marine turtles, and a few marine angiospermous plants, these are probably descended from terrestrial or freshwater forms. On the other hand, the fishes, crustacea, and mollusca found in rivers, and all land-shells are in all likelihood derived from various marine stocks, and some of them have living marine representatives belonging to the same family. Thus freshwater *Percidæ*, *Salmonidæ*, *Clupeidæ*, &c., differ sometimes generically, often merely specifically from the forms found in the sea, and when, as in the carps and in most existing ganoids, whole families are confined to fresh water at the present day, there can be no reasonable doubt that marine ancestors not differing greatly in structure flourished at a former period. The derivation of land-mollusca is similar, and will be dealt with presently. In the case of terrestrial and fluviatile animals derived from marine forms it is manifest that the geological date of origin of the different genera of one family, or even of species of one genus, and above all of different families was not necessarily the same, that is their origin as land or freshwater animals may have taken place, and in all probability did take place, not merely at different periods of the Earth's history, but in different parts of the land-area.

It is reasonable to suppose that all mammalia and all birds have spread from one part of the world in each case, whilst the carps may have originated in one continent at one geological epoch, and another family of freshwater fishes, for instance the *Characinidæ* or *Chromididæ*, at another place at a different epoch. This fact manifestly has an important bearing on distribution; for the original dispersal and evolution of each group must have depended on the position and connexion of land-areas at the time.

At the same time, when the whole of a family, as in the case of the carps or of the *Cyclostomatidæ*, is exclusively freshwater or terrestrial, it is highly probable that all members of that family are descended from one original marine type, and this probability is frequently borne out by the geographical distribution of the family. Thus carps (Cyprinidæ) abound throughout Huxley's Arctogæa, the Palæarctic, Ethiopian, Oriental, and Nearctic regions of Sclater and Wallace, but are absent in Australia and South America.

As in the class Pisces, so in the subkingdom Mollusca, the freshwater forms belong to widely different groups. Thus the *Unionidæ* and *Paludinidæ*, both purely freshwater families, belong to two widely different classes, the Lamellibranchiata or Pelecypoda and the Gasteropoda. Here too, as amongst the fishes, we find some families entirely confined to fresh water, as the examples mentioned above; others marine with freshwater genera, as the *Rissoidæ* or *Hydrobiidæ* with *Bythinia*, *Littorinidæ* with *Cremmoconchus*, *Mytilidæ* with *Dreissensia* and *Byssanodonta*, and finally genera like *Neritina*, with some species marine or estuarine, others fluviatile and even inhabiting mountain-torrents.

Amongst land-mollusca, although there is by no means the same diversity as in the freshwater members of the subkingdom, there are nevertheless several families of very different affinities. The families are, as a rule, entirely terrestrial, but they are frequently allied to other families that are marine. The most important forms belong to the order Pulmonata, including the *Helicidæ*, *Limacidæ*, *Testacellidæ*, and several other purely terrestrial families, the *Limneidæ* and *Physidæ* freshwater, the *Auriculidæ*, *Oncidiidæ*, and *Amphibolidæ* essentially brackish water or estuarine, but with marine representatives, and in the *Auriculidæ* with at least one truly terrestrial genus *Camptonyx*, and lastly the marine *Siphonariidæ*. The estuarine and marine types are, however, without exception littoral, and the whole order may be as thoroughly terrestrial in origin as mammals. Very different is the case with the land-shells

belonging to the order Prosobranchiata and frequently known as Operculata, although some of these have no opercula. These comprise the *Cyclophoridæ*, *Cyclostomatidæ*, *Aciculidæ*, and perhaps *Truncatellidæ* belonging, like the freshwater *Paludinidæ*, *Valvatidæ* and *Ampullaridæ*, and many of the commonest marine univalves, to the Tænioglossate division of the suborder Pectinibranchiata, and the *Helicinidæ* and *Hydrocænidæ* allied to *Neritidæ* and appertaining to the Rhipidoglossate division of the suborder Scutibranchiata*. In the immediate neighbourhood of the *Helicinidæ* there is another terrestrial family, the *Proserpinidæ*, without any operculum. The great bulk of all the divisions and orders of the Prosobranchiata, it is scarcely necessary to say, are marine.

There is nothing in the present distribution of the various families of operculated land-shells antagonistic to the idea of each family having originated from a distinct birthplace at a different period from any other family. The *Cyclophoridæ*, though found in all the principal regions of the earth, are chiefly developed in the Oriental region, and are very largely continental in their distribution. The *Cyclostomatidæ* are best developed on what Wallace has termed ancient continental islands, which have been separated from continents during the later Tertiary periods, and especially on the Antilles and Mascarene Islands; this family is represented only on the skirts of the Oriental region. The *Helicinidæ*, also mainly insular, have a curiously different range from the *Cyclostomatidæ*, although both are chiefly developed in the West Indies; *Helicina* extending through the islands of the Pacific to Australia, the Malay Archipelago and even Burma, but not to India. The last western straggler is found in the Seychelles, and the family is unknown in Madagascar or in Africa. The *Proserpinidæ* are confined to Central America and the West Indies. The last, judging by the small amount of differentiation and dispersal that they have undergone, may be of more recent origin than the others, whilst the abundance of the *Cyclostomatidæ* on old continental islands and their poor development on continents may show them to be of an older and less improved type than the *Cyclophoridæ*. Fossil forms of several kinds have been found in Europe and elsewhere, but their affinities and even the families to which they should be assigned are in general extremely doubtful.

Now this fact, that different subdivisions of an order, class or subkingdom have in all probability originated at different periods in

* The terms are those of Fischer's 'Manuel de Conchyliologie.'

the earth's history and at distinct points of the surface, renders it impossible to accept the evidence of the larger groups as a whole. Neither the evidence of the freshwater fishes nor that of land and freshwater mollusca as to distribution can be viewed in the same light as that of mammalia, birds, or reptiles. In the latter cases all are homogeneous to that extent, at all events, that we are probably dealing with descendants of one terrestrial form, and there can be little doubt that all fresh groups have diverged from one centre; in the former case there may have been several centres and several ancestral stocks. In order to analyze the evidence afforded by freshwater fishes and land mollusca, we must take separately each family or other subdivision confined to land or fresh water.

Land and freshwater mollusca are probably for the most part very ancient, and but for two circumstances would afford invaluable evidence as to ancient distribution of land-areas. The two difficulties are:—(1) that we are too imperfectly acquainted with the animals of the majority of the species in the most important order of all, the Pulmonata, to classify them correctly; and (2) that the mystery of the means of migration by which some of them are transported across the seas is unsolved. The prevalent idea that land-mollusca or their eggs are transported by floating logs appears to me extremely improbable in a great number of forms, because, so far as is known, very few either hybernate in wood, or lay their eggs there; and as the wood is carried to the sea during floods, caused by heavy rains which would certainly make every snail leave its hiding-place, the notion that some would remain ensconced in the clefts appears quite opposed to the habits of the animals. A few shore-haunting forms, such as *Truncatellidæ* or *Auriculidæ*, might very possibly be thus transported, but not *Helicidæ*, as a rule, and still less *Cyclophoridæ**, the majority of which are very rarely or never seen on trees or wood.

The smaller forms and their ova are possibly, as Wallace in his later works has suggested, transported by wind, sometimes attached to dried leaves. This may account for the wide distribution of a small form like *Diplommatina*, which lives amongst dead leaves. But both the animals and eggs of many forms are ill suited for wind-transport; some, like *Acavus*, have round or oval calcareous eggs of considerable weight, not easily carried into

* The genus *Leptopoma* is an exception, as it is said to live on trees. But its distribution is also exceptional, some of its species being found widely dispersed in oceanic islands.

the air, whilst other forms, such as *Ariophanta*, have rather large soft membranous eggs, quite unsuited for wind-transport to any distance. Except with the minute forms, I suspect that transport by wind across the sea to any distance is extremely rare, and it is in favour of this view that the species found on oceanic islands are almost always peculiar, testifying to a long period of isolation. On the other hand, how rapid may be the migration of some fresh-water forms was shown by *Dreissensia polymorpha*, which, in about a century, spread over a large part of Europe from the Caspian to Scotland and the south of France.

If it be the fact, as undoubtedly it is, that different subdivisions of the animal and vegetable kingdoms have originated at different geological periods, the next important question is whether, independently of evidence from fossil remains, there is any clue to difference of age, whether any characters exist by means of which groups of more or less ancient origin can be recognized. It is probable that, as a general rule, the most recent groups are those in which the fewest breaks occur, and in which the distinctions between families and genera are most difficult to define; for these distinctions become better marked as, in course of time, links die out through exposure to the varying effects of change in climate and the distribution of land, the development of enemies and the struggle for existence. It is quite true that much depends upon the power of each group of organisms to resist the influence of change; thus omnivorous animals would have greater facilities for obtaining subsistence, should their usual food no longer be procurable, than forms that feed invariably on fruit or vegetables, or flesh or insects, and animals with the power of flight, as already mentioned, may escape by migration, or those adapted for an aquatic life by swimming, whilst creatures unable to fly or swim are overwhelmed by floods or destroyed by change of climate, famine, or enemies. Still, after taking all these circumstances into account, and bearing in mind that the process of evolution appears much slower in some groups of organisms than in others, we shall probably not be far wrong in concluding that, as a general rule, groups of living beings with all the members nearly related are of more recent origin than those in which there are broad distinctions between the different genera and families.

Amongst the whole of the Vertebrata there is, I believe, no large group all the members of which are so closely connected together as the passerine* birds. They comprise more than 6000 known species,

* Not including picarians such as *Pici*, *Coccyges*, *Cypseli*, &c.

or about half of the whole class Aves. The difficulties of classifying them are so great that no two authors agree as to the number or limits of the families into which they can be divided. They have undoubtedly great powers of migration, and many can adapt themselves to changed conditions, some of the higher forms, for instance, the crows, being omnivorous and ranging all over the world; but very many genera are restricted in food and range, and appear no better adapted to survive extensive changes than mammals or reptiles are. It may be safely inferred that the Passeres are of more recent origin than other orders of birds, and probably than any other order of Vertebrata. Geological evidence, so far as it is available, coincides with this; for no remains of the order have been found below the Miocene. It must be remembered, however, that remains of birds from older systems are very rare.

It will thus be observed that Sclater's regions, adopted by Wallace and others, were chiefly based on what is very probably the most recently developed group of vertebrata, perhaps the most recent in the animal kingdom.

Huxley's scheme of zoological distribution, to which reference has already been made, was first proposed in a paper on the affinities and distribution of *Alectoromorphæ* and *Heteromorphæ*, or what are commonly known as Gallinaceous birds and their allies; but it was shown that other groups of the animal kingdom confirm the scheme first suggested by the distribution of these birds. Now as Huxley's system differs widely from Sclater's, and as both were suggested by different orders of the same class (birds*), it is wise to examine a little more closely how far the distribution of other classes or orders agrees with that of the Passeres.

I have already noticed the great importance attached by Wallace to the mammalia. But there are serious difficulties in the way of accepting the Passerine regions for mammals. In the first place, the difference between the mammals of the Australian region and those of all the other regions is far greater than the distinctions between the latter, and point, as Huxley has noticed, to the Australian region having been divided from the rest of the world by a barrier

* Reichenow (Zool. Jahrb. iii. p. 671, 1888) has proposed the following regions for birds:—

Arctic.
Western,—North and South America.
Eastern,—Africa, Europe, and Asia.
Southern, —Australia, New Zealand, New Guinea, &c.
Madagascar.
Antarctic.

impassable by mammals since a very distant geological period. Secondly, as Huxley has also pointed out, the difference between South America and Arctogæa exceeds the difference between different parts of the latter. Thirdly, the northern part of North America contains so large a proportion, not merely of families and genera, but of species common to the Palæarctic region, that the mammalian fauna differs less from that of Northern Asia than the mammals of Central Asia do from those of Europe. Fourthly, the mammals of Madagascar differ more from those of Africa than those of the Palæarctic do from those of the Oriental region *

* There are about a dozen mammalian genera found in Canada and the northern part of the Nearctic region that are wanting in northern Asia; of these, however, several of the most important, as the Skunk (*Mephitis*), Raccoon (*Procyon*), and Brush-tailed Porcupine (*Erethizon*), are Neotropical forms that have found their way north. On the other hand, the Lynx, Wolf, Fox, Glutton, both Bears, Marten, Elk, Reindeer, Wapiti, Bison, Wild Sheep, Beaver, Marmot, and some other N.-American forms, are either specifically identical with Palæarctic animals or very nearly allied to them. *Hesperomys* has been shown to be congeneric with *Cricetus* (Thomas, P. Z. S. 1888, p. 133). In Central Asia are found several well-marked types, like *Nectogale*, *Uropsilus*, *Ælurus*, *Æluropus*, *Budorcas*, *Panthalops*, *Poëphagus*, *Moschus*, and many others, that distinguish the fauna from that of the western Palæarctic area.

In the case of Madagascar, not only are two mammalian families, *Chiromyidæ* and *Centetidæ*, and one subfamily, *Cryptoproctinæ*, peculiar to the island, but out of about 24 genera of *Primates*, *Carnivora*, *Insectivora*, *Rodentia*, and *Ungulata* found in Madagascar, and about 100 found in Africa south of the Atlas, only two, *Potamochærus* and *Crocidura*, exist in both. The oriental genera of the orders mentioned are about 80 in number, and the Palæarctic (omitting Seals) about the same; of these about 30 are found in both regions. Some 25 genera belonging to these orders are common to the Oriental and Ethiopian areas, and 22 to the Palæarctic and Ethiopian, or to put the matter more clearly, the African mammals comprise 25 per cent. of Oriental, 22 per cent. of Palæarctic, and only 2 per cent. of Madagascar genera, whilst the Madagascar forms comprise 8·3 per cent. of African genera. It must be remembered that the climates of Madagascar and Tropical Africa are similar, that of the Palæarctic region very different.

Omitting New Zealand and Polynesia, the following appears to be the division of the earth's surface into mammalian regions:—

A. Marsupials predominating; placental mammals few; monotremes present.

I. *Australian region*, comprising, besides Australia and Tasmania, New Guinea, and the neighbouring islands east of Wallace's line.

B. Placental mammals predominating; marsupials few or absent; no monotremes.

II. *South-American* region.

III. *Arctogæan* region, comprising the following major divisions:—

1. *Madagascar*.

It may, however, be very fairly urged that the avifauna of Madagascar differs quite as widely from that of Africa as the mammalian fauna does, and that the question of the Nearctic region is, after all, of secondary importance. At the same time the objections noticed tend completely to invalidate the idea of equality in the different regions, so far as mammalia are concerned.

Passing on to the Reptilia, we shall find a greater difference. I have already mentioned that Dr. Günther, who at first accepted Sclater's regions, has been induced by the large additions to our knowledge in the course of the last 30 years to reconsider the whole subject; and he has published the result in the article on reptiles in the 'Encyclopædia Britannica.' He adopts a different set of regions for each of the three living orders of the Reptilia, of which numerous representatives are found in the world. The regions adopted for land and freshwater Tortoises are the following:—

Chelonian Regions.

1. All Europe and Asia, Northern Africa, North and Central America.
2. Africa.
3. *a*. Tropical America.
   b. Madagascar.
4. Tropical Pacific (Australia, New Guinea, &c.).
5. New Zealand.

The divisions for Lizards will be found to differ materially.

Lacertilian Regions.

1. Africa with the Western Palæarctic region.
2. India with the Manchurian (Eastern Palæarctic) subregion.
3. Tropical Pacific (Australia, &c. as before).
4. Madagascar.
5. South and North America.
6. New Zealand.

Lastly, the regions adopted for Snakes show a third arrangement.

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2. *Africa*, south of the Tropic of Cancer.
3. *Oriental*, South-eastern Asia and Malay Islands to Wallace's line.
4. *Aquilonian*, Europe, Asia north of the Himalayas, Africa north of the Tropic of Cancer, and America north of about 45°.
5. *Medio-Columbian*, America, between about 25° and 45° N. lat.

The last being of decidedly inferior value as a distinct division.

In some respects this rational distribution resembles that of Mr. Andrew Murray (Geographical Distr. Mamm. 1866; maps c. ci.).

Ophidian Regions.

1. Africa south of the Atlas.
2. Western Palæarctic region.
3. India with the eastern Palæarctic region.
4. North America.
5. Tropical America.
6. Tropical Pacific.
7. Madagascar.
8. New Zealand.

In the last case it is especially noticed that the relations of Madagascar to tropical America are closer than would be supposed from this classification.

There is, I believe, no zoologist living whose knowledge of the Reptilia exceeds Dr. Günther's, and as his attention was attracted to the question of distribution so long ago as 1858, the views now expressed are the results of a long study of the subject under the exceptionally favourable circumstances of being in charge of the largest collection in the world. I may add, from a long acquaintance with Dr. Günther, to whom I am indebted for calling my attention to the article I have quoted, that he is not in the habit of changing views once published without strong evidence. The following sentence from his article on Reptiles is therefore of great weight:—"The same arrangement of the so-called primary zoological regions is not applicable to all orders of reptiles, and the differences in their distribution are so fundamental that they can be accounted for only on the assumption of the various orders and families having appeared to spread over the earth at very distant periods when land and water were differently distributed over the surface of the globe."

The distribution of the Batrachia has been studied afresh by Mr. Boulenger, who has arranged the regions thus:—

I. Northern zone: *Caudata* abundant; *Apoda* wanting.
   1. Europo-Asiatic region.
   2. North-American region.

II. Equatorial southern zone. Either *Caudata* wanting or *Apoda* present or both *Caudata* wanting and *Apoda* present.

A. *Firmisternia* division.
   1. Indian region.
   2. African region.

B. *Arcifera* division.
1. Tropical American region.
2. Australian region.

The limits are the same as Wallace's. It should be mentioned, however, that New Zealand can scarcely be assigned to the Australian region, for its only Batrachian belongs to a family not known to occur in Australia. Madagascar, too, has strong claims to separation as a distinct region.

Dr. Günther also, in the 'Encyclopædia Britannica' and in his 'Introduction to the Study of Fishes' (1880, p. 217), proposed a scheme of distribution for the freshwater members of the class 'Pisces.' The following are the divisions :—

I. Northern zone.
1. Europo-Asiatic or Palæarctic region.
2. North-American or Nearctic region.

II. Equatorial zone.
A. Cyprinoid division.
1. Indian region.
2. African region.
B. Acyprinoid division.
1. Tropical American region.
2. Tropical Pacific region (Australia, &c.).

III. Southern Zone (Patagonia, Tasmania, and New Zealand).

It will not be necessary to dwell long upon the Invertebrata. They have received less attention than Vertebrates, and except in a very few groups, more remains to be done both in ascertaining their distribution and in determining their structural relations. Wallace, in his work on Geographical Distribution, states that the Lepidoptera and the best-known families of Coleoptera have approximately the same distribution as mammals and birds; but he admits some differences—for instance, the occurrence in temperate South America of a well-marked insect-fauna allied to that of the north temperate zone, and not to neotropical types.

Among the land and freshwater Mollusca, the Pulmonata, and especially the *Helicidæ* and *Limacidæ*, need thorough revision. Without much additional information concerning the animals (the shells alone having been described in a great majority of species and even in many genera) no accurate knowledge of the affinities of

different forms is possible; and without this knowledge the study of geographical distribution is useless. Fischer, in his 'Manuel de Conchyliologie' (p. 196), has adopted regions corresponding with those of Sclater and Wallace, except that a Neantarctic is separated from the Neotropical. So far, however, as the operculated Gasteropoda are concerned (and their affinities are far better ascertained than those of the Pulmonata), I cannot see the least resemblance in many cases to the distribution by regions of mammals and birds. I will only notice one case. The *Cyclophoridæ* (with one genus of *Helicinidæ* and one of *Cyclostomatidæ*) of New Guinea and the neighbouring islands, so far as they are known, appear to differ from those of Borneo much as the latter do from those of Ceylon, as will be seen by the following lists of genera represented, compiled mainly from Fischer's :—

Operculated Land Mollusca.

New Guinea and neighbouring islands.	Borneo.	Ceylon.
Pterocyclus.	Pterocyclus.	Pterocyclus.
Cyclophorus.	Opisthoporus.	Aulopoma.
Leptopoma.	Cyclophorus.	Cyclophorus.
Cyclotus.	Leptopoma.	Leptopoma.
Diplommatina.	Cyclotus.	Cyathopoma.
Leucoptychia.	Diplommatina.	Diplommatina.
Pupina.	Opisthostoma.	Cataulus.
Pupinella.	Megalomastoma.	
Callia.	Alycæus.	
Helicina.	Pupinella.	
Omphalotropis.	Rhaphaulus.	
	Helicina.	
	Phaneta.	
	Omphalotropis.	

It is true that our knowledge of the Papuan mollusca is very inferior to that of the Bornean and Ceylonese, especially the latter; but sufficient is known to show that the three belong to one region as regards operculated land-shells. The same is the case with Northern Australia. It is scarcely necessary to point out that between the mammalia of Australia with New Guinea and those of Borneo or Ceylon there is the greatest difference.

The distribution of land-plants into six regions of approximately equal value has never, I believe, been accepted by any botanist. All schemes of repartition with which I am acquainted differ widely

from those of Sclater and Wallace. Thus Mr. Thiselton Dyer, in his article on the distribution of plants in the 'Encyclopædia Britannica,' follows Bentham in recognizing "three tolerably ancient floras," which he divides thus:—

I. Northern.
   1. Arctic-alpine.
   2. Intermediate or temperate (in Europe, Asia, and N. America).
   3. Mediterraneo-Caucasian (countries around the Mediterranean and part of S.W. Asia, extending east to Sind).

II. Southern.
   1. Antarctic-alpine.
   2. Australian.
   3. Andine (temperate S. America, Andes, and New Zealand).
   4. Mexico-Californian.
   5. South African.

III. Tropical.
   1. Indo-Malayan (including New Guinea and North Australia).
   2. American.
   3. African.

Another classification is that of Oscar Drude*, who has divided the land-surface of the world into the following fourteen botanical regions or, as he terms them, floral realms (Florenreiche):—

1. Northern (northern part of Asia and America, and nearly all Europe).
2. Central Asian (Tibet, Mongolia and Turkestan, and Caspian region).
3. Mediterranean and Orient (countries around Mediterranean, Persia, &c., to Indian frontier).
4. East Asian (China and Japan).
5. Middle North American (United States chiefly).
6. Tropical African (Africa S. of the Atlas, the Cape excepted).
7. East African Islands (Madagascar and Mascarene Archipelago).

* Pet. Mitth. Ergänzungsheft, No. 74, 1884, pp. 43, 44.

8. Indian (India and S.E. Asia, Malay Archipelago, Papuasia, Northern Australia, and Polynesia).
9. Tropical American.
10. Cape of Good Hope (a small region near the Cape).
11. Australian (Australia south of the tropics and Tasmania).
12. Novo-Zelanian.
13. Andian (Tropical Andes, Chili, and the Argentine Republic).
14. Antarctic (southern extremity of America and antarctic islands).

It is sufficient to point out that, in both these systems, the greater part of the two regions of the earth which in mammalia exhibit the greatest diversity, the Oriental and Australian, are combined into one region.

In many respects the distribution of plants accords very well with that of land-mollusca.

If now we proceed to consider, as a whole, the geographical distribution of such different subdivisions of the animal kingdom as have been noticed, it will be observed that the mammals, batrachia, freshwater fishes, and land-mollusca appear, at all events in the opinion of the naturalists who have paid especial attention to the subject, to approach the passerine birds in distribution more than the reptiles or plants do. But, as I have pointed out, the freshwater fishes and land- and freshwater mollusca are heterogeneous groups made up of families and genera of various origin, and having very often, probably as a rule, a distribution not agreeing with each other in the smallest degree. Under the circumstances it is easy to see how the conflicting distribution of different families amongst such groups as land-shells or freshwater fishes will produce a general result, in which the only dominant feature will be trivial generic or subgeneric distinctions, closely connected with the modern distribution of land and water. The batrachians to some extent are open to the same remark, for they consist of three orders, Anura, Caudata, and Apoda, having but little affinity and almost certainly of widely different antiquity. The reason why batrachia agree on the whole with passerine birds and mammalia better than reptilia, is not improbably that anurous batrachia (frogs and toads), the only important living order, are of comparatively recent development. Placental mammalia, too, may be less ancient than the reptilian orders, at all events in the present land area. There is, in short, a strong reason for believing that the more recently deve-

loped groups agree with the present distribution and connexion of land tracts better than those of more ancient origin. The relations between the modern range of ancient families or orders and the ancient distribution of land tracts is a problem which it may be hoped will not always be as difficult as it appears at present.

Reviewing the whole evidence, I can only come to one conclusion, namely, that whilst Sclater's regions adopted by Wallace are convenient, and whilst the recognition of them by well-understood names has been of use and has tended to increase our knowledge of geographical distribution, they are, so far as they are natural, a necessary result of the present and later Tertiary distribution of land and water, and that they are, to a large extent, artificial, whilst the idea of their equality is an error. The attempt to make all forms of life fit into the particular grooves that were designed to accommodate passerine birds appears to me Procrustean.

On the whole, the evidence is far too contradictory to be received as proof of the permanence of oceans and continents.

So far I have merely laid before you reasons for doubting whether the distribution of animals at the present day agrees so closely with the present arrangement of land and oceanic areas as to lead to the inference that these have always been the same. It is evident that if there are wide distinctions in the distribution of different groups of living beings, all cannot be cited as witnesses to the permanence of continents and oceans in past times. It is quite true, however, that within the continental limits there have existed at various geological periods seas that, even if of no great depth, were just as complete barriers to the migration of particular forms of life as deep oceans would be. The familiar example of the British Islands is sufficient to illustrate this fact. As noticed by Wallace in 'Island Life,' Germany possesses nearly 90 species of land mammals and Scandinavia 60, whilst in Great Britain there are only 40, and in Ireland only 22. Of reptiles and batrachia 22 occur in Belgium, 13 in Britain, and only 4 in Ireland. The removal of the isthmus of Suez and the substitution of a shallow inlet, the width of the Straits of Dover, would constitute an impassable barrier to many animals.

It remains to be seen whether indications exist of land-connexions in past times across areas now occupied by deep sea. All the discussion hitherto has been to a large extent preliminary to this.

It must be remembered that different groups of animals vary very

greatly in their power to cross the sea, thus land-mammals and batrachians are, as a rule, unable to cross any marine barriers. Mammals, however, can swim further in the sea than batrachians can, the latter and their eggs being killed by sea-water. Snakes are very rarely found in oceanic islands, and those found belong for the most part to particular genera. The occurrence of land-tortoises on what appear to be evidently oceanic islands, such as the Gallipagos, although unexplained, renders the Chelonia less important as evidence of land-connexion. Lizards, as a rule, have very small migratory powers across the sea, but some scinques and geckoes appear to form an exception. The powers of dispersal in land- and freshwater mollusca are very limited, though some of them are occasionally transported across oceanic barriers.

It must not be forgotten, too, that when we wish to inquire into the evidence of Pretertiary land-areas, we must examine as witnesses the descendants of the oldest inhabitants, and must turn for information to the types that occupied the region before the invading hordes of passerine birds and placental mammals had driven out so many of the aborigines. If we wish to know anything about ancient distribution of land and sea, we must scrupulously ignore the records of a later state of things. Before we can read the old writing on the palimpsest we must clear away all traces of the modern inscription.

I shall proceed to examine in some little detail (except in the first instance) the evidence of ancient land-connexion :—

1. Between New Zealand and Australia.
2. Between the Solomon Islands and New Guinea.
3. Between Africa and Madagascar.
4. Between Madagascar and India.
5. Between South Africa and South America.

1. *New Zealand and Australia.*—The question of a former union between New Zealand and Australia has been discussed with great ingenuity in 'Island Life' by Wallace, who concludes from the geological and biological evidence that New Zealand received its flora and fauna from Eastern Australia at a time when the latter was divided by sea from Western Australia, and that the characteristic marsupial and monotreme fauna, with all the peculiar temperate flora of Australia, must at the time have been confined to the western island, and consequently did not pass into New Zealand.

The time assigned to the union is the latter part of the Secondary era. Here it is necessary to remark that unless the two areas remained united in the latter half of the Cretaceous period, Dicotyledonous Angiospermous plants, which form the great majority of the forms common to New Zealand and Australia, must have existed in the Australian area before there is any evidence of their having appeared in the northern hemisphere. The essential point is, that Australia and New Zealand are now divided by a broad expanse of sea, between 1000 and 2000 fathoms in depth.

2. *The Solomon Islands.*—The next case to be mentioned is very simple, and is a rather curious illustration of the importance of biological evidence. I have already noticed the interesting account of the geology of the Solomon Islands given by Dr. Guppy, and his discovery in those islands of deep-sea deposits. He infers, on what appears at first sight good geological evidence, that the region has undergone upheaval of not less than 12,000 feet in Post-tertiary times. The Solomon Islands, with New Britain and New Ireland, are represented on the 'Challenger' chart as connected with New Guinea by a bank not exceeding 500 fathoms in depth, and they are said by Dr. Guppy to be separated from each other by channels about 400 fathoms deep*.

Now the fauna of the Solomon Islands comprises mammals, snakes, and batrachians in considerable numbers. As, in the seas around New Guinea, floating wood washed down by rivers is said to occur to an extent rarely met with in other parts of the world, the occurrence of the Solomon Island mammals might perhaps be accounted for, without supposing the islands to have been united to New Guinea. The forms† represented comprise, besides bats, several species of *Mus*, a genus that appears occasionally, by some means or other, to be able to traverse arms of the sea, and one kind of *Phalanger* or *Cuscus*, an arboreal marsupial. The same species of *Phalanger* is found in New Britain and New Ireland, and an allied variety, not specifically distinguished, occurs in New Guinea, Ceram, Bouru, and Amboyna. The Phalanger also extends to San Cristoval, the most eastern of the Solomon Islands, a matter of some interest, as will be shown presently.

The presence of the reptiles and batrachia is not, however, to be

* I am indebted to Captain Wharton for the information that no accurate soundings are recorded.

† Thomas, P. Z. S. 1887, p. 320, 1888, pp. 470–483.

explained without communication by land. The species have been described by Mr. Boulenger * and comprise—1 crocodile, 17 lizards, 10 land-snakes, and 13 species of frogs and toads belonging to 5 genera, representing 3 families, *Ranidæ*, *Ceratobatrachidæ*, and *Hylidæ*, the second of which, so far as is known at present, is peculiar to the islands. Our knowledge of Papuan batrachians is, however, very imperfect.

It is a well-known fact, as I have already mentioned, that batrachians and their eggs are killed by sea-water, and that snakes, as a rule, are not found on oceanic islands. No batrachian or ophidian fauna resembling that of the Solomon Islands has ever been observed except in islands that have been part of a continental land. It is impossible to come to any other conclusion than that the Solomon Islands, with New Britain and New Ireland, once formed part of New Guinea, and that portions of the group have never been submerged since the separation.

Nor is this quite all the evidence. The species of frogs and snakes appear to be pretty generally distributed amongst the islands in such a manner as to show that the fauna is probably nearly uniform throughout, with the exception of the easternmost island, San Cristoval, the fauna of which is rather well known. Whilst from the next large island to the westward, Guadalcanar, 5 frogs and 4 snakes have been obtained, San Cristoval has only yielded 1 frog and 3 snakes. Moreover, 2 of the 3 snakes belong to the genus *Enygrus* of the family *Boidæ*, probably all good climbers and swimmers. Both the species of *Enygrus* are widely dispersed, one ranging eastward to the Fiji Islands, the other northwestward to the Moluccas and Pelew Islands. The third snake, *Dendrophis salomonis*, found also in Duke of York Island, between New Ireland and New Britain, and in several other islands of the Solomon group, is a climbing tree-snake, that might be transported by floating trees. Most snakes are unable to climb trees, and would be washed off from floating branches &c. In other respects, too, the reptilian fauna of San Cristoval, as Mr. Boulenger has shown, is Polynesian; whilst Mr. Woodford has pointed out (P. Z. S. 1888, p. 250) that certain birds and butterflies, found in the other islands, are here wanting. Probably San Cristoval was separated from the mainland before the other islands, just as Ireland must have been separated from continental Europe before Great Britain. But the poverty in batrachians and snakes of San Cristoval serves to confirm the

* Tr. Z. S. xii. p. 35; P. Z. S. 1887, p. 333, 1888, p. 88.

necessity for land-connexion between the remaining islands and New Guinea; for if the snakes and frogs came over the sea to all the other islands, why have they not reached San Cristoval?

It is evident that the separation of the Solomon group of islands from the mainland and from each other is due to subsidence. This appears at first opposed to the geological evidence of elevation, and it undoubtedly proves that the islands, none of which are 12,000 feet high, cannot as a whole have been recently elevated 12,000 feet unless, since the elevation took place, they have undergone depression sufficient to isolate them. But the raised coral- and rhizopod-beds described by Dr. Guppy certainly appear to bear out his views of recent elevation, and he brings forward other evidence of much weight. On the other hand, not only are some of the forms of batrachia and reptilia peculiar, but the rodents, and especially the bats, show striking distinctive characters. Two new genera of fruit-eating bats (*Pteropidæ*) and one of *Rhinolophidæ* have been recently described from the Solomon Islands, and are not known to occur elsewhere. It is therefore probable that the Solomon Islands must be ancient land, and the explanation of the apparent contradiction may be that the elevation observed by Dr. Guppy has been partial and local, and has not extended to the whole area. It is also probable that the depression which has separated the different islands, with the exception of San Cristoval, from each other is much more recent than that which divided the group as a whole from New Guinea. It is far from unlikely that the channel separating San Cristoval from the other islands will be found, when accurate soundings are taken, to be deeper than the channels between the remaining islands of the group.

Another instance similar to that of the Solomon Islands is afforded by the Liu-Kiu (Loo-choo) Islands between Japan and Formosa. Here also the depths of the surrounding seas are not, I believe, ascertained; the islands are represented in the 'Challenger' map, like the Solomons, as within the 500-fathom line. From these islands several lizards, land-snakes, and batrachians, including a newt, have been obtained*. Most of the species are peculiar, but one frog is a common oriental form, and the newt is a variety of a Chinese and Japanese species.

3. *The Mozambique Channel between Africa and Madagascar.*—Before passing on to the question of an ancient land connecting

* Boulenger, P. Z. S. 1887, p. 146.

India and Madagascar, I wish briefly to call your attention to the Mozambique Channel. This channel is 250 miles broad at its narrowest part and upwards of 1000 fathoms deep throughout; the least recorded depth (which is close to the African coast in the narrowest part of the channel) being 1130. No one questions for a moment that Madagascar and Africa were united during part of the Tertiary era; the large mammalian fauna of Madagascar alone amply proves the fact. As already mentioned, only two genera of mammals are common to Madagascar and Africa, though a few species of reptiles and batrachians are found in both. One of the Mammalian genera common to both areas is *Crocidura*, probably an ancient type, but also possibly introduced by man; the other is *Potamochœrus*, a kind of pig. Now no other ungulate, except this pig, is found in Madagascar, and hence it is probable that all the South African Ungulata belong to the Miocene and Pliocene European fauna, which is believed to have migrated into South Africa after the separation of Madagascar. As Wallace has pointed out, all pigs swim well, and *Potamochœrus* is said to be more of a water-animal than most pigs, and may very probably have crossed from the mainland after the lemurs, insectivores, and other mammals had been isolated by sea. But how far could *Potamochœrus* swim? Surely it is not likely that it could cross the Straits of Dover. I think we are justified in assuming about 10 miles as a probable limit of its power of crossing the sea, but, to be safe, let us suppose double as much *. Then, in Pliocene or Pleistocene times, quite as probably the latter as the former, when *Potamochœrus* reached South Africa, Madagascar was separated by a channel not more than 20 miles broad. The conclusion is inevitable that nearly the whole depression of upwards of 1000 fathoms is of Pliocene or Post-pliocene date. Of course it must not be understood that this date is proved. What we may consider, however, as beyond any doubt is that the depression cannot be older than Middle Tertiary.

4. *Madagascar and India.*—The question whether there was in Secondary or Tertiary times land-connexion across the Indian Ocean between India and Madagascar has been treated at considerable length, with great ability and literary skill, by Mr. Wallace in the 'Geological Distribution of Animals' and in 'Island

* Elephants are excellent swimmers, and have been known to swim, without a rest, for six hours, and, with a rest, for nine. But the pace is very slow, little, if at all, more than a mile an hour.

Life;' and, although this was not his first view, he has come in the last-named work to the decided conclusion that there is no evidence of any former land-connexion in the direction named. With one important exception, that of the remarks on the Upper Palæozoic and Lower Mesozoic flora *, concerning which I think Mr. Wallace has failed to appreciate the facts as a whole, there is scarcely anything in his arguments with which I am inclined to disagree. Upon the evidence noticed by him, relating chiefly to mammals and birds, his conclusions are, I think, reasonable, and I quite concur in his reasons for rejecting Sclater's and Hartlaub's hypothesis of "Lemuria." But he has overlooked some of the evidence and is, I think, not acquainted with certain material facts.

I have already referred to the remarkable peculiarities of the Madagascar mammal-fauna, and its great difference from that of Africa. Precisely the same phenomenon is presented by birds †. The most characteristic African families, such as plantain-eaters (*Musophagidæ*), colies (*Colidæ*), and *Irrisoridæ*, barbets, hornbills, secretary-birds, and a number of genera, such as *Lamprotornis*, *Buphaga*, *Laniarius*, and *Telephonus*, that are the common and familiar birds of every part of Africa south of the Sahara, are entirely wanting in the Mascarene Islands, including the Seychelles, Mauritius, &c., whilst no fewer than four peculiar families and a number of genera confined to the archipelago replace them. Amongst the Mascarene birds, too, are found several representatives of Oriental genera, or genera closely allied to Oriental types, and without any near Ethiopian relations. Foremost amongst these are certain bulbuls, forming the genera *Ixocincla* and *Tylas*, the former composed of species which have been usually referred to the typically Oriental genus *Hypsipetes*, and the latter nearly affined. In fact, as was shown by Geoffroy St.-Hilaire, and as Hartlaub has since pointed out, there is in the Mascarene avifauna a more marked connexion with Indian than with Ethiopian types. In the Seychelles, especially, out of the 7 passerine genera represented by peculiar species, three, *Nectarinia*, *Zosterops*, and *Tchitrea*, are Indian and African, one, *Foudia*, is Ethiopian, but not Indian, and two, *Copsychus* and *Hypsipetes*, or *Ixocincla*, are Indian, but not African ‡.

Another singular case of distribution that corresponds with that

* 'Island Life,' p. 398, footnote.

† Hartlaub, 'Die Vögel Madagascars u. d. benachbarten Inselgruppen,' 1877.

‡ E. Newton, Ibis, 1867, p. 359.

of the birds is afforded by the large fruit-eating bats (*Pteropidæ*) *. The only African genus belonging to the family is *Epomophorus*, which is confined to the continent, whilst throughout the Mascarene archipelago, and even in the Comoro Islands in the Mozambique channel, the typically Oriental genus *Pteropus* occurs and is represented in various islands by 5 species, one or two of them only distinguished by critical characters from the common "flying-fox" of the Indian Peninsula.

So far as the *Pteropus* and birds are concerned, the explanation afforded by Mr. Wallace seems fully to meet the case. He points out that Madagascar was probably connected with Africa in Middle Tertiary times, before the present mammal and bird fauna of Africa, which in Miocene (and in Greece in Pliocene) times inhabited the Palæarctic region, had been driven south by the approach of the colder Pliocene and Glacial epochs †, and that the connexion with Madagascar was severed before the southward migration of the palæarctic fauna took place, leaving in Madagascar the old African forms which have since undergone no great modification. He, however, points out that the areas now occupied by the Laccadive, Maldive and Chagos atolls, the Saya de Malha and Cargados reefs, are clearly the remains of great islands now depressed beneath the sea, but which must have existed in late Tertiary times, and have afforded means of migration to bats and birds. In the case of *Pteropus*, which is a powerful flier ‡, though I should think certainly incapable of winging its way from India to the nearest Mascarene Islands, this explanation is highly probable, and it applies to such cases as *Copsychus*, but as regards *Hypsipetes* or, rather, *Ixocincla*, and *Tylas*, the derivation from India may be rather more ancient. It should be remembered, however, that distinct genera

* Dobson, Cat. Chiropt. B. M. Introduction, p. xxxii.

† It is, however, important to notice that Mr. Wallace's account of the wide sea occupying the Sahara and Northern India in Miocene times is founded on geological views once current, but now, I think, shown to have been erroneous. There is, as Zittel has shown, no reason to believe that any part of the Sahara has been sea since the Cretaceous period, and there is no evidence that marine conditions prevailed at any geological epoch whatever in the plain of Northern India from Agra to the Brahmaputra ('Manual Geol. India,' i. p. 393). Another error into which Mr. Wallace has been led by geological writers is that of supposing the Pikermi and Siwalik faunas to be Miocene instead of Pliocene. The fauna which was Pliocene in Greece may not have reached South Africa till Pleistocene times, as stated above.

‡ The Indian flying-fox, *P. medius*, has been captured 200 miles from land. Sterndale, Nat. Hist. Mamm. India, p. 39.

in passerine birds are founded on differences that would not be considered generic in other classes of Vertebrata, and that by no means indicate distant relationship.

The Reptiles and Batrachians of Madagascar have been much collected and described of late years, and I am indebted to Mr. Boulenger for some additions to Dr. Böttger's list and for other details*. The reptiles, the snakes excepted, are on the whole more allied to African types than the mammals or birds are, although there is the same remarkable absence of several characteristic Ethiopian families; for instance, there are no *Trionychidæ*, *Agamidæ*, *Lycodontidæ*, *Elapidæ*, or *Viperidæ*. The Oriental relations are very slight. The genus *Phelsuma* (Geckonidæ) is only represented outside of the Mascarene Islands by one species found in the Andamans. This, by itself, is not of much importance, for some geckoes are rather widely distributed on oceanic islands. The distribution of the genus *Acontias* and its allies is more important. This little group of scinques, with rudimentary limbs or none, and very peculiar head-shields, was formerly classed as a distinct family, but has now been placed, rightly, I believe, in the great family of *Scincidæ*. About 12 species are known with certainty, of which 4 are found in Ceylon, 3 in Madagascar, and 5 in Southern Africa. In the batrachians Oriental affinities are rather better shown, for in the Mascarene Islands are found 16 species of *Rhacophorus* (Ranidæ), all the other species being Oriental, and a species of *Calophrynus* of which the only other 2 species are Oriental, whilst the only member of the family *Dyscophidæ* found outside the Mascarene archipelago is the Burmese *Caluella guttulata*. The *Dyscophidæ* comprise 7 genera and 11 species in Madagascar.

In freshwater fishes there is one very curious case of affinity. There is a family known to ichthyologists as *Chromides* (*Chromididæ*), entirely composed of freshwater species at the present time. This family occurs in South America and throughout Africa, being well represented in the Nile; and species belonging to two genera, *Chromis* and *Hemichromis*, are found in the Jordan and the Lake of Galilee, in Palestine. Three species have been described from Madagascar, one of these constituting a separate genus under the name of *Paretroplus*, and forming a link between *Hemichromis* and the only Oriental genus, *Etroplus*, which is peculiar to the Indian

* The data concerning the relations and distribution of reptiles and batrachians in the present address are chiefly taken from Mr. Boulenger's recently published British Museum Catalogues.

peninsula and Ceylon, not extending even into the Indo-Gangetic plain. Thus we appear, in this family of fishes, to have two lines of migration indicated from Africa into Asia; one by the Nile Valley to Palestine, the other by the Mascarene Islands to the peninsula of India, each branch terminating in types quite distinct from the terminal representatives of the other, and no form of the family being known to occur in Asia, except in the localities mentioned.

In the Seychelles, to which I have already referred as the only thoroughly authenticated case of oceanic islands composed of granitoid or gneissoid rocks, two Frogs and two Cæcilians are found. The latter belong to an order entirely unknown in oceanic islands elsewhere, and not yet recorded from Madagascar. One species pertains to a genus found also in Africa, the other to a peculiar generic type; but the order *Apoda*, consisting of the Cæcilians, is particularly well represented in Southern India. The presence of the Batrachia serves to prove the former union of the Seychelles to a continent; but this might have been Africa, or Madagascar when forming part of the African land.

The land and freshwater Mollusca of the Mascarene Islands are just as peculiar as the vertebrates, and exhibit the same remarkable affinities; nothing can better show that we are dealing with a very ancient fauna. A large proportion of the molluscan genera are peculiar, such as *Helicophanta*, *Ampelita*, and *Gibbus* amongst the Pulmonata, *Acroptychia*, *Hainesia*, and *Tropidophora* amongst the Prosobranchiata, but perhaps the chief claim to recognition is that in these islands, as in the West Indies, there is a remarkable development of the *Cyclostomatidæ*, possibly due in both cases to the preservation, under insular conditions, of the members of a family exposed to too many enemies for vigorous development amongst the modern denizens of Africa and S. America. Attention has been directed by the late Mr. G. Nevill * to the connexion with the Oriental fauna exhibited by the land-mollusca of the Seychelles in particular. It would take up too much time to go into detail, and therefore I will merely say that some Madagascar shells of *Helicidæ* so closely resemble Indian forms that I suspect them to be congeneric, but that without detailed knowledge of the animals it is impossible to speak with any certainty. A Comoro *Glessula* and a Seychelles *Streptaxis* have decided Indian affinities, however, whilst a species of *Cochlostyla*, a characteristic Philippine genus, and the small Indian *Helix barakporensis* have been obtained from Madagascar.

* P. Z. S. 1869, p. 62.

In the operculate land-shells the evidence is clearer. Of the *Cyclostomatidæ*, the genus *Cyclotopsis* is peculiar to the Mascarene Islands and the peninsula of India, and affords a case somewhat similar to that of *Etroplus* in the freshwater fishes, the only other members of the family found in the Oriental region being an *Otopoma*, met with in Cutch, and *Realia* (*Omphalotropis*)*, another Mascarene genus, in the Andaman and Nicobar Islands and some of the Malay islands †. But *Otopoma* is also found in Southern Arabia, Socotra, &c., and does not penetrate India further east than Cutch; whilst *Realia* is an insular type, probably possessing peculiar faculties for migration, and ranges through various islands to Polynesia and New Zealand. It is reasonable to suppose that, in whatever way the transfer may have taken place, *Cyclotopsis* reached India from the Mascarene Islands, where *Cyclostomatidæ* abound. On the other hand, there are found on the Seychelles *Cyathopoma*, a genus chiefly developed in Peninsular India, *Leptopoma*, a Malay type, found also in Ceylon, and *Helicina*, not found in India or Ceylon, but occurring in Burma and ranging throughout the Malay Archipelago and Polynesia to America and the Antilles. These types, belonging to two totally distinct families, *Cyclophoridæ* and *Helicinidæ*, must apparently have reached the Seychelles from the eastward, for not one of them is found in Africa. Now if there was not land-connexion between India and the Seychelles, these mollusks must have been transported either by floating objects, a means of migration concerning which I have already expressed grave scepticism, or through the air. But anything floating would be transported from the Seychelles to the Indian coasts, never the reverse, as is shown by the Seychelles double cocoanut, or *cocos de mer*, having been known long before its origin was discovered through being occasionally thrown upon the Maldives and Sumatra. I have examined the weather-charts of the Arabian Sea and neighbouring portions of the Indian Ocean, on which the currents for different periods of the year are shown, and I think it is evident that the westwardly currents which prevail in parts of the sea from November

* Many of the shells referred to *Omphalotropis* in works on land-mollusca really belong to *Assiminea*, a brackish-water form belonging to a different family.

† The peculiar Madagascar shell called *Acroptychia metableta* is wonderfully like *Cyclophorus foliaceus* from the Nicobar Islands, and *C. Leai* from the Andamans. The Madagascar *Mascaria* is represented in Ceylon by *Cataulus*, in the Himalayas, Burma, and Borneo by *Coptochilus*, and in the Neotropical region by *Megalomastoma*.

till April are too slight and irregular, especially in the neighbourhood of the Indian coast, to transport any objects from India to the Mascarene Islands.

Wallace has suggested that in a stormy area like many parts of the Indian Ocean, small organisms, such as seeds of plants and eggs of invertebrates, may be transported by the winds across seas of considerable breadth, and he supposes that the Azores and some other Atlantic islands have thus been stocked with plants, insects, and mollusca*. In the latter case he especially points out that the efficient transport in this case is not by ordinary winds such as the trade-winds, for otherwise the Azores would have derived their plants, insects, and shells from America, but by violent gales and storms, which are in the north Atlantic very capricious and irregular in direction. With regard to storms in the Indian Ocean, I consulted my brother Mr. H. F. Blanford, who called my attention to the weather- and current-charts already mentioned, and he tells me that no storm in the Indian Ocean ever crosses the Equator, that the storms travel on each side, away from the equinoctial line, and that consequently, as the Mascarene Islands lie south of the Equator, and India to the northward, the transports of seeds or eggs from one to the other by storms is impossible. A good steady wind blows in the S.W. monsoon (May to October) in a somewhat circuitous course from the Mascarene Islands up the African coast, and thence eastward across the Arabian sea ; but this, like the trade-winds of the Atlantic, is not likely to transport solid objects to any distance. The N. E. monsoon in the neighbourhood of the Indian coast is too light and irregular to be of any importance.

Of course, under exceptional circumstances, light objects might be carried by violent upward currents, such as occur in tropical cyclones, into the higher regions of the atmosphere, as the volcanic dust was carried from Krakatao ; but independently of the fact that the eggs of tropical mollusca and insects would probably be killed by the cold, this mode of transport might explain diffusion throughout the world, but would not account for partial dissemination of special forms confined to certain islands in particular directions. It is true that the difficulty of transport, either by floating objects or by the wind, would be greatly diminished by the presence of large intervening islands as already explained ; but still it is doubtful whether the presence of these islands would have any important effect on the winds or currents, so as to obviate the difficulty of transport from India to the Mascarene Islands.

* Island Life, pp. 247, 251, 253, &c.

Numerous cases of affinity between Mascarene and Oriental insects have been noticed, and there are similar alliances amongst the plants, but it is impossible to enter into these. There can be no question that the Mascarene fauna and flora, taken as a whole, with the exception of the land-mammalia, contains a well-marked Oriental element. This has never been questioned, but it has been urged, with much force, that the presence of this element may be accounted for without its necessarily involving land-connexion between India and Madagascar. It is, however, admitted that the existence at a late Tertiary epoch of large intermediate islands is essential.

If, however, any geological evidence can be produced in favour of the view that the Indian Ocean, between India and South Africa, was bridged by land before either country was inhabited by placental, or perhaps by any mammalia, it is, I think, clear that all the peculiar relationships of the Mascarene Islands would be satisfactorily explained. I think that the requisite geological evidence does exist. In the first place, attention must be called to the remarkable flora that extended from Australia to India and South Africa in Upper Palæozoic times. No doubt until very recently the principal European palæontologists refused to admit that this flora was Palæozoic, and even now the statement is occasionally made that the Carboniferous * flora of northern lands had a world-wide range. But the mass of evidence now available to show that the Newcastle flora of Australia and the Damuda-Talchir flora of India are really Upper Palæozoic, despite the absence of European palæozoic plants and the presence of what are, in Europe, Mesozoic types, is so clear that I feel sure any geologist who will examine the question will be convinced of its truth. In Australia the facts have long been perfectly well known, but in India they have only recently been fully cleared up, chiefly by the progress of discovery in the Salt Range of the Punjab. In South Africa the evidence is less perfect, though some important additions to our knowledge have resulted from Dr. Feistmantel's examination of the fossil plants, the account of which he has been so good as to send to me. In this account, which only reached me two days since, the representation of the peculiar Damuda flora of India in South Africa is shown to be beyond question, and much more complete than has hitherto been supposed.

Now this flora is so strongly contrasted with the Carboniferous flora of Europe that it is difficult to conceive that the countries in which the two grew can have been in connexion, and the hypothesis

* In the following remarks, Carboniferous must be understood to include Permian.

of Gondwána-land, as it is termed by Suess *, a great continent including Australia, India, and South Africa, seems more in accordance with facts than Mr. Wallace's view that "fragmentary evidence derived from such remote periods" is "utterly inconclusive"†. For if each flora could be transported across the sea, why are no European Carboniferous plants found in the contemporaneous deposits of Gondwána-land and *vice versâ*. Carboniferous plants of the European type are not confined to the northern hemisphere even, for they are found on the Zambesi in Africa and in Brazil. The accounts of their occurrence in Africa south of the Zambesi are as yet too indefinite for any clear idea of their relations to be formed, and it remains to be seen whether the *Lepidodendron* said to be found in Natal and the Transvaal is not Lower Carboniferous or Devonian, as in Australia.

There is some evidence, though less complete than that from Carboniferous strata, of similar floras in Jurassic beds in Australia, India, South Africa, and also in South America.

The evidence of the Carboniferous flora is, however, open to one objection. It may be urged that the distinction between the Northern and Southern floras is too great to be due solely to isolation, and that some other agents, such as climate, must be the cause of the difference. Very possibly the difference may be due to both isolation and climate; for in the lower part of the series in India, Africa, and Australia, the best-marked proofs, yet recorded, of glacial action in ancient rocks have been noticed, and, despite some curious occurrences of boulders in coal-seams, no such unequivocal evidence of glacial conditions has been noticed in the Carboniferous of the Northern hemisphere. But additional facts in favour of land-connexion between India and South Africa are met with in Cretaceous times, and in this case the evidence is derived from marine, not from fluviatile deposits.

The Echinoderm-fauna of the Cenomanian beds found around Bág, near the Nerbudda, in Western India, comprises 8 species ‡, only 2 of which are not found in beds of the same age in Europe. The number of species found in the Cenomanian Utatur group of South India of the same age is 10 §, 4 of which, all species of *Cidaris*, are referred to European species, but three of the four are doubtful. The

* Das Antlitz der Erde, Bd. i. p. 768. † Island Life, p. 398, note.

‡ Duncan, Q. J. G. S. xliii. p. 154.

§ Stoliczka, 'Palæontologia Indica,' ser. viii. vol. iv. p. (125). See also Manual Geol. India, pp. 290, 297, &c.

Arialur beds of Southern India (Senonian) contain 26 species, of which 4 only are known from European Cretaceous deposits, and of these 4 2 are doubtfully identified. Not a single species is common to the Nerbudda and S. Indian Cretaceous rocks; but this is far less important than the fact that the former contain 75 per cent. of European forms, and the latter a percentage certainly not exceeding 40 *, and probably considerably less. The fauna of the S. Indian beds generally is widely distinct from the Cenomanian forms of Europe, that of the Nerbudda beds, so far as known, is very similar. It is a reasonable conclusion, as I pointed out ten years ago †, that the Nerbudda beds were deposited in a sea in direct communication with the Cenomanian sea of Europe, and the Trichinopoly beds in waters that were separated by a land barrier.

But the European Cenomanian fauna is found again in Southern Arabia and in Palestine. The Trichinopoly fauna recurs in the Khási hills, south of Assam, 1200 miles N.E. of Trichinopoly, and again in Natal, more than 4000 miles to the S.W.; and it appears almost a necessary inference that these points were on the south coast of a tract of land that extended across the Indian Ocean. Since I first suggested this view in 1879, it has been strongly supported by Prof. Martin Duncan's revision of the Nerbudda Echinodermata.

Nor is this all. From a study of the Jurassic fauna of the world, that is to say from the consideration of an entirely different group of facts, Neumayr has come to precisely the same conclusion as to a land union between India and S. Africa across the Indian Ocean ‡, and this view is especially founded on the Neocomian fauna of Uitenhage §, in Cape Colony. It should, however, be noticed that near India, very possibly to the eastward, but not, I think, precisely in the direction indicated by Neumayr, there was probably in uppermost Jurassic or lowest Cretaceous times, some communication between the seas to the North and South. This would explain the occurrence of a few identical species of Mollusca, found in very high Jurassic or low Neocomian beds in Cutch on the one hand, and near the mouth of the Godávari on the other. A shallow strait would

* It must not be forgotten that this percentage is higher in the Cenomanian Echinodermata than in other groups, that the total percentage of European forms in the Echinodermata of the S. Indian Cretaceous rocks is only 18 per cent., and that of European species in the whole fauna 16.

† See Man. Geol. India, Introduction, p. xxxix, & p. 297.

‡ Denkschr. k.-k. Ak. Wiss. Wien, math.-nat. Cl. Bd. l. (1885), p. 132, map 1.

§ *Loc. cit.* p. 54.

have sufficed, and if this was subsequently converted into land, the progressive diminution of European species in the three stages of the S. Indian Cretaceous beds would be explained by the increasing effect of isolation.

Since the above was written another and very noteworthy piece of evidence has been pointed out, again by Neumayr, in one of the last papers that he wrote *. In our Quarterly Journal of last year, as an appendix to Mr. Baron's paper "On the Geology of parts of Madagascar," a list of fossils identified by Mr. R. B. Newton was added †. Four of these fossils, all species of Belemnites, were Neocomian, and consequently of similar age to the Uitenhage beds of Cape Colony, formerly supposed to be Jurassic. In the Uitenhage beds a single Belemnite (*B. africanus*) occurs. Not only have none of the species recorded from Madagascar been found in the Uitenhage beds, but three of them belong to a group of Belemnites called *Notocœli*, and one to the *Hastati*; whilst *B. africanus* is referred to the *Absoluti*. Now the *Notocœli* are typically equatorial forms, whilst the *Absoluti* are as typical, in the northern hemisphere, of boreal regions. *B. pistilliformis*, the Madagascar representative of the *Hastati*, is also a distinctly southern form in Europe. The inference that the sea to the north-west of Madagascar in Neocomian times was part of the warm equatorial ocean, whilst the sea of the extreme south of Africa was part of a cold southern ocean with a distinct fauna, is inevitable, and agrees with the other points cited in showing that a belt of land probably extended from South Africa across the Indian Ocean in Cretaceous times.

The evidence relating to the old land-connexion between India and South Africa has been given at greater length than would otherwise have been necessary because of its importance, and because this is a crucial case. So far as I am able to judge, every circumstance as to the distribution of life is consistent with the view that the connexion between India and South Africa included the Archæan masses of the Seychelles and Madagascar, that it continued throughout Upper Cretaceous times, and was broken up into islands at an early Tertiary date. Great depression must have taken place, and the last remnants of the islands are now doubtless marked by the coral atolls of the Laccadives, Maldives, and Chagos, and by the Saya de Malha bank. It is immaterial whether Bourbon, Mauritius, and Rodriguez ever formed part of the Mascarene land or not.

* Neues Jahrb. f. Mineral. &c. 1890, p. 1.

† Quart. Journ. Geol. Soc. xlv. p. 331.

It is perfectly true, however, that the charts hitherto published, for instance, that accompanying the 'Challenger' narrative, show deep water between the various banks that support the Mascarene Islands and the Laccadives, Maldives, Chagos, and other groups. But the soundings in the portion of the Indian Ocean between these islands are insufficient to enable the contours of the sea-bottom to be laid down with any approach to acccuracy; and I anticipate that, when the contours are better known, a bank will be found to connect the whole series from India to Madagascar. Even should this not be the case, the evidence of land-connexion appears so strong that it may be a question whether the whole of the ocean-bottom between Africa and India may not have sunk to its present depth since Cretaceous times.

5. *South Africa and South America.*—The only other hypothesis to which I shall ask your attention is that of an ancient southern continent, and especially the possibility of ancient land-connexion between South America and Africa on the one hand and between South America and Australia or New Zealand on the other. The latter, if it ever existed, must have been, I think, the later of the two, and I will give the biological evidence in its favour first. The most interesting relations are those of freshwater fishes, the peculiar distribution of which has already been noticed. Two families, *Haplochitonidæ* and *Galaxiadæ* *, are found only in the southern extremity of America, New Zealand, and Tasmania with Southern Australia, and they form a considerable proportion of the small river-fish-fauna of those countries.

There are some well-marked alliances between the frogs and tortoises of Australia and those of South America. The batrachian family *Cystignathidæ* and the chelonian family *Chelydidæ* are restricted to the two areas; but on the other hand no tortoises are found in New Zealand, and the only frog occurring there is a member of a family otherwise confined to the Palæarctic region. Moreover fossil representatives of *Chelydidæ* have been found both in Europe and in India, so that it is not improbable that the *Cystignathidæ*, which are not very high forms, may also have once had a more extensive range. The land- and freshwater shells, too, afford but little evidence of connexion. If, as Wallace has suggested, the New Zealand, Tasmanian and Patagonian freshwater fishes or their ova can have been transported by floating ice from the Antarctic

* A *Galaxias* has been described from the Indian coast, but the determination appears somewhat doubtful.

continent, the biological evidence may be accounted for without the necessity for land-communication. Singularly enough, so far as our present information as to the depth of the southern oceans goes, there would appear at first sight to be less difficulty in supposing a former extension of the southern continent to Australia and South America than to Africa, the depth as shown on the 'Challenger' chart south of the former continents nowhere exceeding 2000 fathoms, whereas to the south of Africa there is represented a considerable belt of greater depth. But on an Admiralty chart, for which I am indebted to Captain Wharton, R.N., F.R.S., and on which all the known deep soundings are marked, none are shown south of the southern extremity of Africa; and it is clear that, in this and other regions, more soundings are required before the contours of the sea-bottom in the oceanic area can be considered as determined with accuracy. So far as our present information goes, the ocean south of the Cape of Good Hope may be no deeper than the Mozambique Channel, though probably the depth is greater in the former case.

The faunal relations between Africa and South America are very different from those between the latter and Australia. Here, again, there are marked cases of affinity between the freshwater fishes, the two important families *Chromididæ* and *Characinidæ* being (with the exception of the few Asiatic *Chromididæ* already mentioned) confined to the two continental areas. Nor is this all, for in the *Characinidæ*, a large and important family, three out of the eleven subfamilies into which the family is divided by Günther are both Ethiopian and Neotropical. The importance of this fact is so great that it deserves particular attention, for it proves a very large amount of communication between the two areas, it being manifest that members of all three subfamilies were transferred from one to the other continent after extensive differentiation had taken place in the family.

Again in the *Siluridæ*, two subfamilies are confined to the same two regions, and amongst the few living representatives of Dipnoans, two closely allied genera, *Lepidosiren* and *Protopterus*, represent each other, the former in South America, the latter in Africa.

In the reptiles the principal noteworthy cases of relationship are the following:—The Chelonian family *Pelomedusidæ* comprises three genera, all found in Madagascar; two are also met with in Africa, but not in South America, whilst one genus, *Podocnemis*, is also South American, but not African. The Lacertilian family *Amphisbænidæ*

is almost equally divided between South America and Africa, except that one genus extends north into the Mediterranean area, and that two are found in North America. That the original connexion was between the southern continents is, however, indicated by two of the genera, *Amphisbæna* and *Anops*, being represented in both, whilst the Palæarctic and Nearctic genera are not nearly related to each other. Another Lacertilian family peculiar to Africa and South America is that of the *Anelytropidæ*; but these are not of much importance. Some genera of snakes, e. g. *Ahætulla*, *Dryiophis*, *Dipsadoboa*, and *Leptodira*, have the same distribution. One genus of apodous Batrachians (*Cæciliidæ*), *Dermophis*, is also African and S. American. Amongst the *Batrachia* the most remarkable instance, however, is afforded by the *Aglossa*, a low but peculiarly specialized group of toads, of which one family, *Pipidæ*, is purely Neotropical, the other, *Xenopidæ* (*Dactylethridæ*), peculiar to Africa. It is possible that this may be a case of a group having formerly a much wider range, and the same may be the case with the dipnoans *Lepidosiren* and *Protopterus*; but it is difficult to account for the distribution of the *Chromididæ*, *Characinidæ*, and *Amphisbænidæ* on such an hypothesis. All three are well-marked and well-developed families in both areas. Of the *Chromididæ*, fossil representatives, especially *Pycnosterinx*, are said to have been found in the Cretaceous rocks of the Lebanon; but the relationship of these forms is not free from doubt, and in any case they were marine, and the marine representatives of the *Chromididæ* are extinct. It is also true that a wide-spread marine family, the *Labridæ*, is closely allied to the *Chromididæ*, so that although it is far from probable that the African members of the latter have originated separately from the American, such a contingency might be suggested but for the evidence afforded by the *Characinidæ*. This family is unknown in the fossil state, and there is nothing to indicate that it ever inhabited Europe or North America.

There is another piece of evidence. If Africa was formerly in land communication with South America, it is probable that before the Ethiopian fauna was profoundly modified by the incursion of Palæarctic types in the Pliocene and Pleistocene periods, several Neotropical forms that are wanting there at the present day existed in South Africa. If this was the case, and if, as has already been pointed out, there is a remnant of the old African fauna, preserved from contact with the improved Palæarctic forms, in Madagascar, several alliances with S. American types should be found there that can no longer be traced in continental Africa. This is precisely

what occurs. The case of the Chelonian family *Pelomedusidæ*, in which the American genus *Podocnemis* is represented in Madagascar but not in Africa, has already been mentioned. Besides this, two genera of the typically American Lacertilian family of *Iguanidæ* occur in Madagascar. It is true that another genus is Polynesian *, so this may be an instance of former wide distribution; but even in that case, the occurrence in Madagascar of two out of the only three genera that are not American is significant. Amongst Mascarene snakes, four characteristically American genera of *Colubridæ* are represented—*Heterodon* (2 species), *Liophis* (2), *Dromicus* (6), and *Phylodryas* (2), whilst two other genera are common to America and to other regions. In fact the ophidian fauna of Madagascar, comprising 36 species, is very much more American than African. Lastly, amongst the *Batrachia*, the family *Dendrobatidæ* consists of one genus, *Mantella*, with 5 species inhabiting the Mascarene Islands, *Dendrobates*, the only other genus of the family (7 sp.), being Neotropical.

There is one case of affinity between the Neotropical and Ethiopian regions, amongst freshwater shells, that deserves notice. The very peculiar family *Œtheriidæ*, consists of the genus *Œtheria*, which is African, and two genera *Mulleria* and *Bartlettia* confined to South America. If, however, the West Indies have the same biological relations to the Neotropical region that the Mascarene Islands have to the Ethiopian, and the Lower or Middle Tertiary fauna of each region has been preserved in the corresponding insular groups respectively, the extraordinary development of *Cyclostomatidæ* in the Antilles and in the Mascarene Archipelago may be due to the prevalence of the family in both Africa and South America at the time when they possessed means of communication no longer existing. The occurrence of a few scattered species in Africa and South America, and the extremely poor representation of the family elsewhere, are quite in favour of this view. Even amongst the mammalia there are some curious relationships; the only family of Insectivora belonging to the lower section of the order with narrow

* This genus is found in the Fiji Islands, which may possibly have been the eastern extension of the great continent which doubtless at one time included part of Australia, New Caledonia, and New Zealand. This possibility is admitted by Wallace. The occurrence in the Fiji Islands of three species of frogs, belonging to a genus represented also in the Solomon Islands, New Guinea, the Philippines, &c., affords a strong confirmation of the view that the Fijis are ancient continental islands. [Mr. Boulenger informs me that a genus of Elapoid snakes (*Ogmodon*) is peculiar to the Fiji Islands.]

V-shaped molars that is found out of Africa and Madagascar is that of the *Solenodontidæ* of the West Indies. These insectivores are some of the most lowly organized of all placental mammals, and may be more ancient than other members of the subclass. Amongst the rodents, another placental order of low organization, one family, *Octodontidæ*, is restricted to Africa and South America.

Of course some of the instances mentioned may be explicable by the former existence of allied forms in Europe and North America. But it is very difficult to conceive that so many cases of relationship between the lower vertebrata of Africa and South America can be explained in this manner. The biological evidence of a former land-connexion between South America and Africa is much stronger than that in favour of a belt of land between Africa, Madagascar, and India, although the latter is supported by geological data. It is probable that the land-barrier across the South Atlantic, if that was the form of union, lasted to a later geological epoch than that across the Indian Ocean.

The direction in which the communication between South America and Africa lay is very difficult to indicate. The relationship is chiefly shown by tropical forms, but these may have migrated far to the southward during warm periods. It is highly probable that the southern extremity of South America at one time extended to the eastward, beyond South Georgia, and land may have united this tract with South Africa; but there is nothing known of the sea-bottom to indicate the probability of union in this direction.

The only ancient palæontological evidence, so far as I am aware, is that pointed out by Neumayr in the paper already referred to *. He infers land-connexion between Africa and South America in the Jurassic and Lower Cretaceous periods from (1) the absence of Jurassic marine beds on the western coast of Africa and on the eastern coast of South America; (2) the evidence of ancient land in the Cape Verde Islands and St. Paul's; (3) the fact that the Neocomian Uitenhage fauna of the Cape of Good Hope differs entirely from the European, whilst the Jurassic fauna of western South America does not. The first two grounds appear insufficient, even if the facts were fully admitted; but the third has more force and would appear to indicate a westward or southward prolongation of the South-African land so as to meet a corresponding south-eastward extension of South America.

It must not be forgotten that the area around the South Pole as far north as about 60° of south latitude, so far as is known, is occu-

* *Loc. cit.* p. 132.

pied either by land or by sea of no great depth. If the difficulty about the depth of the intervening ocean is overcome, there is no improbability in the suggestion that at some period of geological history an important continent, having connexions with South America, South Africa, and New Zealand, may have occupied the Antarctic area. I have already referred to the fact that many biologists regard the present distribution of terrestrial life as evidence of original dispersion from an arctic centre. But unless we are acquainted with the distribution in past times of various groups of animals and plants, there is always a liability to regard the stage on the road of migration from which the present representatives of any group diverged as the original centre of distribution. Unless we can trace the actual line of migration (and that we may probably never succeed in doing), how are we to tell whether placental Mammals, for instance, appeared first at an arctic centre and diverged thence to Africa, Asia, and America, or whether the original stock came from a southern continent, for instance, South America, and after travelling to the northern hemisphere and migrating into Asia or Europe, ramified thence again into the Oriental and Ethiopian regions? During the period of migration and evolution great changes would take place in the country whence the type originally sprang; and as each fresh and improved branch appeared, it would spread forward to new regions and backward to the country of its ancestral stock, where it might either exterminate in the struggle for existence those descendants of its own ancestors who had not progressed in structure, or live on beside the more favoured races that had progressed sufficiently to hold their place.

That some families of living animals may have originated in the southern hemisphere is shown by such examples as the *Amphisbænidæ*, *Aglossa*, and *Characinidæ*, and especially by the *Galaxiidæ* and *Haplochitonidæ*.

In this connexion there is one series of palæontological facts of some interest. At particular geological horizons, apparently throughout the world, there is a sudden appearance of terrestrial animals and plants belonging to orders or even subclasses not represented in older strata by any probable ancestors. Amongst the most remarkable instances is the sudden appearance in the Upper Cretaceous epoch, almost or quite simultaneously, of Acanthopterygian fishes and Dicotyledonous Angiospermous plants *, now the dominant and

* I have heard lately of Dicotyledonous Angiosperms in Lower Cretaceous beds in America, but the age of the beds appears to have been determined by the fossil plants, an unsatisfactory method which has often led to error.

most abundant types throughout the globe. A little later in the geological sequence, in the Eocene, there is a similar advent of placental Mammals, anurous Batrachia, Ophidia, and perhaps of modern types of Lacertilia. The origin of the placental Mammalia was discussed twenty years ago by Professor Huxley, in one of the most interesting and suggestive addresses ever delivered from this Chair, and the conclusion to which he came affords the only satisfactory explanation hitherto offered. He showed that the subclass had in all probability been developed for ages before the Eocene period in an isolated continental area that has now apparently disappeared, but which he suggested may have been in the Pacific.

I am inclined to believe that the origin of Dicotyledonous Angiosperms is even a more remarkable case than that of placental Mammals. There is much evidence in favour of the process of modification and evolution amongst plants being far slower than in the higher animals, and many of the Cretaceous and Eocene Angiospermous genera are undistinguishable from those existing at the present day. This Angiospermous flora could only have originated in a great tract of land, and unless that tract was isolated by ocean from all countries in which the earlier Mesozoic flora of Cycads, Conifers, Equisetaceæ, Ferns, &c., has been found, it is difficult to understand why no traces of the ancestral Angiospermous forms have been detected amongst the latter.

The Mesozoic flora itself appeared in a considerable portion of the northern hemisphere in the Triassic period as suddenly as the Angiospermous flora did in the Cretaceous. But in this case we have a clue to the origin of the invaders; for we now know that this Mesozoic flora came from the south, and had established itself in Australia, India, and in South Africa at an Upper Palæozoic epoch, whilst the well-known Palæozoic flora of gigantic *Lycopodiaceæ* and peculiar *Equisetaceæ* and Ferns still flourished in Europe, Northern Asia, and North America. There is, moreover, some evidence in favour of the view that the transfer of the southern plants to the northern hemisphere was caused by a period of low temperature that drove a southern temperate flora northward to the equator. It is known from the scanty remnants of an older Carboniferous (or Upper Devonian) flora found in Australia that Lycopodiaceous plants, similar to northern Palæozoic forms, occurred in the southern area at an earlier date, and it is quite possible that the Newcastle flora of Australia and the Gondwána flora of India, the evident precursors of the Mesozoic flora of Arctogæa,

came originally to Australia from an antarctic continent. It is highly probable that many other forms of terrestrial life besides the Mesozoic flora originated in the southern hemisphere; and unless a very considerable area of what is now deep ocean was occupied by land in Mesozoic and Palæozoic times, a change in favour of which there appears but slight evidence, it is far from improbable that the Antarctic continent was the original area of development.

The land-areas of the present day may differ in one important particular from those which existed at earlier periods of the earth's history. With the exception of America and Australia, all the great land-masses are joined together in the northern hemisphere, and there cannot be a question that the division in the case of America is of extremely recent date; for, as I have already mentioned, a considerable proportion of the higher land-animals, especially carnivores and ungulates, found in the northern parts of America, Asia, and Europe are identical, and it is evident that the duration of species in those orders is not great, for very few, if any, were living in Pliocene times. It is far from unprobable that formerly the great land-masses were more isolated, and consequently terrestrial organisms, such as mammals and most terrestrial reptiles, may have had far less facilities for spreading throughout the globe. The extraordinary diffusion of terrestrial forms in the Upper Cretaceous and Eocene periods may perhaps have been caused by some great breaks in the continuity of the general land-area having been then filled up. As plants have, as a rule, greater power of diffusion than mammals, it is not surprising that the dissemination of angiosperms throughout the northern hemisphere preceded that of placental mammals. There is just a possibility, if higher forms of terrestrial life originated in the southern hemisphere in Palæozoic and early Mesozoic times, that the origin may have been due to a greater development of land in that direction, and to the great land-masses being connected to the southward up to the Cretaceous or Eocene period, much as they have been united to the northward in the later geological epochs.

There may even, in the Mesozoic era, when South Africa was united to India *viâ* Madagascar on one side and to South America on the other, especially if the Indo-Malay continent was also connected with the Australian, have been a girdle of land, chiefly in low latitudes, round nearly three quarters of the earth's circumference from Peru to New Zealand and the Fiji Islands; and this

arrangement of the land-areas would perhaps explain the distribution of the modern flora in belts, as shown by Mr. Thistelton Dyer, and account for the dissemination round so large a part of the globe of a great tropical flora and of certain tropical forms of animal life, for instance, *Iguanidæ*, apodous Batrachians, and some families of land-mollusca.

It will thus be seen that whilst the general permanence of ocean-basins and continental areas cannot be said to be established on anything like firm proof, the general evidence in favour of this view is very strong. But there is no evidence whatever in favour of the extreme view accepted by some physicists and geologists that every ocean-bed now more than 1000 fathoms deep has always been ocean, and that no part of the continental area has ever been beneath the deep sea. Not only is there clear proof that some land-areas lying within continental limits have at a comparatively recent date been submerged over 1000 fathoms, whilst sea-bottoms now over 1000 fathoms deep must have been land in part of the Tertiary era, but there are a mass of facts both geological and biological in favour of land-connexion having formerly existed in certain cases across what are now broad and deep oceans.