common ancestral type. These relationships may be thus indicated, taking only a few of the characters of each.

| *Lizard.* | *Pterosaurian.* | *Bird.* |
|---|---|---|
| Cerebellum small, optic lobes meeting, paroccipital formed chiefly by the opisthotic. | Cerebellum large and between optic lobes, paroccipital formed chiefly by the opisthotic. | Cerebellum large and between optic lobes, paroccipital formed chiefly by exoccipital. |

*Ancestral Type.*

Cerebellum small, optic lobes meeting, paroccipital small, and formed by both exoccipital and opisthotic.

## II. "The Atoll of Diego Garcia and the Coral Formations of the Indian Ocean." By G. C. Bourne, B.A., F.L.S., Fellow of New College and Assistant to the Linacre Professor in the University of Oxford. Communicated by Professor E. Ray Lankester, F.R.S. Received March 12, 1888.

[Plate 4.]

The whole of the following paper was planned and a great part of it was written when Captain Wharton's letter appeared in 'Nature,' on Feb. 23. Captain Wharton has anticipated my objections to the theory put forward by Mr. Murray in explanation of the formation of atolls and barrier reefs, and has suggested that the growth of corals on the periphery of a submerged bank is sufficient to explain the elevated rim of a barrier reef or atoll, and the contained lagoon channel or lagoon. In this I cordially agree with him, and can only express my satisfaction that so eminent an observer should have arrived, after an extended study, at conclusions nearly identical with mine. In accounting for the luxuriance of coral growth upon the peripheral slopes of an atoll, I differ slightly from Captain Wharton, and the publication of his letter has led me to extend and modify the plan of the latter half of this paper, in order to show more clearly the points in which I agree with and those in which I differ from him. I may take this opportunity of expressing my thanks to Captain Wharton for his kindness in sending me notes on the structure of the Cosmoledo and Farquhar groups, and to Dr. S. J. Hickson who has given me the benefit of his experience in N. Celebes.

In my visit to Diego Garcia in 1885 I took with me, among other works, the splendid papers of Alex. Agassiz on the Tortugas and Florida reefs, and diligently compared all his observations with structures existing at Diego Garcia. I was much struck by the analogy between the formations, but I also found differences in the stratification of rocks, &c., which led me to the conviction that there has been a very small amount of elevation in the Chagos group, which certainly has not been the case in the Florida reefs. This conviction was shared by an old resident on Diego Garcia, M. Spurs, a naturalist who has devoted many years to the study of coral reefs.

A reference to the map will show that Diego Garcia is a typical atoll; a narrow strip of land varying in width from a mile to 30 yards, nearly completely encircles a lagoon of irregular shape. The lagoon is open to the ocean towards the north-west, its mouth being divided by three small islets into four channels, of which three are sufficiently deep to allow ships to enter the lagoon. The three islands are known by the names of Bird Island, Middle Island, and East Island (Ile des Oiseaux, Ile du Milieu, and Ile de l'Est), the last named being the largest of the three, and the one on which I spent much of my time during my visit. The whole of the land composing the atoll is very low; the highest point in the island is not more than 30 feet above the level of high tide, and this height, which is quite exceptional, is due to the accumulation of great heaps of sand through the action of the S.E. trade winds which blow with considerable strength for more than one-half of the year. Diego Garcia is the southernmost atoll of the Chagos group; it lies in S. lat. 7° 26′, E. long. 72° 23′, and forms the last of the great chain of coral formations reaching from the Laccadive Islands through the Maldives to the Chagos group. To its south-west lie the submerged atoll-shaped reefs known as Pitt's Bank and Centurion's Bank, to its north lies the huge submerged atoll known as the Great Chagos Bank. It is an interesting fact that throughout the Laccadive, Maldive, and Chagos groups there is no instance of a fringing or of a barrier reef; nothing but coral structure rises above the waves, all the islands are atolls; none of these are upraised, but there are several submerged banks. The existence of this long line of atolls seemed to be one of the strongest arguments in favour of Darwin's theory on the formation of coral reefs. If the depths given in Stieler's hand-atlas are correct, the three groups stand on a submarine bank lying 1000 fathoms below the surface in an ocean of an average depth of 2000 fathoms.

In Diego Garcia the nature of the soil varies considerably from place to place. In some localities it consists of nothing else than bare coral rock upon the surface of which coral boulders are scattered about; in other places it is composed wholly of calcareous sand, and one may dig down for 6 or 8 feet without finding coral rock. It is obvious after a short examination that some parts of the land are older than others, and that the great strip of land was formerly a series of disconnected islets which have since been joined together by the accumulation of sand and coral *débris* between them. In the older parts of the island, which have apparently been covered with vegetation for a considerable period, a thick peaty mould has been formed by the decay of fallen leaves and stems of trees and shrubs.

Throughout the island the outer or seaward shore is higher than the inner or lagoonward shore, owing to the pile of coral boulders thrown up in the form of a low rampart along the former by the action of the waves. In most places a flat reef extends fully 60 yards seaward of the rampart; and this reef is just uncovered at low spring tides. As a rule the inner shore slopes gently down into the lagoon for some distance and then pitches down rather suddenly to a depth of 10 or 12 fathoms, but in some places there is a depth of 6 or 8 fathoms close up to the inner shores. Marshy pools of fresh or brackish water are found in the centre of the strip of land on the S.E. and W. sides of the island; into these the sea enters in many cases during the highest spring tides, and at the S.E. and S. ends of the island it has established permanent breaches into some of these pools, through which the tide runs in and out regularly from the lagoon. Thus there are formed sheets of water like secondary lagoons within the strip of land; these are known on the island by the name of *barachois*, and they are of some importance when one comes to consider the amount of change which is continually going on in the island.

Externally the shores slope away very rapidly to considerable depths, the sounding line giving depths of 250 fathoms and upwards at a distance of a few hundred yards from the edge of the reef, excepting at Horsburgh Point at the S.E. side, where a depth of 45 fathoms is found at a distance of 1 mile from the shore. Unfortunately I had not the apparatus wherewith to make a series of sectional soundings outside the island, nor if I had had the apparatus should I have had the means of making use of it. The depths within the lagoon have been accurately determined by H.M.S. "Rambler" in 1885; they vary up to 19 fathoms. After a stay of two or three months on the island one cannot fail to be impressed with the immense amount of change which is continually in progress. Large masses of sand are in the space of a month deposited in one spot to be swept away during the next month and deposited in another. Everywhere there is evidence that the sea has encroached upon the land or that the land has in its turn gained upon the sea. In one place numerous dead and fallen coco-nut palms show where old established land has been carried away; in an adjoining spot tracts of sand, either bare or covered with a scanty growth of young shrubs, show where the combined action of wind and waves has added a new piece to the island. Within the lagoon the currents are constantly changing in force and direction, and their every change affects the growth of coral in their track. In estimating the structure of the atoll these changes should be kept in mind, although their complexity makes it far more difficult to arrive at a correct conclusion.

In the course of my investigations I learnt to distinguish the following kinds of coral rock formed by the action of the waves or wind or both combined.

Firstly, *reef rock*, a tolerably homogeneous mass of compacted coral *débris*, the component parts of which are so thoroughly infiltrated with carbonate of lime held in solution in the sea-water that the masses and fragments of coral composing the rock are rarely distinguished from one another. This form of rock exhibits a fine horizontal stratification; it is invariably formed under the sea or between tide marks.

Secondly, *boulder rock*, formed just above high tide mark by means of the masses of coral which are transported across the reef by the waves and are piled up to form the low rampart already alluded to. The interstices of the boulders are soon filled up with coral *débris* and sand, and are cemented together by the spray. Such rock is only formed on the seaward shores and invariably shows a stratification dipping downwards towards the sea.

Thirdly, *shingle rock*, which may be of two kinds. The first kind is horizontally stratified and is scarcely distinguishable from reef rock, except in its finer texture; it is formed below water or between tide marks by the agglomeration of small pieces of broken coral, among which are included numerous shells of molluscs, remains of crustacea, echinoderms, &c., and in the more sheltered parts of the lagoon it may include considerable masses of dead madrepores imbedded in their natural position in the rock. This rock is of looser texture than the reef rock. The second kind of shingle rock is formed above high-water mark by the action of the waves. It is entirely composed of small fragments and exhibits a fine stratification dipping seawards at an angle.

Lastly, there is the *sand rock* formed above water by the action of the wind. Wherever masses of fine sand are piled up within reach of the spray they are gradually compacted, and form a friable rock, the stratification of which dips seaward.

In many parts of the island I observed that the land was composed of stratified reef or shingle rock, the strata of which were perfectly horizontal, and did not dip down towards either shore. Having observed the manner in which the different kinds of coral rock were formed, I was at a loss to understand how such horizontally stratified masses could have been formed in their present position above high water mark, and could only believe that they were originally formed as reef or shingle rock below high water mark, and had been subsequently raised to their present position. I was thus led to believe that a slight elevation had taken place, and this belief was strengthened by a study of the formation of East Islet. This islet is about 800 yards long, and nearly 100 yards broad; its westernmost extremity is composed of masses of sand piled up on the underlying reef rock, and in this place there is a clump of high trees (*Hernandia peltata*). The eastern and by far the larger part of the islet is of different formation. The even surface of the soil is covered with a low scrub, but bears no high trees nor coco-nut palms. It forms a low plateau, the surface of which does not slope down towards the lagoon, but is perfectly horizontal, and stands 4 feet above the very highest spring tides. The shore on the lagoonward side shows an abrupt fall of 6 feet to the reef, which in this place extends for a distance of 50 yards towards the lagoon, and is only left uncovered at the lowest spring tides. At the eastern extremity of the island there is no reef, but from $1\frac{1}{2}$ to 2 fathoms of water are found within a few yards of the shore. This point is exposed to the ocean, and a strong and constant current sets against it, so that it is undergoing a considerable amount of erosion. On the north or seaward side the reef again extends outwards from the shore, the latter differing from the inner shore in the presence of a talus of large boulders which have been thrown up against it by the waves. Wells have been sunk in various parts of the island, though for some reason which I cannot explain, water is only found in one of them. Numerous pits, some of which are 9 feet deep, have also been dug for the purpose of planting coco-nuts. These pits and wells expose the interesting structure of the superficial part of the island. Beneath a thin surface layer of sand and mould lies a horizontal layer of stratified shingle rock, in which large imbedded coral masses may occasionally be distinguished; this layer is about $2\frac{1}{2}$ feet thick. Beneath it is a layer of loose coral sand about 18 inches thick, and beneath that is another layer of coral rock of the same character as the first, and about 3 feet thick. Beneath this is another layer of friable sand lying on the solid reef rock into which the excavations did not penetrate. These layers lie perfectly horizontally, and do not dip in any direction. They crop out above the reef on the steep eastern and southern shores, and as the loose sand is washed out by the waves the overhanging layer of rock breaks off and falls down in large masses. The central parts of this area are absolutely beyond the reach of any waves at the present time, and as the strata of rock and sand run evenly through it, there is no evidence of its having been formed by successive additions of material through the action of the waves. Nor can it possibly have been formed under the surface of the water unless it has since been raised to its present position, for, as I have said, its upper surface is 4 feet above the level of high spring tides. On one occasion when the tide rose to an abnormal height and invaded several parts of the main island, I saw that the water reached to within 3 feet of the top of the shore, but even then the whole of the upper stratum of coral rock was well above the waves. It is scarcely credible that an even layer of shingle rock could have been formed above the highest high water mark.

Owing to the dense growth of bushes it was not easy to explore the surface of East Islet; but in one spot where the undergrowth was less thick I observed a very shallow, basin-like depression, of which the edges were surrounded by a miniature beach of coral *débris*, giving evidence that the sea had formerly occupied this spot, and yet it is now 4 feet above high water mark. Near this spot were lying great blocks of *Mœandrina* and *Astrœa*, which could not possibly have been thrown by the waves to their present position if the surface on which they lie had not formerly occupied a lower level than it does now. Similar blocks were noticed by Semper in the atoll of Kriangle in the Pelew Islands, but in that case the blocks appear to have been of much larger size.

These facts may not be convincing testimony in favour of a recent elevation of a few feet, but my belief in such an elevation is further strengthened by the following facts communicated to me by M. Spurs, a resident for twenty-five years at Diego, an ardent naturalist, and much interested in coral formations.

A small shore crab of the genus *Ocypus* is always to be found on the sandy flats between high and low water mark. These crabs, as is well known, form numerous galleries in the fine muddy sand, which they line with seaweed, &c., to prevent their falling in. These galleries open to the surface by short passages placed perpendicularly, the mouths of which open only a few inches above the level of low tide. This crab is only found on the shore between tide marks; on the dry land its place is taken by *Gecarcinus*, another genus of crab, which forms different burrows. In the west part of East Islet there is an aggregate of friable, scarcely compacted sand, which has somewhat the appearance of half-dried clay. It lies 5 feet above high water mark, and was found by M. Spurs, during some excavations which he had to make for the purpose of constructing a slip for boats, to be riddled with the seaweed-lined galleries of *Ocypus*, evidently long since disused and empty.

Having made this observation on East Island, M. Spurs made a search in similar formations on the main island, and found, he tells me, precisely the same facts in several instances, aggregates of sand lying at some distance above high water mark, riddled with the abandoned burrows of *Ocypus*. Now since the burrows of *Ocypus* are quite characteristic, and could not have been mistaken by so good an observer as M. Spurs for those of another species, and since they are in the present day only found between tide marks, these observations afford a further presumption in favour of a slight elevation having recently taken place. In any case they preclude the idea of any subsidence being in progress, as Mr. Darwin fancied to be the case in the Keeling atoll. M. Spurs further informs me that during the time that he was superintendent of the oil company's estate, he caused more than 30,000 pits to be dug on the main island for the purpose of planting coco-nut palms, and that he frequently observed in different localities the same alternate layers of sand and rock that I have described as existing on East Island. These alternations of sand and rock would suggest alternations of very slight subsidence with very slight elevation, rather than a single movement of upheaval; yet on the supposition that all the layers were formed beneath the water, as their horizontal stratification leads me to believe, I can venture on the following explanation. The mass of rock which forms the base upon which the islets and other dry land rest is solid reef rock, and the whole floor of the lagoon is similarly formed. The latter is covered at depths of 3 or 4 fathoms and upwards by a layer of fine sand, which may attain a thickness of 2 or 3 feet. In protected parts of the lagoon and in spots where the changeable currents have ceased to deposit any quantity of sand, corals will grow in considerable quantities, chiefly those wide-spreading species of Madrepora which cannot find a lodging on the exterior of the reef, where they would be dashed to pieces by the waves. By the continual growth of new colonies on the top of the old ones which have died, a layer of solid rock of considerable thickness may be formed. Whilst diving for corals at the lower part of the lagoon, I often noticed such layers of half-formed rock on which living coral was growing or not, according as the constantly changing currents were at that time throwing up sand in the locality or not. Thus on the west side of the lagoon, off Point Marianne, there are large tracts of recently formed coral rock, on which no living corals are to be seen, whilst on the east side of the lagoon, exactly opposite to Point Marianne, a similar basis of rock is luxuriantly covered with growing coral.

Now as the currents are constantly changing, and as the changes may, as I saw, affect an area some miles in extent, one may suppose that an area was first covered with corals growing on the sand, which everywhere covers the reef rock, when the latter lies more than a fathom below the surface. A change in the currents brought abundant sand to the spot, killed the corals, and deposited an even layer of sand of some little thickness over the rock formed by the skeletons of the dead corals. A further change in the currents would again render the spot suitable for coral growth, and a new layer of rock would be formed over the last layer of sand. I have seen quite analogous formations in progress in a fathom of water a little way above Point Marianne. Raise the formation to the surface, and you get that stratification which occurs in so many parts of the island, a stratification which cannot be explained on any theory of subsidence, and is scarcely less difficult to explain on the supposition of rest. At first I had some hesitation in extending to an island on the borders of the lagoon, as is East Island, a view of the formation of layers of sand and rock derived from an inspection of the interior of the lagoon, but afterwards I saw that similar layers were being formed just within the large reef known as Spurs' Reef, west of Middle Island, so that no objection can be raised on that score. The whole character of the Chagos Group is very much opposed to the theory that atolls and barrier reefs are formed during subsidence. There are several atolls rising above the waves, that of Peros Banhos being 55 miles in circuit, and composed of numerous small islets placed upon a ring-shaped reef through which there are several large and deep channels. Egmont or Six Islands is an instance of an atoll in which the encircling reef is perfect and unbroken by any channels, the land consisting of six islets placed for the most part on the southern and western sides of the reef. There are several submerged banks, nearly all of which have an atoll form. Of these the best known is the Great Chagos Bank, a huge submerged atoll 95 miles long and 65 miles broad, having a depth of 4—10 fathoms over a narrow rim around its periphery, and a central lagoon of a depth varying up to 45 fathoms. South-west of the Great Chagos Bank, distant less than 15 miles, lies the atoll of Six Islands, and on the other side of these, scarcely 12 miles distant, lies another submerged atoll, known as Pitt Bank. South-west of Pitt Bank are two smaller banks, Ganges and Centurion's Banks. Darwin considered that the Great Chagos Bank afforded particularly good evidence of the truth of the subsidence theory. He regarded it as an atoll carried down by a too rapid subsidence below the depth at which reef-building corals flourish. The same would be the case for Pitts Bank and the two others just mentioned. A more intimate knowledge of the Great Chagos Bank, and of the relations of it and other submerged banks to existing land, shows this view to be untenable. In the first place the rim of the Great Chagos Bank is on an average not more than 6 fathoms below the surface, and therefore situated in a depth eminently favourable for coral growth, and there are actually six islets on the northern and western edges rising above the water, and some of them inhabited. Secondly, any such rapid subsidence could not have affected areas only 30 miles apart without involving the Six Islands atoll lying directly between them. A similar argument might be extended to the more northern islands of the Chagos group, and even to Diego Garcia itself, although it lies somewhat apart from the rest of the group. Again, if atolls and barrier reefs are formed around subsiding peaks, it is at least curious that throughout the Laccadive, Maldive, and Chagos groups there are no instances of high islands surrounded by barrier reefs, marking the last remnants of pre-existing land. In the more western parts of the Indian Ocean, between Madagascar and the Seychelles, there are numerous atoll islands, and in long. 60° E. there lie the submerged Saya de Malha Bank and the reef known as Cargados Carajos. Between these two lies the extensive Nazareth Bank, having over it depths of from 14 to 45 fathoms. The Saya de Malha Bank appears to have the characters of a submerged atoll, having a central depression of 65 fathoms, surrounded by a rim which has only 8 to 16 fathoms on its eastern side, but 22 fathoms on the western. Some of the groups north of Madagascar afford very good evidence of upheaval. Aldabra Island, situated in lat. 9° 22′ S., long. 46° 14′ E., is a perfect instance of an upraised atoll. Captain Wharton describes the external shores as consisting of low coral cliffs, about 20 feet high, the surface of the land being composed of jagged coral rock. The lagoon is entered by a passage varying from 11 to 5 fathoms in depth, but its internal portions are either very shallow or partly dry at low water. Not far distant is the Cosmo Ledo group, a perfect atoll, with a lagoon some 4 fathoms deep, or less. There are ten islets of various sizes on the reef, and all of them appear to have been elevated some 10 feet. There are some hills 40 and 50 feet high on the two largest islands, but these appear, according to Captain Wharton, to be formed of blown sand. The Farquhar group and Assumption Island, situated within the same area, have been raised, according to the same authority, some 10 feet. Providence Island, in lat. 9° 14′ S., long. 51° 2′ E., appears to be a low island situated upon the edge of the atoll-shaped Providence reef. At a distance of 19 miles from Providence Island is the island of St. Pierre, which has no fringing reef. It is particularly interesting, for although it is in close proximity to the low Providence atoll, it has been raised about 40 feet above high water, and in the absence of a fringing reef the sea breaks with great violence against a low cliffy coast, hollowing out a number of caverns which, from the description given in the sailing directions for Mauritius and its islands, appear to open inshore by "blow-holes."*

Near and among these raised coral formations are several submerged banks, the most important of which is McLeod Bank, situated in lat. 9° 57′ S., long. 50° 20′ E., between Providence Island and the Cosmo Ledo group. The details show that there is a group of coral

* For the information on the islands north of Madagascar I am indebted to the courtesy of Captain W. J. L. Wharton, R.N., F.R.S.

formations, situated near lat. 10° S., north of Madagascar, in which are found raised atolls—atolls whose dry land just rises above the waves and submerged banks. There can be no clearer proof that atolls are formed in areas of elevation, and, if the facts which I have already stated concerning Diego Garcia are of any weight, it would seem that most of the coral formations of the Indian Ocean mark areas of elevation rather than of rest; certainly they are not evidence of subsidence.

Those who have felt that the evidence brought against Darwin's subsidence theory is too strong to be resisted, must often have felt that no satisfactory explanation of the lagoons of atolls or the lagoon channels of barrier reefs has been given in its place. Semper was the first to suggest that the lagoon was formed by a solution of the interior parts of the reef, and more recently this view has been urged with great force by Murray, who points out in addition, that corals on the periphery of a reef must, from their position, get the advantage over those more interiorly situated, being more directly in the track of food-bearing currents. Neither of these explanations has completely satisfied me. That sea-water exercises a solvent action upon carbonate of lime does not admit of doubt, and that the scour of tides, combined with this solvent action of the water, does affect the extent and depth of a lagoon is obvious. But I challenge the statement that the destructive agencies within an atoll or a submerged bank are in excess of the constructive. It would be nearer the mark to say that they nearly balance one another. In the first place the carbonate of lime held in solution by sea-water is deposited as crystalline limestone in the interstices of dead corals or coral *débris*. Anyone who is acquainted with the structure of coralline rock knows how such a porous mass as a Mæandrina head becomes perfectly solid by the deposition of lime within its mass. This deposition can only be effected by the infiltration of sea-water. In reckoning the solvent action of sea-water, therefore, account must be taken of the fact that a not inconsiderable proportion of the carbonate of lime held in solution is redeposited in the form of crystalline limestone. Of this, it seems, Mr. Murray has not taken sufficient account, and has, therefore, overstated the destructive agency of the sea. Secondly, the growth of corals, and the consequent formation of coral rock within the lagoon, is generally overlooked.

Whilst diving for corals at Diego Garcia I had abundant opportunities of studying the formation of coral rock within the lagoon, in depths under 2 fathoms. The layers of tolerably compact rock thus formed are of no mean extent or thickness; they soon become covered with sand, and are thus protected from the solvent action of the water. I have found it impossible to reconcile Mr. Murray's views with what I saw of coral growth within a lagoon. Not only do the more delicate branching species of the Madreporaria flourish in considerable numbers, but true reef-building species, *Porites*, *Mœandrina*, *Pocillopora*, and various stout species of *Madrepora*, are found there. It is a mistake to suppose that certain species of corals are restricted to the external shores, others to the lagoon. My collections proved that many of the species growing in the lagoon at distances of 5 miles and upwards from its outlet are identical with those growing on the outer reef. In addition to them are numerous species, such as *Seriatopora stricta*, *Mussa corymbosa*, *Favia lobata*, *Fungia dentata*, and many others that are not found on the outside. The reason is that the last-named are either free forms such as *Fungia*, or are attached by such slender and fragile stems to their supports that they could not possibly obtain a foothold and maintain themselves among the powerful currents and waves of the open ocean.

These various species, numbers of which grow close together, form knolls and patches within the lagoon, and it cannot be doubted that their tendency is to fill it up. Again, in reefs which do not rise above the surface, or are awash for the greater part of their extent at low tides, great quantities of *débris*, torn from the outer slopes, are constantly carried over the rim of the reef and tend to fill it up. Hence it follows that in a lagoon entirely surrounded by dry land, or nearly so, as is the case at Diego Garcia, the tendency to accumulation of material within the lagoon would be less than in submerged or incomplete atolls, for *débris* cannot be swept over into the lagoon, and the only constructive agency is the growth of coral. If the power of solution of sea-water is so great, it must be supposed that in complete or nearly complete atolls the lagoon would be deepening rather than shallowing; yet at Diego Garcia the lagoon is obviously shallowing in many places, and has nowhere increased in depth since Captain Moresby's survey in 1837. Indeed, the southern part seems to have shoaled a fathom since that time, and this is the more remarkable, since the S.E. trade winds are by far the most constant and strongest winds there, and tend to accumulate material at the northern rather than at the southern end. The fact is, that these winds sweep the sand out of the southern part, and thus leave an area particularly favourably situated for the growth of corals. Mr. Murray points out that larger atolls generally have deeper lagoons than small atolls, and urges this fact in support of his theory; but here again the facts in the Chagos group are against him. Victory Bank is a submerged atoll, the Solomons is an atoll with a large extent of dry land, in each the lagoon attains a depth of 17—18 fathoms, and in Diego Garcia the lagoon, although far larger, does not attain a greater depth. Peros Banhos is far smaller than the Great Chagos Bank, yet in both the lagoons attain nearly the same maximum depth, viz., 41 fathoms for Peros Banhos, 44 fathoms for the Great Chagos Bank.

Speaker's Bank is very little larger than Peros Banhos; its lagoon is far shallower, having a maximum depth of 24 fathoms.

These considerations have led me to discredit the solution theory as an explanation of lagoons and lagoon channels, and other objections have been lately urged with great force by Captain Wharton. The conclusion which I reached, after carefully considering the conditions of submerged banks of atoll form, is that the ring-shape of the outer reef is to be explained by the peculiarly favourable conditions for coral growth found on the external slopes. Although corals may and do flourish in lagoons, they are only found in knolls and patches, and are always liable to be smothered when, by a change in the tidal currents, sand is thrown down upon the place where they are growing. On the external slopes, however, corals grow in extraordinary abundance, and chiefly those massive forms whose skeletons take so conspicuous a share in the formation of coral rock. If once it is admitted that the periphery of the reef offers peculiarly favourable conditions to the growth of reef-forming corals, it follows that, as the reef rises to the surface its external parts will outstrip the more internal, and will reach the surface first, forming a rim around a central depression or lagoon. This elevated rim will be as marked a feature in submerged as in complete atolls. Not long after I had arrived at this conclusion, and whilst the earlier part of this paper was writing, Captain Wharton published a letter on coral formations in 'Nature,' in which he arrives at identical conclusions. His knowledge of coral islands is so extensive that his views have great authority, and I am extremely pleased to find that his opinions on this subject are the same as those which I have formed. The only point in which I differ with him concerns the explanation of the favourable conditions on the external slopes.

Following Agassiz, Murray, Guppy, and others, Captain Wharton supposes that the favourable conditions consist in the increased food supply brought by the superficial currents of the ocean. This I cannot believe to be a complete explanation. The quantity of food present must of course determine the existence of coral polypes in any particular locality, as it does that of all other animals, but it cannot be considered to be the chief favouring cause of coral growth on the external shores of an atoll for several reasons. If the prime cause of luxuriant coral growth is an abundant food supply, and if, as we may assume for the present, the food consists in the minute pelagic animals borne in ocean currents, there must always be a definite relation between ocean currents and coral formations. Some authors (Agassiz and Murray) have gone so far as to say that coral reefs are only formed in the track of great ocean currents. This is hardly the case. In the Pacific a study of the chart shows that atolls and barrier reefs are formed irrespective of currents, and some large groups, such as the Paumotu Islands, seem to lie altogether to one side of the prevailing currents. The islands north of Madagascar (Cosmo Ledo, Farquhar groups, &c.) do not lie in the track of the Mozambique current, but to one side of it, and the Chagos group does not lie in any constant current, but is at one season of the year washed by the currents caused by the S.E. trades, at another by the irregular currents caused by the N.W. monsoons. During the latter season there are often long periods of absolute calm during which the currents are merely tidal. The S.E. trades, however, are the dominant winds both in force and frequency, and if the coral growth were dependent chiefly on the supply of food brought by surface currents, those corals growing on the windward side would naturally have the advantage in the food supply. Situated in the direct tract of the current, they would receive an abundant supply of living organisms, and then the impoverished current, sweeping past the sides of the reef, would become poorer and poorer in organic life as it flowed towards the leeward side, till finally on the further shore, the backwash would hardly bring any sufficient supply of food for coral growth. A reef, therefore, would tend to extend in the direction of the current, and the longer diameters of the atolls might be expected in the Chagos groups to lie S.E. and N.W. This is not the case. Diego Garcia and Speaker's Bank lie north and south; Peros Banhos is nearly square; the Solomons lie N.E. and N.W.; the Great Chagos Bank lies east and west. Pitt's Bank does lie S.E. and N.W., but the rim on the northern and north-western side is nearer to the surface by some 5 fathoms than it is on the southern and south-eastern side, indicating a more vigorous coral growth on the side turned away from the prevailing current. In the case of a submerged bank it is difficult to see why the corals situated to leeward should be better off as regards food supply than those living in the interior of the lagoon, for the superficial parts of the current would flow freely over the windward rim and bring abundant food into the lagoon. But in the Great Chagos Bank the northern rim is, on the average, higher than the south-eastern, and all the islets are placed on the northern and western parts of the rim. A study of the corals growing within the lagoon of Diego Garcia is in this case of considerable interest. If their existence depended upon pelagic life brought to them by currents, it would be expected that the most numerous coral patches would be found at the northern end of the lagoon in the track of the tidal currents. There is a considerable area of active coral growth to the south and west of Middle Islet, but beyond this there is no relation whatever between the luxuriance of the coral patches and the mouth of the lagoon. Corals grow most vigorously along the shore between Minni Minny and East Point, and most vigorously of all at the southern end of the lagoon, where they are most remote from the influence of currents setting in from the ocean. Yet, as I have already shown, it is to the growth of coral alone that the shoaling of this part of the lagoon can be attributed. These facts are a sufficient argument against the idea that currents teeming with pelagic life are the prime factors in determining coral growth. It must be remembered that we are very ignorant about the food of corals. There are very few accounts of the food found in their digestive cavities, and it is purely an assumption to speak of their feeding only on pelagic organisms. I have in another place reported the presence of vegetable matter in the curiously modified digestive stomodæum of *Euphyllia*, and I have no doubt, after what Dr. Hickson has told me of the relations of corals to mangrove swamps in Celebes, that far more corals are vegetable feeders than has hitherto been supposed. The lagoon of an atoll is always full of decaying vegetable matter derived from the shore bushes and palms, and it seems likely that there is a connexion between the richer coral growth along the shores of a lagoon and the supply of vegetable *débris* from the shore.

My observations incline me to the belief that the most important circumstances affecting coral growth are the direction and velocity of currents. My observations are confirmed in every particular by those made by Dr. Hickson in Celebes, and communicated by him to the British Association in 1887. Corals grow best in places where a moderate current flows constantly over them. They are killed in still water by the deposition of sediment, and they will not grow in places where a strong current sets directly against them. I noticed at Diego Garcia in many places, but particularly at the east end of East Islet, that a strong and direct ocean current is most unfavourable to coral growth, and that the reef is barren and suffering rapid erosion at such exposed spots as allow the whole force of the current to fall directly upon them. As the current parts and flows round the obstacle, one meets with a reef covered with *débris*, but barren of live coral; further on, as the current moderates in force, one finds a few growing heads of coral; and, finally, at the further end of the reef, where the current has abated its force considerably, there is a luxuriant bed of living corals and Alcyonaria. This can be seen in perfection on the southern reef of East Islet. Dr. Hickson tells me that he has observed the same facts at Celebes, that direct and strong currents are unfavourable to coral growth, that moderate tangential currents are extremely favourable, and sluggish or still water again unfavourable. This view, which both of us can support by many observations, is much at variance with the old accepted saying that corals grow best where the breakers are the heaviest. It appeared to me that heavy breakers are not favourable to coral growth, because of the quantity of shingle which they dash against the soft-bodied polyps. Some massive forms might withstand the force of breakers and violent currents if the polyps could be sufficiently protected from the shingle, but the branching Madrepores are soon broken off and swept away, and even the more massive Mæandrina soon follows, for whilst the surface of the colony grows the base is dead, is soon riddled by boring sponges, Serpulæ, &c., and is no longer able to bear the strain put upon it. The great mass then breaks off and is rolled along the reef, pounding other corals in its course. I was long puzzled at Diego Garcia when I found that the outer reef was nearly barren of coral, even where it is covered by a foot or two of water at the lowest spring tides. I noticed directly after my arrival that the sea always broke on the reef west of Middle Islet (Spurs' Reef), and believing, from what I had read, that this must be a most favourable spot for coral growth, I took the first opportunity of visiting it at low tide. To my surprise I waded for nearly a mile, nearly waist deep, without finding a single living coral on the seaward flat, although the lagoon just within the reef was filled with knolls of living corals growing at various depths. All around the shores I found the same thing, flat reefs of barren coral rock, sloping very gently down to the ocean, on whose surfaces, even where they were constantly covered with water, no live corals were to be found. Just at the edges of the reef, where the sea breaks at low spring tides, I could detect during the reflux of the waves, solid masses of *Millepora*, and dead rock covered with Millepores, but no live Madrepores, excepting where narrow channels ran up into the reef, the sides of which generally bore a few colonies of *Mæandrina*, *Porites*, or *Madrepora aspera*. On the other hand, it can readily be seen that the external slopes, just beyond the rim of the reef behind the breakers, are covered with masses of coral. A short experience of wading across the reefs showed me the reason of the want of coral on the flat upper surfaces. *Débris*, torn from the corals growing on the slopes, is continually washed across the flat reef surfaces, and in strong breezes large masses are rolled along. Even in the calmest weather the coarse fragments can be felt sweeping past one's legs with some force, and one can readily understand that the soft polypes could not withstand the constant wear and tear. The moderate currents, on the other hand, do not carry large fragments, but prevent deposition of sand which would choke the corals, and at the same time supply the conditions of nutrition necessary to their growth. In still water, sand is thrown down in large quantities, and this and the absence of a constant supply of food prevents coral growth. The conclusions to which I came were that the external slopes afforded conditions eminently favourable to coral growth, that the upper surfaces of the shore reefs were very unfavourable, and that in certain parts of the lagoon favourable conditions again occur, though the growth is never so luxuriant there as on the external slopes. The favourable conditions on the last-named places are explained by the behaviour of a current when it meets with an obstacle which presents a sloping wall to it. The lowest parts of a strong and deep current are the first to strike the sloping wall or glacis; they are in part divided and sweep around the sides of the obstacle, but a large part of the current is deflected upwards over the slope, and its action, combined with that of the more superficial parts of the same current, results in a moderate current flowing upwards over the slope (*vide* Plate 4, fig. 2). This moderate current favours coral growth on the slope, but at its upper edge the superficial current combines with the upward stream, and the two dash onwards with increased force over the flat upper surface, destroying all coral life there. At the sides of an island the current flows tangentially, with moderated force, especially in its more superficial portions, and affords the necessary conditions on the external slopes there, whilst on the reverse side of the island the backwash affords weak currents, which are highly favourable to coral growth. Thus it is that everywhere around the island the external slopes are covered with a luxuriant bed of corals.

To fully understand the manner in which currents are moderated in flowing past an obstacle, it is necessary to remember that water possesses a certain amount of adhesiveness, and tends to cling to the sides of the obstacle, so that the current is always rather stronger at a little distance from the obstacle, whatever it may be, than it is where it runs close against it, and the rougher the surface past which it flows the greater is the adhesion, as is well known to everyone who has had experience in boating or shipbuilding.

The net result of all this is that the corals are always thickest along the slopes around a coral reef, and the reef tends to increase at its periphery, growing upwards there, whilst it tends at the same time to spread outwards. These principles hold good in the case of a submerged bank as well as in the case of a reef that is awash, and a submerged bank must tend in the course of time to reach the surface in its circumferential portions, and form an atoll-shaped reef, on the rim of which detritus may be heaped from place to place, forming shingle cays or islets which may temporarily form dry land. In atolls where storms are of frequent occurrence, regular storm-beaches may be formed, till the fragments piled high upon one another may form low islets standing some 6 or 10 feet above high water mark, upon which vegetation may subsequently find a footing. Atolls are often formed in this way, without any elevation taking place, and such has undoubtedly been the case in the Florida reefs, where atolls (the Tortugas) and barrier reefs and islands have been formed in an area of complete rest. No one who has read the admirable work of Alex. Agassiz on the Florida reefs can fail to agree with the author's conclusion that the islets there have been formed by the action of the wind and waves alone, without any assistance from the upheaval of the bed of the sea. But I am not satisfied that this has been the case in the Chagos group. Storms are of very infrequent occurrence there, and the horizontal masses of reef rock standing above high water mark cannot be attributed to the normal action of the prevailing winds and currents.

In the Florida reefs the nature of the soil betrays its origin—its strata slope towards the sea on every side, and the lamination of the rocks attests the long-continued action of waves and spray. But the alternate horizontal layers of sand and rock occurring so abundantly at Diego Garcia are quite different; they do not dip seawards, their composition differs from the rocks of the Florida reefs, and their edges, instead of showing signs of accumulation of fresh material, are often bluff, and show that the sea is gradually eating them away. It is difficult to explain these appearances except on the hypothesis of slight elevation. It might be objected that if any upheaval had taken place, the banks lying at various depths below the surface would have been raised to different heights, and that it would be in the highest degree unlikely that so many would be raised some 4 or 5 feet above high water mark and no more throughout so large areas as the Laccadive, Maldive, and Chagos Islands. and the various low groups in the Pacific. The force of the objection must be admitted, but it may be observed that atolls raised from 10 to 40 feet above the waves are not so uncommon as has been hitherto supposed, and that the numerous submerged banks lying at very various depths show that all the reefs have not been raised to one height in a single area of elevation. The uniform level of many atolls and barrier reefs admits of a further explanation. A reef raised some few feet above the sea level is at once attacked by the waves, and as the rim is very narrow, it must soon be worn away till the whole of the land is eaten away, and its surface is brought awash once more. Thus every slight movement of elevation would soon be compensated by the denuding action of the waves. The island of St. Pierre, already described, is a good instance of this process of erosion. It cannot be doubted that this island, which has recently been raised 40 feet, is undergoing rapid waste, and must soon be reduced to the level of the sea. At Diego Garcia I was astonished at the rapid destruction of dry land which is in progress, on the outside as well as the inside of the lagoon. The destruction is not so great on the outside as on the inside as a rule, for in the former case the rampart of coral boulders thrown up by the waves compensates in many places for their erosive action. But in the bay above Horsburgh Point, exposed to the full strength of the S.E. trades, the destruction is very great. M. Spurs, an old resident on the island, writes to me on this subject: "Cette déstruction est très rapide; Diego perd en moyenne un pied de terrain par an, tant intérieurement qu'extérieurement, excepté aux pointes N.E. et N.O., où une partie des sables entrainés du fond de la baie par les vents de sud-est, conservent à ces deux pointes leur largeur première."

M. Spurs has overestimated the rate of destruction, but there can be no doubt that it is very considerable. It is most conspicuous along the shores bordering the lagoon. The stumps of coco-nut palms, the newly-made breaches into the land, forming shallow inland lagoons, the vertical faces of old banks of half consolidated sand all attest it. Just above Point Marianne is a road running along the lagoonward shore, which when I left the island had been narrowed by the action of the sea to a mere path, and was in some places almost impassable, as the sea had made clean breaches across it, and found its way into some shallow fresh water lagoons lying on the other side of the road. I was assured that this road had been over 12 feet wide some years previously, and that it was formerly separated from the lagoon by a narrow strip of land of an equal width. Perhaps the best evidence of the destruction of land is afforded by the "barachois" at the southern extremity of the island. These barachois are inland lagoons connected with the main lagoon by a narrow outlet some 2 fathoms deep or more. They are filled and emptied every tide, and their floor is intersected by numerous small channels running in every direction. No corals grow within the barachois, and a slight study convinces the observer that the daily scour of the tides is denuding their shores and floors very considerably.

Barachois are formed in the following way:—During unusually high tides, when the waters of the lagoon are dammed back by a north-westerly wind of unusual violence, the water rises to great heights and invades the land in several places. In some instances it actually makes a breach in the lagoonward shore, and fills up the shallow depressions which are often found in the middle of the strip of land. A pool of salt water is thus formed, which kills the coco palms and other vegetation growing in its bed, and as this process is repeated again and again, in the course of a few years a channel is cut out between the pool and the lagoon, which finally becomes so deep that spring tides, and finally even neap tides, run in and out of the pool regularly. As soon as these conditions are established the channel is scoured out and deepened, and the daily tides scour out the bed of the pool, forming a complete barachois.

It is not easy for one who has not seen it to understand how much of the loose soil of a coral islet can be moved by a single tidal encroachment. It happened that I was riding past the very thin strip of land between Minni Minny and Barton Point the day after an abnormally high tide. The strip of land here is not more than 30 yards across, and the sea had washed right over it on the previous day, clearing away an amount of soil which was almost incredible. My companion M. Casimir Leconte told me that the sea had not been known to wash over this place before. It was apparent that after a few more of such high tides as I had witnessed, a permanent breach would be made at this spot, and another lagoon outlet would be formed, which would be continually deepened as the tide set through it. At the south-eastern side of the island I noticed that the land was being rapidly destroyed on the outer shores just opposite to a half-formed barachois, whose margins are situated not 60 yards from the outer shore. If the same process of external destruction continues, whilst the barachois is deepened and scooped out from within, it will not be many years before the ocean makes a new channel into the lagoon at this point. Thus the continuous strip of land which now nearly encircles the lagoon of Diego Garcia is tending to be split up again into a series of islets. At the points where the breaches are made the tides and ocean currents will rush with great force into the lagoon and will scour out deep channels similar to that now existing between Middle and East Islets.

These facts taken together show how the normal action of tides, winds, and waves is constantly tending to lower to the sea level any dry land that may have been formed by elevation or otherwise. It does not seem to me to be surprising that the majority of atolls and barrier reefs are, under such circumstances, only just able to maintain their surfaces above the sea level.

No explanation of atoll formation would be complete if it did not include an explanation of the great Maldive atolls. Without attempting to enter into a lengthy discussion of Darwin's views, I will give my own explanation of the atoll. Tilla-dou-Matte atoll is, as is well known, a huge atoll composed of atolls. The islets forming the rim of the main atoll are themselves atolls with their own lagoons; the main lagoon contains a few secondary atolls corresponding to the coral patches in an ordinary atoll. It will be generally admitted that coral reefs are constantly increasing to seaward because of the excessive growth of coral on their external slopes.* As the inward shores of an atoll are constantly being removed, and an atoll if completely formed tends to be broken up again into small islets when it has reached a certain size, and as the channels between the islets must be continually deepened by the scour of the tides until deep passages are formed, an atoll like Diego Garcia

* This statement may at first sight seem at variance with what I have just said about the rapid destruction of land on the outer and inner shores of an atoll; but in the latter case it is *land above water* that is destroyed. Coincidently with this process the reef-rock below water is constantly tending to raise itself and to spread in all directions, owing to the perpetual growth of corals and the accumulation of their skeletons.

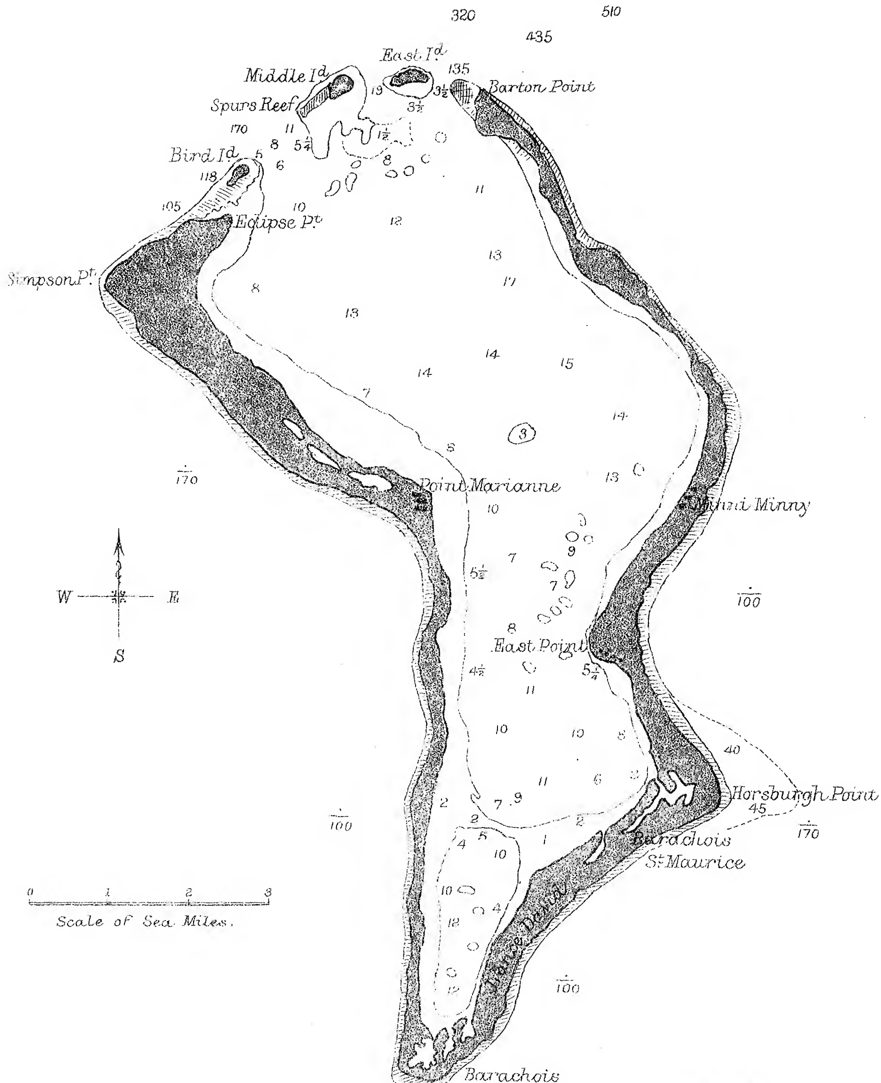
may be expected to reach in time a condition like that of Peros Banhos. It is probable that a large bank like the Great Chagos Bank, when it reaches the surface, can never give rise to a continuous strip of land, but must consist of a chain of islets separated by channels of some depth and by tracts of submerged reef. The islets and tracts of reef in either case would be bounded by deeper channels, and these channels, swept by strong currents, would become wider and deeper, for corals could not thrive in them. After a time the islets would become so far isolated, and the entries into the lagoon would become so large and numerous, that oceanic conditions would prevail in the lagoon, and then there would be around each separate islet or piece of reef all the necessary conditions for the formation of a new atoll. The currents would strike upon one side of the islet or reef, sweep round it, and give a backwash at the further side; the corals would flourish in the circumferential parts of the reef surrounding the islet, and new atolls with shallow lagoons would be formed.

In Tilla-dou-Matte the lagoons of the secondary atolls are tolerably deep. In this case they must have been formed before any land reached the surface. Applying the same reasoning as in the former case, it can readily be understood how in the case of the Great Chagos Bank, which has wide and deep breaches in many places, the isolated reefs as they grow to the surface must tend to assume an atoll form. An examination of the chart shows that this is the case. The Great Chagos Bank in the course of time will rise to the surface as an atoll composed of secondary atolls or atollons, similar to, but on a smaller scale than, Tilla-dou-Matte atoll. The explanation of atollons in the centre of a large lagoon in which oceanic conditions have been established, is quite obvious.

In conclusion, I may sum up by saying that the strength and direction of currents appears to me to be the main influence on coral growth; that the behaviour of currents on meeting an obstacle with sloping shores, explains the superabundant growth of corals on the outer slopes of a reef, whether submerged or awash; that the growth of corals on the periphery of a bank being in great excess of the growth in its interior portions is sufficient to explain the formations known as atolls and barrier reefs without the aid of the solution theory proposed by Mr. Murray, and ably defended by him in a recent number of 'Nature.' I have shown that Mr. Murray has overestimated the effects of solution in neglecting the compensating action of the re-precipitation of the carbonate of lime held in solution, and the formation of coral rock within the lagoon through the agency of coral growth there. I have also shown that the *rôle* played by currents is not what is supposed; that the carriage of food by currents must be considered of subsidiary importance in estimating their effect, though

I would be the last to deny that organic material brought by currents must determine the existence of coral polyps in every instance. I have confined myself to a discussion of the islands of the Indian Ocean, because I have no practical knowledge of coral formations in other parts of the world, and it would be rash to dogmatise about their structure when the conditions may be different. In the Indian Ocean I may fairly assume that the coral groups are subjected to the same influences that I studied at Diego Garcia. No doubt many of my statements will be contradicted by observers in the Pacific Islands and elsewhere. I can only say that they are true of the group which I have visited, and that within the limits of that group they form contradictions to existing theories. The seas in which coral reefs are formed are not all subject to the same conditions. In the Chagos group there is always a heavy swell on the ocean, and the sea breaks with a great force against the outer shores, and even over the shallower parts of submerged banks; the breakers are said to reach a height of 15 to 18 feet, but I never saw them so large at Diego Garcia. In other groups of coral formations the sea is wonderfully calm, and the sea rarely breaks on the outer shores with any violence. Some islands are situated in the direct course of great ocean currents, others are not, and are swept by the minor currents caused by prevailing winds. However one looks at the subject one must realise that the laws governing the formation of coral reefs are exceedingly complex, and that many circumstances have to be taken into account before any perfect explanation of their structure can be obtained. Action and reaction, destruction and reconstruction, growth and decay are constantly at work; the result of the multitude of nicely balanced forces, seemingly antagonistic, is the atoll or reef. It seems to me that the current theories of the formation of coral reefs attempt to explain everything by one or two agencies, whereas the agencies are numerous, and interact in a most complicated manner. Mr. Murray is undoubtedly right in laying stress on the necessities of nutrition suitable for coral growth, and the solvent action of sea water, but he has not taken count of other agencies which tend to modify and obscure these, and therefore his theory is not in itself sufficient to explain the question. I cannot expect that my views will be of universal application, since my observations were made on so limited a field, but I hope that competent observers will spend some months on coral formations in different parts of the world and give the closest attention to their facies, without overlooking the minutest particular bearing on coral growth on the formation of the reef. Then only shall we be in a position to construct a general theory of coral reefs.

[*Note.*—The life history of corals shows that they are not adapted to live in strong and direct currents. The free larvæ (planulæ) swim


East Id.
Middle Id.
Spurs Reef
Barton Point
Bird Id.
Eclipse Pt.
Simpson Pt.
Point Marianne
Minni Minny
East Point
Horsburgh Point
Barachois St. Maurice
Barachois de Sud
W
E
S
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1
2
3
Scale of Sea Miles.

Fig. 1.

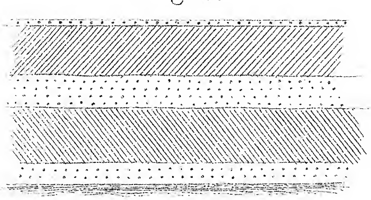
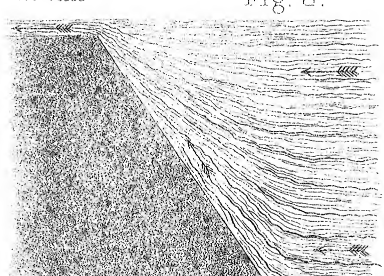


Fig. 2.



about for some time by means of their cilia before they attach themselves to a suitable spot, and undergo their further development. These planulæ are necessarily swept away by strong currents to the further shores of a reef, and it has been shown experimentally by von Koch that they will not attach themselves in a strong current, or if attached, will loose their hold when a strong current is directed upon them. Although coral colonies grow larger by budding, they originate in every case from planulæ, and no great group of corals could grow in a place where the strong currents prevented planulæ from attaching themselves.—*March* 20].

EXPLANATION OF PLATE.

FIG. 1 represents a diagrammatic section through the surface soil of East Islet showing the alternate layers of sand and rock of which it is composed. Scale $\frac{1}{8}$ inch to the foot.

FIG. 2 shows the way in which a current striking a sloping bank is deflected upwards over its surface until it joins the superficial part of the main current at the upper edge of the reef.

## III. "The Chemical Composition of Pearls." By GEORGE HARLEY, M.D., F.R.S., and HARALD S. HARLEY. Received February 23, 1888.

Although there are many qualitative analyses of pearls, from our being unable, in their voluminous literature, to find any evidence of a quantitative analysis of their ingredients having been recorded, we undertook the examination of several varieties, of which the following is an account:—

1st. As regards oyster pearls. Of these three varieties were examined, British, Australian, and Ceylonese.

The qualitative analyses showed that they all had an identical composition, and that they consisted solely of water, organic matter, and calcium carbonate. There was a total absence of magnesia and of all the other mineral ingredients of sea-water—from which the inorganic part of pearls must of course be obtained. Seeing that ordinary sea-water contains close upon ten and a half times more calcium sulphate than calcium carbonate, one might have expected that at least some sulphates would have been found along with the carbonates, more especially if they are the mere fortuitous concretions some persons imagine them to be—a view we cannot endorse, from the fact that by steeping pearls in a weak aqueous solution of nitric acid, we are able to completely remove from them all their mineral constituents without in any way altering their shape, and but very slightly changing their naked eye appearances, so long as they are

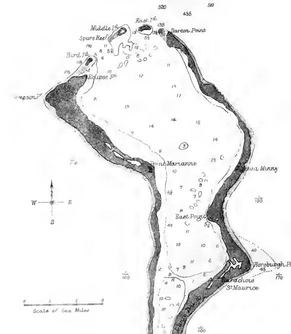

Middle Id
East Id
Barton Point
Spurs Reef
Bird Id
Eclipse Pt
mpson Pt
Point Marianne
Minny
East Point
Horsburgh Pt
Barachois St Maurice
Barachois de Sud
W
E
S
Scale of Sea Miles

Fig 1

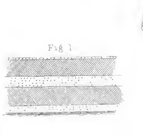


Fig 2