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The Fauna and Geography of the Maldive and Laccadive Archipelagoes

Being the Account of the Work carried on and of the Collections made by an Expedition during the years 1899 and 1900

Edited by

J. STANLEY GARDINER, M.A.

Fellow of Gonville and Caius College and Balfour Student of the University of Cambridge.

VOLUME I. PART I.

With Plates I—V and Text-Illustrations 1—23

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PREFACE.

In March, 1899, I left England, in pursuance of my appointment as Balfour Student of the University of Cambridge, with a commission to explore and investigate the Coral Reefs of the Laccadives, Maldives, and Ceylon. As the south-west monsoon is unsuitable for work from small craft in the Indian Ocean, it was proposed to devote the summer of 1899 to a thorough survey of the atoll of Minikoi, the most southern reef of the Laccadives. In regard to subsequent work the Managers of the Balfour Studentship gave me complete latitude to do as might seem fit.

Subsequent donations of £300 from the Government Grant, administered by the Royal Society, and of £30 from the British Association, decided me to proceed in October to the Maldive Archipelago for an extended winter cruise. The latter was entirely successful in its main results, although the expedition was considerably curtailed and seriously crippled owing to the general rise in prices caused by the war in South Africa.

I would like here to express the indebtedness of my party to His Excellency Sir E. Noel Walker, K.C.M.G., late Acting-Governor of Ceylon; to the Hon. Mr Taylor, C.M.G., late Acting-Colonial Secretary; to His Highness Mohammadu Imaduddin, Sultan of the Maldives, and his Viziers; to the Board of Trade for passages to and fro between Ceylon and Minikoi; to Capt. Channer, R.N., formerly an officer of H.M.S. Challenger, now Superintendent of Lighthouses in the Ceylon district, for many valuable hints and much local information; to Sheikh Jeevunjee Noorbhai for his generous help and assistance during the time we were in the Maldives; to Rear-Admiral Sir W. Wharton, Hydrographer, for advice and loan of scientific instruments; to Dr David Sharp for taking charge of the insect collections; to Sir John Murray, K.C.B., Prof. Judd and Prof. Agassiz for advice and assistance in many ways; and indeed to all kind friends and contributors for their aid.

Above all I wish to acknowledge the great obligations of myself and my party to Mr Adam Sedgwick for his great assistance and very active interest in the progress and work of the expedition.

In the work I was voluntarily assisted by Mr L. A. Borradaile (Selwyn College) and Mr C. Forster Cooper (Trinity College), who have largely contributed to whatever measure of success may have been attained. During five weeks in March and April, 1900, Mr Forster Cooper took charge of the work single-handed at a time when I was incapacitated by fever. My thanks are also due to Capt. Molony, S.S. Ileafaee, for his help in surveying Suvadiva and Addu atolls; and further to Mr Geo. Sheldrake, in charge of S.S. Thrunscoe, during our visit stranded on Minikoi, for practical help on many occasions.

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NARRATIVE AND ROUTE OF THE EXPEDITION.

(With 2 Maps.)

AT the end of March, 1899, I left England for Ceylon in the company of Mr L. A. Borradaile. On arrival at Colombo we found that the Board of Trade s.s. *Ceylon* had just left for Minikoi owing to a wreck on that atoll. This necessitated a delay of seven weeks, before we could hope to sail thither, a detention further increased to eight weeks owing to stress of weather. Mr Borradaile accordingly proceeded to the Jaffna Peninsula, where he spent a month in familiarising himself with the life and conditions on coral reefs. I meantime prepared our stores, and made arrangements for the Maldive cruise, subsequently visiting the raised limestone hills and area of the north of Ceylon[1]. After returning to Colombo I traversed the entire coast between Negombo and Dondra Head, a distance of about 120 miles. Mr Borradaile joined me, and we then settled down for a fortnight at Weligama—the Beligam of Prof. Haeckel—where there is a deep bay with reefs of small size across its entrance. The rich variety of animal life on the reefs both here and off the Jaffna coast as compared to the reefs of the Maldives and Minikoi is a most noticeable feature.

After a tedious week's detention in Colombo, we finally left Ceylon for Minikoi on June 17th, experiencing a very heavy north-west gale the whole way; in spite of this the sea one night was white with phosphorescence, a very unusual phenomenon in these waters. We located ourselves, and built a bungalow at a distance of about one-third of a mile from the south-west end of Minikoi island, under the shadow of the lighthouse, the boat belonging to which was through the kindness of Capt. Channer, R.N., freely placed at our disposal. The island here is about 470 yards across between tide-marks, and a broad ride has been cut, giving the only open space of any size in the island. The vegetation is extremely dense, and forms a low jungle of *Pandanus, Hibiscus, Hernandea, Ricinus*, coconut and other trees, with *Pemphis acidula, Scaevola koenigii* and *Tournefortea argentea* on the shores. At the south-west end of the island is a shrine, the grave of a holy, Moslem sheikh, connected by a good, shaded path with the village in the centre of

[1] Vide *Report Brit. Ass.*, pp. 400—2, 1900.

the island. A small settlement formerly existed round the shrine, but it has long been abandoned, and the jungle near it is now far thicker and less trodden than elsewhere. The land has the same character up to the village, but further north it is much more open, and can indeed be traversed almost anywhere[1]. Our situation then was not unnaturally the best possible for the land fauna, on which the lighthouse lamp too had doubtless no inconsiderable influence. The open ride formed both by night and day our best collecting ground, sugaring never meeting with any measure of success elsewhere.

For marine observations and collecting, we had within a stone's throw of the house on the seaward face of the island a broad reef-flat, on which the sea continually breaks. Towards the north this gradually narrows, but westwards broadens, and continues round the atoll. A broad boulder zone, which can be waded conveniently up to half-tide, extends the main (Minikoi) island inside the reef-flat to Wiringili and thence to Ragandi and round the atoll. These islets are mere rocky patches, the former with a few coconut trees, under the shade of which strangers are buried. Towards the lagoon there is a great sand-flat, exposed at spring tides from 100 to 200 yards from the beach. The situation was also chosen, as during the summer months the south-west monsoon blows, the effect of which I wished particularly to study. Unfortunately the monsoon of 1899 was very abnormal, the prevailing winds coming from west to west-north-west until the second week in August, when the proper monsoon commenced, bringing heavy rain in its train. The latter made work extremely difficult and unpleasant; the bottom could nowhere be seen on account of the surface disturbance; bottom living animals contracted, or retired into the sand or other shelters; the surface fauna sank to considerable depths.

The disadvantages of the position lay in the considerable distance of the house from the village and from the north passage into the lagoon, through which alone access to the open sea could be obtained in this monsoon. Natives had to be hired from the village for each several job, and it was too far for the children or fishermen to bring any strange animals they might find. The wind being dead in our teeth, and the numerous shoals making short tacks necessary, it was difficult to visit the northerly reefs of the atoll, and on no occasion was I enabled to approach them from seaward within about 200 yards.

During the months of July and August a heavy easterly swell came up with large rollers, three times dying down and again regaining force. This swell was very abnormal at the time of year, and apparently was due to some cause completely outside the ordinary winds and currents. On enquiry I ascertained that it was also observed on the east coasts of Ceylon and India and on the large Ocean Liners proceeding from Ceylon to Albany. Subsequently I found that it had been felt throughout the whole of the Maldives; in Suvadiva and Addu it did considerable damage, sweeping over islets and land, which had never been

[1] Owing to an old arrangement the produce of half the island is deemed to belong to the Bebe of Cannanore. An arbitrary line of division exists near the village with gates and guards, who rigorously exact three-fifths of the coconuts gathered south of the fence. In this portion no timber of large size or old growth exists, the whole surface at one time having been cleared and planted. Subsequently on the hold of the Bebe becoming weakened or relaxed, vegetation was allowed again to assume its sway, resulting in the present dense, jungly growth. On the management of the Bebe's dominions being undertaken by the British Government, the old line of division as found was retained permanently with much injustice to the inhabitants, as it had been formerly periodically open to revision. Since that time the north half of the island has been very rapidly washing away, while the south half has, if anything, been increasing somewhat in breadth. The north half cannot now annually support one-third of the present population, while the south has become a dense jungle, rapidly going to waste. It produces annually under the present system only a few hundred rupees' worth of coconuts, which the government might well commute for a fixed annual charge.

affected before. The origin of the swell can only, I consider, have been due to submarine volcanic disturbances probably towards the East-Indian region.

During the first five weeks of our stay at Minikoi, while I was engaged in a survey of the land and shores, Mr Borradaile occupied himself mainly with a thorough study of the land Crustacea[1]. An incautious exposure on the reef, while collecting, then laid him up with sunstroke, so that I had no option but to send him to Ceylon, whence he was ordered to return as soon as possible to England. For the remaining eight weeks I was absolutely alone, being deprived by illness even of my Singhalese servants.

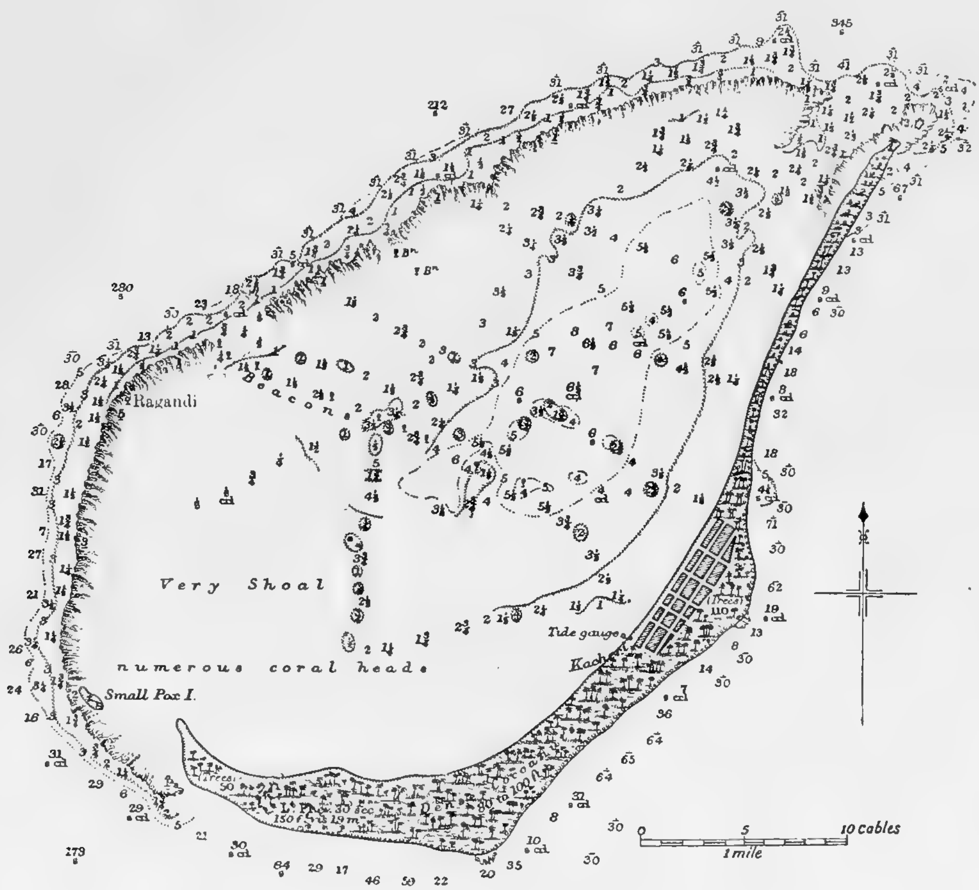

Fig. 1. Minikoi Atoll, from the Admiralty Chart. (*Wiringili, native name for Small Pox I.*).

I returned to Ceylon in the middle of September, Mr Forster Cooper shortly afterwards joining me from England. After some unavoidable delay we left Colombo on Oct. 18th for Male, the capital of the Maldives and residence of the Sultan. Owing to a succession of accidents we did not arrive until Oct. 23rd, when we at once landed our stores, transferring sufficient for a three months' cruise to our schooner. The latter was lent to us by His Highness the Sultan; she was a vessel of about 16 tons, built in the islands, of coconut

[1] *Vide* Mr Borradaile's account in the same part of this publication.

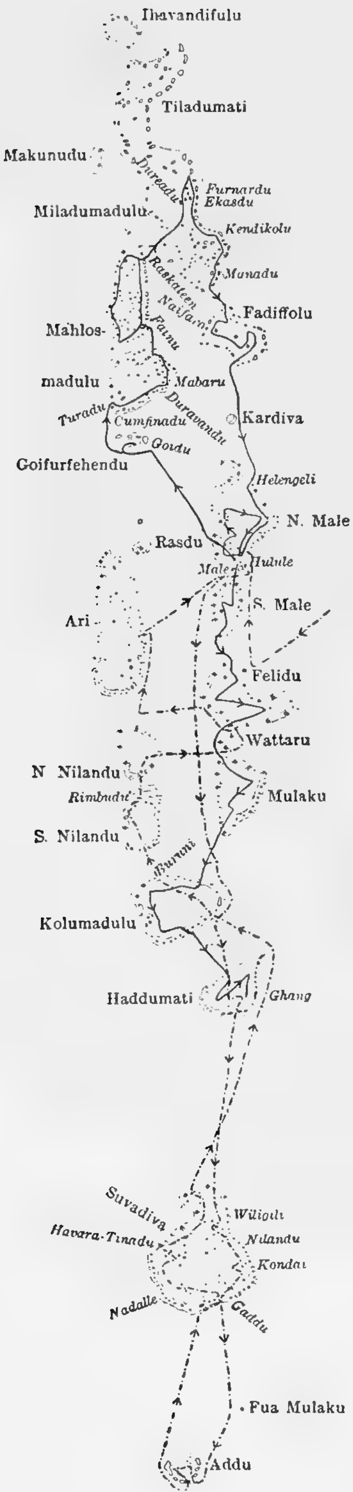

Fig. 2. Maldive Group, showing the route of the expedition. *Scale 60 miles to 1 inch.*

wood, moderately seaworthy, but not laying within six points of the wind. The Sultan also appointed Hassan Didi Velanamanikofanu, his third vizier, to accompany us, and gave orders that every facility should be granted to us. After presenting our offerings to the Sultan and his viziers, we sailed from Male for Goifurfehendu (Horsburgh) atoll.

We at once had a house built on Goidu island, from which as centre we visited all the other land of the atoll and the greater part of the reef. A stay of altogether eleven days was made, and everything was unpacked and properly stowed on the schooner; the dredges and instruments were overhauled, and indeed all preparations were completed for the work in Mahlos and other atolls. The reef-animals were collected and preserved, being sent by native boat to Male to await our arrival. On leaving Minikoi I brought with me two boys, whom I had taught to collect in that atoll; these I largely employed in Goidu and subsequently in other islands in collecting the land fauna and flora.

The remainder of October, 1899, was spent in S. Mahlosmadulu. This group of reefs really consists of three atolls, a small central one separated from larger on each side by narrow channels of over 100 fathoms in depth. The three lie on a shallow bank, which tapers to the north but has a broad base to the south-east. The plateau is studded all over with reefs, the outside ones forming a chain round the perimeters of the three parts. The reefs along the west side of the bank are for the most part ring-shaped, small atolls (atollons or *faro*) with deeper water (the lagoon or *velu*) in the centre. On the east and south sides, however, isolated islands with fringing reefs mostly form the boundaries. The general depth of the atolls is about 27 fathoms, most of the channels between the numerous encircling reefs having over 20 fathoms.

The weather during our stay in S. Mahlos was extremely calm, our vessel indeed being towed by boats from island to island. This was singularly unfortunate, as usually strong winds may be depended upon in November. We had hoped to systematically dredge a large number of the deep channels between the reefs, that edge the atoll. As their general depth is about 25 fathoms, this was found to be impracticable, rowing boats not having sufficient weight to carry even the smallest dredges along a rough bottom at this depth. Accordingly we confined ourselves to a traverse of the whole south of the atoll. Our first anchorage was off Turadu, an island situated on the rim of a somewhat ill-defined *faro* at the south-west corner of the bank. We visited every part of its reef and collected a few animals. The lagoon (*velu*) of the *faro* was dredged, yielding

Asymmetron and *Ptychodera* from 20 fathoms. The island itself proved most interesting. Its rocky barrier of beach-sandstone had in 1896 been overlapped by the waves of a cyclone. These attacked the sand behind, eating deeply into the island, with the result that the beach-rock has been left in lines many yards from the shore. The natives have now erected breakwaters round a great part of the island—and also a new mosque—but in spite of these no trace of it is likely to be left in 20 or 30 years' time, unless some considerable change in the currents or reefs alters its conditions.

From Turadu we visited all the reefs to Mabaru, the most easterly point of the whole group, anchoring at Hitadu, Heddufuri, Mahrus and Duravandu. At Cumfinadu we found some large rocks, standing up in the lagoon well inside the boulder zone; *Bonellia* was living on the reef-flat, and *Ptychodera* was the most abundant form of life on the shores of the island.

We finally left for N. Mahlos on Nov. 29th, but, meeting with strong currents to the west-south-west, we only fetched Kuderah-Heelu in the central atoll that evening. However we reached Fainu in N. Mahlos on the following day, and remained there at anchor for three days, which were devoted to dredging and an examination of the islands of Fainu, Kenurus and Ingurahdu, and Berriam-furi faro. We then separated, Mr Forster Cooper dredging with the schooner along the east side, and examining its islands and reefs. I meantime embarked in a small open boat for the western side, where the lagoon of the atoll is filled up with a perfect maze of small reefs and shoals. I first visited five of the lagoon islands, and then, a strong north-east breeze setting in, worked up along the edge of the atoll, sailing from dawn to dusk, and anchoring at night to leeward of the nearest reef. I examined all the reefs and islands, and sounded the velu (lagoons) of all the faro (atollons) along the western rim, rejoining the schooner on Dec. 11 at the north of the atoll. Unhappily a series of collections, made by myself and my boys, to illustrate the populating of sand-banks by both animals and plants, was ruined by my capsizing our fishing boat near Cunderudu.

On Dec. 12th, after taking in wood and water, we sailed for Miladumadulu, a similar bank to Mahlosmadulu but with relatively far fewer reefs and a less determinate rim. We anchored the same night at Guthardu, and at daybreak made sail towards the east side of the atoll. Owing to a strong south-westerly set of the current we took two days in reaching Dureadu in the middle of the bank, a distance of seven miles. This is the island of a round faro, one mile in diameter; its lagoon has 19 fathoms of water, a depth which makes the faro peculiar among all its fellows in the Maldives. We landed the same night for firewood and water, but, none of the latter being obtainable, were compelled to sail at dawn. A strong north-east gale coming out, we stood up the atoll and watered at Rymaggu, anchoring that night at Furnardu, a large island on the east edge of the atoll. The islands of this rim of Miladumadulu tend to be closely fringed by the reef on all sides, and to have a *kuli* (shallow lake, French *barachois*) in the centre, surrounded by mangroves, through which the sea has in some found access. While Mr Forster Cooper dredged with the schooner down to Kendikolu, I visited ten of these islands in a fishing boat; two were very small, three had definite kuli or else mangrove swamps (Ekasdu, a large lake swarming with a species of *Leander*), and four were crescentic in shape, their kuli now open to the sea. Kendikolu is one of the largest islands in the Maldives, being two-and-a-half miles long by two-thirds of a mile in breadth. There are four kuli down the centre surrounded by mangroves, which abound in rails; on their surfaces we saw a few duck, while their waters, which are quite fresh, four to five feet deep, teem with small fish. However, as Ramazan, the Mahommedan fast month, was approaching, we had to hurry on, and only stayed two nights. We accordingly, on Dec. 19th, dredged down to Landu, obtaining a large variety of sponges and Polyzoa with a quantity of red *Polytrema* and some nullipores, in addition to corals, of which the black *Dendrophyllia ramea* was very abundant in 12 to 20 fathoms off the reefs. We visited and dredged Ma and Eddu faro with three to four fathoms of water in their velu, obtaining a few Cephalochorda, and examined some of the central islands of the atoll. At Manadu we caught a single specimen of *Typhlops*, which is evidently very rare in the archipelago, since it has no native name.

Fadiffolu atoll was reached on Dec. 23rd; it differs from the preceding in being a true atoll, having a well-defined, encircling reef, especially to the east, and an open lagoon with but few shoals. We first moved down the east side, examining the reefs, but then dredged across to Innawari. The natives, although not actively hostile, were very unfriendly, so that on Christmas morning we sailed down to Naifaro. The winter rains now commenced, and continued intermittently with heavy squalls from the north-east for a month, making navigation among reefs difficult. The schooner too was decidedly unpleasant, as the whole of our cabin accommodation had to be utilised for storing our books, instruments and various collections. We remained at Naifaro four days, restowing and repairing our vessel, as she had been somewhat strained in the recent heavy weather. The time was occupied in a survey of the neighbouring islands and reefs, and in thoroughly dredging some of the passages into the atoll.

The shores of all the islands at the north end of Fadiffolu I found abundantly strewn with the shells of *Spirula*. Enquiring of the natives as to its "fish," I was surprised to receive an accurate description of it. It appeared that the animals were extremely abundant in January of 1897 in the channel towards Miladumadulu. "They float on the surface, and may be picked up with the boat-bailer. They are never seen inside the atoll, but periodically occur in the north-east monsoon in the open sea. None were seen in 1898." I offered a reward of 50 rupees for the first specimen, but, although eight or nine boats went out daily during my stay, I did not secure one. That the people of Naifaro and Innawari really know the animal is undoubted. Yet this is peculiar, as I did not find on close enquiry that it was known to the natives of any other part of the whole archipelago, though its shell occurs sparingly everywhere. The native name for the shell is *markana taludandi*, the heron's key.

Leaving Naifaro we again dredged across the atoll on a more southerly course, subsequently cruising along the eastern side, dredging and examining the islands and reefs. On Jan. 2nd, 1900, we set sail for Male atoll, anchoring off Helengeli the same afternoon. This atoll is intermediate in its characters between Mahlos and Fadiffolu; except at the south end it has practically no islands in the lagoon. There are evidently great changes in its topography since the original survey, two islands of the eastern edge at least, resting on their own reefs, having disappeared. There seemed to be still greater alterations in respect to the shoals in the lagoon, but in our somewhat dependent position any real survey was impossible owing to constant interference from Male. We, however, saw some of the western reefs on our way to Goifurfehendu, and on our return journey to Male, which we reached on Jan. 5th, 1900, we dredged down as close as possible to the eastern reefs. Further Mr Forster Cooper in the middle of February made a most successful dredging cruise of eight days in the atoll, taking 34 hauls, to ascertain the character of the bottom in every position, and I at the same time visited most of the islands and reefs within five miles of Male.

Ramazan had now commenced, and, dependent as we were entirely on Mahommedan boys, it would have been useless to continue our cruise. Our vessel too was in want of a thorough overhaul, the rigging being very bad. After a couple of days in Male, we had a house erected on Hulule, the island of a neighbouring faro, and at once transferred to it sufficient stores for a stay of four or five weeks' duration.

Hulule island is about $1\frac{1}{4}$ miles long by 800 yards broad; it is about two miles distant from Male. The greater part of its surface is covered with coconut trees, but a large patch along the western side has been allowed to revert to jungle. The principal trees are the banyan, candle-nut and *Calophyllum*, the branches of which abound in frugivorous bats. On account of the island's proximity to Male, where all foreign vessels for the group have to enter, many plants have been introduced. Few of the fruits thrive, but half-a-dozen brilliant flowers relieve the everlasting green. Sweet-smelling plants, jessamine, frangipanni, roses and various herbs, make the proximity of the mosque and village pleasantly fragrant. The western shores are fringed with *Pemphis acidula*, the white, perfumed flowers of which prove a great attraction to insects. As some of our boys delighted in this work, the land fauna and flora was exhaustively collected. As compared with Minikoi, we found the insect and spider faunas to be decidedly poor except in butterflies, although it may be deemed to be thoroughly representative of any rich island in the centre of the Maldives. A certain number of insects must have been introduced with the plants, but the successful acclimatisation of any considerable number of the latter only dates back to the eruption of Krakatoa in 1883. Before this time pumice (*feng-bo-ga*, the water-swimming stone) was not known in the group. Its fertilising properties have now been discovered, and in many islands baskets of it are collected and strewn over the garden land. The capture of two specimens of snakes on pandanus trees at Hulule was of interest.

The whole faro is $4\frac{1}{2}$ miles long by $1\frac{1}{2}$ broad; its lagoonlet, or velu, in the centre has a depth of 6 to 7 fathoms. The reef everywhere is awash at low tide, and, though differing greatly in its characters, quite well defined on the side towards the lagoon of the large atoll. Besides numerous rocks there are two islands respectively at the north and south ends, Farukolufuri and Hulule. During our stay every part of the faro was surveyed, and the fauna carefully collected for comparison with that of Minikoi atoll. *Asymmetron* was very abundant in certain places in and around the velu, and at least three species of Enteropneusts of two or three genera were found, each in its own characteristic environment. Two specimens of a remarkable *Thalassema*, 2 feet long when alive, were secured from the boulder zone, besides a number of specimens of smaller species. The sand was remarkably rich in Actinians of many species, all of which withdrew into the shelter of the sand at every rain-squall. Mollusca were not numerous, but *Cryptoplax*, *Chiton*, and each of the three families of the Zygobranchiata were represented; autotomy of the foot seems to be a widespread phenomenon, as several forms with the foot thus cut off were obtained.

We returned to Male in the middle of February. Mr Forster Cooper at once sailed for his dredging cruise in the atoll, while I remained to carry on a series of observations on the currents in the channels on each side of the island. During my whole stay I dispensed medical aid freely to the people. At this time there was in one district of Male an epidemic of malaria, with which I was naturally much brought into contact. Mr Forster Cooper returned to find that I had caught the infection. I saw, however, our collections to date properly packed for England, and the schooner victualled and equipped. As complications set in and I was getting worse instead of better, Mr Forster Cooper on Feb. 28th took advantage of the chance visit of a British India Steamship Co.'s steamer to place me in charge of Capt. Pigott, R.N.R.[1], for Colombo. He himself determined to carry out his part of the projected work, and sailed from Male on March 3rd for the southern atolls.

I cannot speak too highly of the pluck, determination and resource, shown by Mr Forster Cooper, who had had no previous experience of the tropics. He worked his native crew in a manner, which I have never seen excelled even in the Pacific, and took no less than 88 dredgings in five different atolls. However, I append Mr Forster Cooper's report, which may be allowed to speak for itself:

"On March 3rd, accompanied by Mahommed Didi as interpreter and representative of the Sultan, I crossed over to S. Male, in which three days were spent. Gurahdu island and reef were visited, but neither land nor reef in the atoll appeared to exhibit any novel features. The group consisting of a series of almost isolated reefs, I dredged principally in the outer passages and in the centre to ascertain the differences in the bottom-fauna. The hauls in the centre were very unproductive, but in the channels a large quantity of the same sessile forms, as in the northern atolls, was brought up. Just inside the northern passage a coral, *Goniopora stokesi*, was obtained; it forms round heads on thick stalks, covered by an epitheca, which is completely buried in the sand, or mud.

"On March 6th we sailed on to Felidu atoll, where we visited Alimata and Tinadu islands alone, at night anchoring generally to the nearest reef. We remained eight days, but only took 18 hauls of the dredges owing to head winds, strong currents across the atoll and dead calms. Indeed throughout the whole cruise the unfavourable winds and the poor sailing qualities of the schooner prevented us from surveying as much of the atolls and from taking as many dredgings, as I would have liked. We attempted for three successive days to get up the almost completely enclosed eastern horn of the atoll, but were unable to tack up more than half-way. The lagoon in it is open with few reefs or shoals, and has a general depth of 40 fathoms; its bottom is hard, covered with sand, and absolutely unproductive to the dredge. In the rest of the atoll weed and broken shells were found towards the centre of the lagoon and rubble in the channels. *Diaseris* is very common almost everywhere and its skeleton forms one of the chief constituents of the rubble.

"We fetched Mulaku atoll on March 14th, and remained six days, taking 17 dredgings. The atoll is remarkable for the broad, almost continuous reef along its eastern side. There are a number of very narrow, shallow passages to the north, but from Maduveri to Curaille a distance of 30 miles, the reef is continuous save for a single passage opposite Mulaku island. All the islands lie on the seaward side of this reef; extending down its centre is a series of long, linear velu (small lagoons), which off Raimandu is double, two series lying parallel to one another and the edges of the reef. In dredging I ran two lines across the lagoon, and then moved down along the eastern side. Among other forms we collected a

[1] I cannot sufficiently express my indebtedness to this gentleman for all his kindness to me.

large number of soft-bodied echinoids, a few black crinoids and some holothurians, with which were associated a number of Polychaeta, crabs, caribs and molluscs. All were of the same ground shades as their various Echinodermata, whose colour was, as it were, photographed upon them.

"Kolumadulu atoll was entered on March 21st, but no work could be done from the schooner owing to the calm weather until the 26th inst. I meantime took the small boat out, and made various scattered dredgings in the north-east corner of the atoll with but indifferent success, while I sent the collecting boys to Kolufuri to obtain the land fauna and flora. I did not personally visit any of the islands in this atoll nor Haddumati, which we next dredged, as they all appeared to me to present the same features as in the northern groups. I was also anxious, as these two atolls are almost completely encircled by reefs, to ascertain precisely the characters of the bottom in every part. I sailed finally right across the centre of Kolumadulu lagoon, taking 16 dredgings down to 45 fathoms and incidentally running the vessel ashore on a small reef, off which we warped her without any great difficulty. The centre was found to be covered with fine mud, on which a few Crustacea, molluscs and flat-fish of small size alone appeared to exist. We obtained also a larval form of *Fierasfer* out of a holothurian from 25 fathoms.

"In Haddumati atoll I took 16 dredgings in the centre and eastern part of the lagoon, where the bottom was mostly covered with fine mud. They were very unproductive owing doubtless to the all but continuous reef of the eastern side. Relatively little work could be accomplished, as the schooner was in a horribly dirty state with bilge, etc.; she also had been somewhat strained on the reef, and her bottom was thickly covered with barnacles and weed.

"To summarise, the cruise yielded between March 3rd and April 8th 88 dredgings in every part of the lagoons of five different atolls. The hauls must have averaged at least one mile each, and hence 88 miles of the bottom was covered. The latter was found to be of an almost uniform dead-level between the reefs and shoals, which, arising precipitously, uniformly reach to within a few feet of the surface. It was to me most remarkable that we did not meet with a single knoll of any sort jutting up to indeterminate depths[1]."

After paying a second visit to the Jaffna district, I returned to the Maldives, having secured Sheikh Jeevunjee Noorbhai's steamer Ileafaee, Capt. Molony, for a short cruise. I took on board at Male Mohammed Didi, Chief Vizier and uncle to the Sultan, Mafekiligefanu, the religious head of the community, and Hassan Didi, third vizier, with their suites as well as a Said, descendant of the Prophet, who had a family in Addu. After discharging some of our Male cargo we steamed south down the deep central basin of the group, coasting S. Male and Kolumadulu atolls. We steamed into Haddumati atoll on April 8th, and relieved Mr Forster Cooper, who joined us. After transferring the collections, instruments and nets, we sent the schooner back under the native mate to Male, and at once sailed on to Suvadiva atoll, which we entered by the north-east passage on the morning of the 9th. This atoll lies between the equator and lat. 1° N.; it is separated from the central group by the "One and a half Degree Channel," 55 miles in breadth.

[1] It is scarcely necessary to point to the great importance of this fact, as bearing on the question of the formation of the atolls and reefs of the Maldives.

It has a well-defined rim with passages at intervals, and is about 34 miles long by a little less in breadth; its lagoon has a maximum depth of 50 fathoms. As Addu atoll was to be our turning point, we now spent only two days in Suvadiva, dredging and sounding along the east side of the lagoon. We anchored with banked fires for two nights at Nilandu and Gaddu, and I further, leaving the dredging to my companion, visited Wiligili and Kondai.

Addu is a small atoll, 10 miles long by 6 broad, lying about lat. 0° 40′ S. Its reef is perfect except for two small passages to the north and two larger ones to the south. The lagoon has a maximum depth of 36 fathoms; it is fairly open in the centre, but against the encircling reefs has a perfect maze of coral heads, arising from 7 to 10 fathoms. It is noticeable that the greater part of the circumference of the atoll is surrounded by land. The "Equatorial Channel," 48 miles across, separates Addu and Suvadiva. In its centre is the island of Fua Mulaku, said to have a deep kuli (lake) in its midst; it is two miles long by one broad, and has a fringing reef only. On our passage to Addu, and subsequently on our return journey, we tried to visit it, but the heavy sea made both anchoring and landing quite impossible. We remained at Addu until April 15, examining the reefs and islands, in both of which there have been great changes since Moresby's survey. We also checked the soundings on the chart, and took 14 hauls of the dredge in the lagoon and on the outer slopes. In one of the latter from 40 fathoms we obtained a large quantity of *Heliopora coerulea* with almost colourless corallum. The vegetation of the islands was far more luxuriant than any we saw in other parts of the Maldives, but the land fauna was very scanty as compared with Hulule. The animal life of the encircling reefs seemed to be both poorer and less varied than to the north; the growth of fixed forms of life in the lagoon was, however, decidedly lavish.

Revisiting Suvadiva on our return journey, we dredged and sounded within the lagoon along the south and west sides, anchoring for three nights at Gaddu, Nadalle and Havara-Tinadu, beyond which I did not land anywhere. On April 19th we entered Kolumadulu, having in the morning coasted along the east side of Haddumati. We dredged the passage, as we entered, and dropped anchor at Buruni, at once going on shore.

On April 20 we ran a line of soundings across to S. Nilandu, an atoll somewhat similar to Male. We twice traversed the lagoon, anchoring that night at Rimbudu. Six dredgings were taken in 19 to 35 fathoms; they proved to be in their result the richest series that were obtained in the whole archipelago, although I do not think we found any forms of which we had not previously preserved specimens.

On April 21 we sounded the channel across to N. Nilandu atoll, which we crossed. We then ran a line of soundings to Wattaru atoll across the central basin, which has very generally been supposed to owe its origin to the lagoon of a much larger atoll, now completely lost. We further sounded the channel between Mulaku and Wattaru atolls, anchoring for the night off Rakidu in Felidu atoll. On April 22nd we sounded the channel between Felidu and Wattaru atolls, and then ran a second line across to the western chain, about 15 miles north of the first. We sounded the channel between N. Nilandu and Ari atolls, continuing northwards sounding at intervals to Mahiaddu in the latter atoll, where we dropped anchor. On April 23rd we made a straight course for Male, putting down our third line of soundings across the central basin. We ran our line out along the channel between N. and S. Male atolls, obtaining finally a depth of 1005 fathoms, two miles S.W. ¼ W. of the S. point of the reef of Hululc faro. That night we anchored off Male and, after taking our collections on board, bade good-bye to the Maldives on April 25, 1900.

The collections may be allowed to speak for themselves in the subsequent parts of this publication. A word is necessary as to the dredgings, of which 273 were recorded in the Maldives. They were intended to ascertain the character of the bottom within the atolls as well as its fauna in every position, in which the physical conditions might vary. Naturally a considerable number were under these circumstances absolutely barren, but all served their purpose. Seven dredges were used, both rectangular and triangular, of Naples or Plymouth models, as well as an otter and three beam trawls of 3, 4½ and 6 feet. The latter were made to my own design, an adaptation of Prof. Agassiz' model; they were for trawling from the steamer weighted with fire-bars; their nets were of coconut fibre (sinnet or coir), and were made by my boys. Swabs of hempen rope, three feet long, were found best adapted to our work; they were always thrown overboard, when we were at anchor, about one fathom of rope being allowed beyond the depth, if the bottom was fairly level. For sounding from the schooner and small boats, besides regular lead lines, we used loosely spun cod-fishing line, as recommended by Mr J. Y. Buchanan. On the steamer we had an old Lucas deep-sea machine, which was lent us by the Admiralty, Mr Lucas kindly providing about 3000 fathoms of wire. Of leads we employed the Telegraphic Construction and Maintenance Company's snapper, and valved leads of the Admiralty pattern. Other apparatus and instruments will be referred to where necessary in the account of the work of the expedition.

J. STANLEY GARDINER[1].

[Note. The collections of plants have been presented to the Royal Botanical Gardens, Peredeniya, Ceylon. A full report on them will be shortly published in the "Journal of the Gardens" by Mr J. C. Willis, the Director. J. S. G.]

[1] This account has been checked by Mr L. A. Borradaile and Mr Forster Cooper.

THE MALDIVE AND LACCADIVE GROUPS WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN.

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(With Plates I. and II. and Figs. 3—11.)

CONTENTS.

(*To be continued.*)

CHAPTER I.

THE CORAL REEFS OF THE INDIAN OCEAN.

THE topography of the Indian Ocean gives but little aid to the student in attempting to determine the character of the foundations of the various island groups. Far less indeed is this the case here than in the Pacific Ocean, where the trend of each of the larger groups has a tendency to run somewhat parallel to that of others and to continental land, suggesting that they lie on lines of weakness of the earth's crust, lines of former volcanic activity. The two oceans are alike in that the western part of each is almost bare of coral islands, the Pacific absolutely so, the Indian Ocean with Cocos-Keeling[1] and Christmas islands[2] alone. Of these the former is the type, on which descriptions of most atolls have been moulded, and the latter is an ancient atoll, which has undergone great elevation, the only one indeed in the whole Indian Ocean. This lack of raised reefs is remarkable, as compared with the Pacific Ocean, and can only be taken as an indication of the absence of any considerable volcanic activity in modern times, at any rate between Madagascar and India.

There are only two changes in the past in connection with the topography of the Indian Ocean, about which there is any general consensus of opinion, *i.e.* a former water connection with the Atlantic Ocean, and a land connection between Madagascar and Africa. The permanency since the Jurassic period of the Arabian Sea and of the great basin between Chagos and Rodriguez on the one hand and Australia on the other has not been seriously impeached, so that there is only left a belt between S. Africa and S. India, and it is in this that all the considerable coral reefs lie. The general depth of the whole Indian Ocean is remarkably uniform, about 2500 *f.* (fathoms), a single sounding only of over 3000 *f.* (3097 to the S.W. of Christmas island) having been obtained. What however is still more noticeable is, that not a single sounding N. of the line between Cape St Mary (S. Madagascar) and Cape Leeuwin (S.W. Australia) has been run of less than 2000 *f.* except near continental land, or close to islands and shallow reefs, the existence of which is known at the present day. The soundings, such as they are, although not quite close enough, give strong indications, that the belt between Madagascar and India is cut by a depth of over 2000 *f.* in three places, *i.e.* between the Maldives and Chagos, between the latter and Saya de

[1] *Vide* "*The Structure and Distribution of Coral Reefs,*" by Chas. Darwin (1889) and "The Cocos-Keeling Islands" by H. P. Guppy, *Scottish Geo. Mag.* (1889).

[2] *Vide* "A Monograph of Christmas Island, Indian Ocean." British Museum (1900).

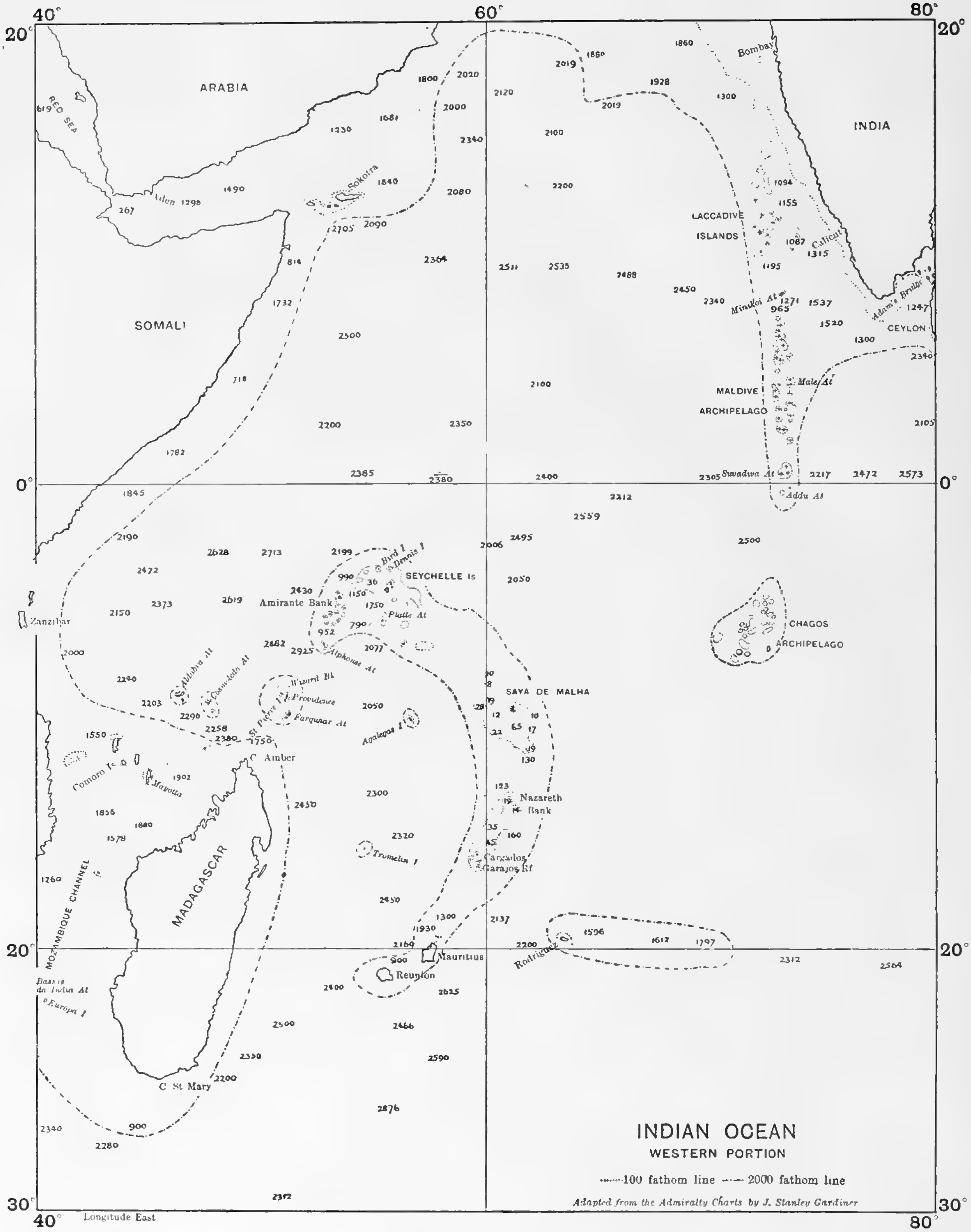

FIG. 3. Indian Ocean, Western portion.

Malha Bank, and between Farquhar atoll and Madagascar. These channels divide the coral-reef areas into four sections, which may be termed respectively the Malagasy, Seychelles, Chagos, and Maldive[1].

1. Malagasy Section.

Madagascar itself displays a nucleus of granite running from end to end of the island, broken only by patches of recently active volcanoes. No raised rock of coralline origin is known, but nummulitic limestones of the eocene period form a belt along the western side. The reefs round the island are of inconsiderable extent, mostly mere isolated fringing banks. The former connection of this island with Africa is indubitable, and its structure indicates that it has experienced several changes of level since that connection was broken down. The Comoro islands, a volcanic group N.W. of Madagascar, have only fringing reefs except Mayotta, which possesses a barrier, 3 to 6 miles distant, with upwards of 35 *f.* of water in its lagoon. Two small high volcanic islands arise in the barrier itself, indicating that its formation was probably *sui generis*, on a bank formed of volcanic debris from the central island.

Of isolated coral formations there are to the south about lat. 22° in the centre of the Mozambique channel Europa island, 50 to 80 feet high, with low cliffs and sandy hommocks, and a small fringing reef, and the Bassas da India bank, a round atoll-reef 9 miles in diameter, completely enclosing a central lagoon of shallow depth. Between the Comoro and Cape Amber (N. Madagascar) are a series of banks, of which the Geyser is to all intents an atoll with a wide passage to the S.E.; Glorioso has two islands, for which the descriptions do not indicate any elevation.

To the north of Madagascar, about lat. 9° 50′, are a series of banks and islands, which show an unmistakeable and very uniform elevation of something over 30 feet. Of these two banks to the east Providence and Wizard never probably had an atoll form, they have now merely sand cays (Providence two small islands as well) and isolated rocks, while St Pierre in their vicinity is a raised island, one mile in diameter; its elevation would seem to have been but very recent, as it is described as having no fringing reef, the sea directly breaking on its coast. In addition there are three indubitably raised atolls, Cosmoledo, Farquhar and Aldabra. They differ from most similarly elevated atolls, in that their rock still retains even at the surface its organic structure. The lagoons of the original atolls can in each be traced, and the greater part of their basins appears to be covered with water at high tide, although their mud-banks increase in extent in the order named. It is remarkable that the lagoons of all have maintained, or obtained passages with a few fathoms of water to the sea, and they would appear to be regaining their former extent. Aldabra, 19 miles long by 7 broad, has save for two small passages a perfect rim of land, covered by jagged coral, while its lagoon is surrounded by mangroves, which are said to be everywhere "eating the coral away[2]."

[1] The southern islands of the Indian Ocean (Prince Edward, Crozet, Heard, Kerguelen, Amsterdam and St Paul) are separated by at least 1200 miles of ocean from the nearest islands of coral formation, or with coral reefs of any sort. They are all volcanic, and can have no conceivable connection with the islands to the north, being separated from them by over 2000 *f.* They must be regarded rather as outliers of the great Antarctic Continent, since they all rest on the somewhat shallower bank, which extends northwards from its shores.

[2] "Islands in the Southern Indian Ocean." *Admiralty*, p. 366, 1891, from which also much of the information in

2. Seychelle Section.

This section comprises a semicircle of reefs and islands, extending from Reunion to the Seychelles and then southwards to the Amirantes and the Alphonse-Francois islands. Rodriguez is an outlying basaltic island to the east of Mauritius, with a little raised coral-rock; the reef is fringing or slightly barrier with low coral islets[1]. Agalegas and Tromelin between the line and Madagascar seem to be of coral formation with fringing reefs; they are probably slightly raised, though no definite evidence on this point is available. These three islands may well all be separated from the rest by over 2000 *f.* of water, but the main line so far as the soundings go would rather appear to be on a bank with at most 1000 to 1500 *f.* of water.

Reunion to the south is a volcanic island, 10,069 feet high, with fringing reefs in places, while Mauritius, also volcanic, 2700 feet high, has both barrier and fringing reefs, which were visited by Darwin. Tracing the line to the north Cargados Carajos is a crescent-shaped reef, awash, 30 miles long, in one place 4½ miles wide, with 7 low, coral islands, which appear to be washing away; it has a shallow bank extending 16 miles off to the west, but has in no way begun to assume an atoll form. The bank known as Nazareth probably extends down with shallow water (under 50 *f.*) and includes the last-named, giving a total length to the bank of 280 miles; the shallowest sounding is 14 *f.*, but the whole is ill-surveyed; there does not appear to be any deeper central part. The Saya de Malha, 150 miles further north, consists really of two considerable banks which are probably not separated by more than a few hundred fathoms from the last, as comparatively shallow soundings extend out from each for a long distance. The northern bank, 75 miles long by 23 broad, has a ring-shaped reef, about 12 *f.* deep (shoalest water 5 *f.*) with a central basin of 40 *f.*, while the southern is 140 miles long by 120 broad, with a rim to the N. and E. at 12 *f.* but only a little shoaler (25 *f.*) to the S. and W., and a central basin about 50 *f.* deep, a great bight in one place running in from the S. with 60 to 70 *f.* The two banks are remarkable for the great breadth of their rims, about 7 miles in the N. bank and 12 miles in the southern. A further small bank to the S.E. has one sounding of 57 *f.* in the centre and rim 25 *f.* deep.

The Seychelles lie about 200 miles N.W. of the last, with no bottom soundings in the channel between. They consist of ten high granitic islands, mostly with fringing reefs, on a bank 35 *f.* deep, 200 miles long by 120 broad. The northern outliers, Bird and Dennis

this section was obtained. Most of the surveys of isolated islands in the regions comprised in this and the next section appear to have been made by Admiral Sir W. Wharton, F.R.S., a most expert and careful observer. For information on Madagascar consult "Madagascar, Mauritius and the other East-African Islands" by Prof. Dr C. Keller, 1901, who gives a full list of references.

[1] *Vide* "The Physical Features of Rodriguez," by Is. Bayley Balfour, *Phil. Trans. R. S.*, vol. 168, pp. 289—292, 1879. The raised coral-rock is described as forming large, coralline, limestone plains of inconsiderable elevation. Prof. Bayley Balfour proceeds:—"The existence of these masses of coralline limestone indicates clearly a former lower level of the island, and the evidence of raised beaches confirms this. But a consideration of the coral-reefs points as clearly to a time when the island stood at a higher level. The present coral reef fringes the coast, extending about 3 miles on the south-west side, but coming close inshore on the east. An older reef, however, exists, now quite submerged in some places to a depth of over 90 fathoms. Upon it the present reef rests, and it extends westwards nearly 15 miles from the present coast, while to the east it stretches about 6 miles. We have thus proofs of great and intermittent oscillations of the level of the island." I may be permitted to point out, that it is *assumed* that this submerged reef is of coral formation. Its contour corresponds, so far as it is known, neither with existent fringing, nor barrier reefs. Its origin is probably rather to be traced to the former erosive action of the sea on a volcanic coast.

islands, are both of coral formation with no evidence of change of level. Platte island to the south lies on a bank, 17 miles long, separated by a channel, 25 miles wide; it has a low coral island, apparently on a reef awash, having a lagoon. Coetivy, 60 miles S.E., is a low coral island with sand hills, 5¾ miles long, by 1½ broad, on a bank of about twice the size; near it and in the dividing channel towards the Seychelles are several other banks not properly surveyed. Continuing the main line to the S.W., separated from the Seychelles by a 22 mile channel with 1150 *f.* of water, is the Amirante bank, running 89 miles N.N.E. and S.S.W., varying in breadth from 5 miles at the north end to 23 miles at the south. There are nine principal reefs and islands, which tend to lie near the edge of the bank; none of them attain a height of even 20 feet. St Joseph and Desroches are atolls with soundings of 2 and 17 *f.* respectively in their lagoons, the rest being mostly round reefs, drying all over at low tide, with mere sand cay islands. Separated from the last by a channel, 46 miles across, with one sounding of 952 *f.* nearly in the middle, are two reefs, Alphonse and Francois; the former is an atoll with basin 10 *f.* deep, and the latter a reef, 8½ miles long by 5 broad, with two islands, drying in patches, a little hollowed in the centre, but not enough to form a definite lagoon.

3. Chagos Section.

The Chagos Archipelago differs from either of the preceding sections, in that all its islands and reefs are of coral formation alone, hence bearing a much closer comparison to the Maldives. It lies almost in the same latitude as the south of the Seychelle group, but 600 miles further eastwards than that line of reefs; no soundings exist between. The group covers an area of about 170 miles north and south by 110 miles east and west, and is formed by five atolls, three atoll banks and three other banks of no very determinate shape; there are no bottom soundings between the different atolls and banks, a line of more than 150 *f.* being seldom used in Moresby's time (1835), the usual being about half this.

To the S.S.W. lie three banks:—Centurion, 5 miles long by 2 broad, rim 7 to 10 *f.* deep, a single sounding of 14 *f.* in the central basin; Ganges, 4 miles long by 3 broad, rim 8 to 12 *f.* deep, a single sounding of 12 *f.* in the centre; and Pitt,

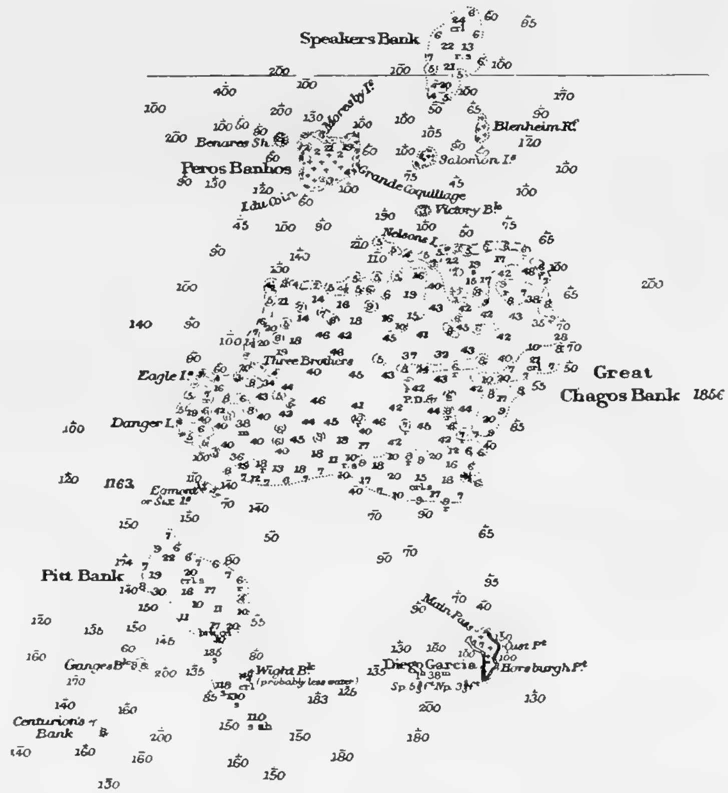

Fig. 4. Chagos Archipelago. (*From the Admiralty Chart.*)

26 miles long by 16 broad, rim varying with 6 to 12 *f.* of water, very imperfect to the south, inside a shallow basin at about 20 *f.* with a few soundings up to 24 *f.* Egmont atoll lies between Great Chagos reef and Pitt bank; it is perfect in shape, $5\frac{1}{2}$ miles long by 2 broad, with only one passage to the north, six islands to the south, lagoon 10 *f.* deep. S. by E. from Great Chagos lies Diego Garcia, another atoll, completely surrounded by land to the south, but with three passages ($3\frac{1}{2}$, $3\frac{1}{2}$, and 6 *f.* of water) to the north; it is 13 miles long by 6 miles in greatest breadth, lagoon maximum depth 19 *f.*, much shoaler to the south. This atoll was visited in 1885 by Mr G. C. Bourne, who subsequently gave an account of it. He came to the conclusion that the whole atoll had been raised a few feet[1].

The Great Chagos bank is of somewhat irregular shape, about 82 miles east and west by 70 miles along a line at right angles. It has one island to the north, described as rocky, and seven to the west. The reef can nowhere be described as awash, save immediately in the neighbourhood of some of the islands, but the line all round the bank is markedly shallow, forming a reef. The general depth of the latter west and north is about 6 *f.*, least 4 *f.*, while east and south it is about 10 *f.*, least 6 *f.* The lagoon basin has an average depth of about 44 *f.*, greatest depth in centre 48 *f.*; it is connected to the sea by twenty-three passages. The shallow, encircling reefs are between the passages, great broad flats, sloping in from their outer edges to a depth of 20 *f.*; some are obviously small atolls, having shallower water at the edges and deeper in the centre. Against the lagoon basin the 20, 30 and 40 *f.* lines are practically conterminous, the reefs down to 40 *f.* being as precipitous in their slope on this side as towards the deep sea. About sixteen shoals arise in the lagoon from the bottom in 40 *f.* to within 6 to 10 *f.* of the surface, a striking uniformity in depth with the rim. Although the atoll from the soundings would appear to have been well surveyed it is remarkable that there are in the lagoon no shoals between 10 and 40 *f.* in depth. Of the passages five have about 40 *f.* of water right through, while six others appear to have over 30 *f.*

North of Great Chagos the Victory bank, 4 miles long by $2\frac{1}{2}$ broad, has a perfect rim at 3 *f.* with 18 *f.* of water in the centre. Peros Banhos is a perfect atoll with 27 islands, in shape nearly a square 13 miles across; the greater part of its reef is awash save to the S.E., where it is submerged by about 4 *f.* of water, but even here two islets rise above the surface. The lagoon has thirteen passages to the exterior and is much studded with shoals; its general depth is less than 30 *f.*, but one sounding of 41 *f.* is recorded. The whole atoll bears a very close comparison to some of the more southern ones in the Maldives.

[1] *P. R. S.*, vol. 43, pp. 440—461, 1888. Mr Bourne has informed me that masses of the conglomerate (or reef-rock) exist everywhere on the outer reef in pinnacles and buttresses, extending out from the beach between tide-marks. The stratification of these is stated to be horizontal. No coral-rock is built up thus above the low tide limit, so that these absolutely prove a change of level. Mr Bourne in his account bases his views rather on the horizontal stratification of "shingle rock," an agglomeration of broken corals, mollusc and echinoderm shells, etc.; this rock was probably originally a formation on the lagoon side of a reef awash, and it would be interesting to know more of its distribution. The observations on *Ocypode* I cannot admit as referring to a crab of this genus at all; as Mr Borradaile points out in his paper in this publication the crabs of this genus do not construct burrows lined with weed, and one species lives above tidal limits; the holes of shore forms cave in, and are made afresh after every rise of tide, not necessarily too in the same place. Mr Bourne's deductions on lagoon formation in general by solution do not seem to me to carry much weight. They are based on experience of one atoll alone and that of abnormal form, in that it is of considerable size but completely surrounded with land except to the north; the circulation of water in the south half of the lagoon, which is especially referred to, cannot be anything but inconsiderable as compared even to any atoll with reef only awash in several positions.

Salomon atoll to the east of the last is oval, 5 miles long by 3 broad, with eleven islands on the rim, which is awash everywhere save for a single passage to the north, which itself has a shoal of 1 *f.* in the centre; the lagoon averages 12 *f.* deep, greatest sounding 17 *f.* Blenheim reef to the E.N.E. of the last, 6 miles long by 2 broad, would closely resemble Diego Garcia, if the latter instead of land had only a reef, swept by the tides; its opening, however, lies to the south-west, and its lagoon has only 10 *f.* of water. Finally, Speaker's Bank to the north of the last two is an irregular oval reef, 24 miles long by 13 broad; depths of 5 to 7 *f.* are recorded right round its circumferential reef with 24 *f.* in the central basin.

4. Maldive Section.

As my remarks on the Maldives are mainly based on my own observations and soundings I shall defer them, together with those I may have to offer on the Laccadives, to a separate chapter. The most southern atoll of the Maldive group, Addu, lies due north of the Chagos Archipelago at a distance of 240 miles, and the latter group might well be considered to be a continuation of the Laccadive-Maldive line. There is, however, one sounding of 2500 *f.* so close to the centre of the channel between, that it is practically certain that there is no bank at about 1000 *f.*, connecting the Chagos, as assumed by Mr Bourne. Since to the north the Laccadive banks very closely approach the Indian coast, it is important to note that the 1000 *f.* line has been traced everywhere between.

The Indian Peninsula has practically no reefs of any sort; its southern part towards Ceylon partakes of the same formation as the north portion of that island. The latter has locally fringing reefs, mostly in bays along the south and north coasts; above these to the south a loose rock, composed mainly of fragments of coral, often forms broad flats, 3 to 4 feet above high tide, now being rapidly washed away wherever they impinge on the beach[1]. Near Dambula in the centre of the island I saw limestone hills, at least 700 feet high, which from their general contour I should judge to have been of reef-formation; the rock is now completely crystallised, all trace of organic structure being lost. The Jaffna Peninsula, the outlying islands and the northern part of Ceylon are all formed of raised coralline rock, which still retains most of its organic structure; the elevation, as I saw it, did not appear to me to have been more than 40 feet, if as much. A former land connection with India was clearly indicated, of which a reef, known as Adam's Bridge, between the islands of Manar and Ramesvaram, is the remains[2].

[1] These can be seen in numerous places between Matale and Weligama.

[2] See "Ramesvaram Island," by Edgar Thurston, Madras Government Museum, Bulletin 3, 1895; also *Report Brit. Ass.*, p. 400, 1900.

CHAPTER II.

Meteorological Conditions.

The Challenger Reports, edited by Sir John Murray, have shown how important it is to consider the meteorological conditions of any region whose geography it is desired to study. In the "Introduction" to this work I have briefly indicated the great variability found in the topography of the different atolls of the Maldives. As the latter group together with the Laccadives extends from lat. 1° S. to lat. 14° N., it will be readily understood that the meteorological conditions must vary very widely over this great region.

In respect to coral reefs, winds and storms are usually supposed to be the chief factors in the formation of land. Dana[1] has pointed out that their distribution follows the isocryme of 68° F. both N. and S. of the equator. Semper[2] drew attention to the effects of currents in shaping reefs, a point which has subsequently been further emphasized by several naturalists. The eroding action of rain has been referred to by many authors, chief among whom is Prof. Agassiz, who has also laid great stress on the action of the sea and waves on all coasts in general, but on coral-shores in particular[3]. The subject then being of wide interest in respect to the formation of coral reefs and islands, I shall consider the meteorological conditions of the region without in this place examining minutely their effects. The following account is derived largely from personal observations and native information, with which I endeavoured to check the account in the "West Coast of Hindustan Pilot" (1893); I have also consulted the captains of various steamers, which regularly ply in these waters.

The **winds**, experienced in the Laccadives and Maldives, are those of the two monsoons, influenced to the north by the proximity of the Indian coast and affected in the south by the equatorial winds. The north-east monsoon becomes set in the Laccadives about the end of November and continues until the end of March; during this period a more or less northerly wind prevails together with long calms, but little or no heavy weather. The monsoon gradually travels down the Maldive group, becoming regular from N.N.E to E.N.E. in Male atoll early in January. It is ushered in by a fortnight of strong winds from north to east with heavy rain squalls. The monsoon becomes definitely set as far south as Suvadiva atoll before the end of January. It is felt too even in Addu (lat. 0° 40′ S.)

[1] *Corals and Coral Islands*, 3rd ed. pp. 108 and 335.

[2] "Animal Life," *Internat. Sci. Series*, chaps. VII. and VIII.

[3] *Vide* "The Islands and Coral Reefs of Fiji" (*Bull. Mus. Comp. Zool.* vol. XXXIII. pp. 1—167, 1899) and numerous previous publications.

from January to March, but the wind is here very irregular, veering at any time six points to either side of north-east. Heavy rain squalls are frequent during the whole of the monsoon in the southern atolls, but the wind, although often blowing very fresh, has little weight. Fine weather, little rain and calms may be expected at the same time to the north of Male atoll.

The south-west monsoon is not felt in Addu atoll, where the "Pilot" states that from May to December the winds are from west to south and S.S.E. with much rain and squalls. It is well set in the Maldives during the months of June, July and August; fresh gales with heavy rain squalls occur frequently from any direction within four points of south-west. The period in the Laccadives is rather longer, the south-west wind usually becoming definitely set towards the end of May and continuing regularly until September. As already mentioned in the "Introduction" it did not in 1899 commence at Minikoi until the second week in August, up to which time the prevailing winds were from west to W.N.W.

The months, which intervene between the monsoons, form in the Maldives a period during which winds from any direction may be felt. Fresh gales of short duration tend to come up, the wind commonly veering from the north or south, right round to east, or west. In April we experienced in the channels between Addu and Suvadiva, and between the latter and Haddumati, heavy gales from the west. During these intervening periods cyclonic storms or hurricanes are especially liable to occur in the Arabian Sea. I have obtained no record of winds of this force having been ever experienced further south than Male atoll. They occasionally sweep over Tiladummati and Ihavandifulu atolls, the last occasion remembered by the natives being in February about 24 years ago, when very great destruction is stated to have been wrought among the larger native vessels, many of which were at the time lying at anchor in the lagoons. As negative evidence of the absence of such strong winds I may refer to the fact that throughout the Maldives I have found no true negro-heads—actual parts of the reef—which have been thrown up by the breakers on to the reef-flat. Hurricanes visit Minikoi at intervals of about 12 years, but, their centres usually lying considerably to the north, they may practically be neglected as factors in shaping the original reef and land. The more northern parts of the Laccadives are, however, much affected. The effects of hurricanes in this locality are admirably described in the following account of one, which visited Kalpeni in 1847:—"The sea washed over the island, and the storm-wave carried away the very soil of the narrower parts. Of 1600 inhabitants 250 were washed away and drowned in that night, 100 to 150 died of famine and disease, about 450 remain on the island and the rest have dispersed themselves. Of a lakh (100,000) of (coconut) trees about 700 sickly ones are standing[1]." At Androt of a population of over 3000 only 900 were left after the same hurricane.

The **currents** are of course largely dependent on the winds and tide. The direction from November to March in the Maldives to the north of lat. 2° N. varied from north-west to south-west; the drift in the centre of the group averaged about 18 miles per diem during the same time. Although we experienced strong winds from the west during April in the "Equatorial" and the "One-and-a-half-Degree" channels, there was at the same time practically no current. The native skippers, however, will not start across either channel unless the wind is fairly strong and at least nine points off the direct line from

[1] "Report on the Laccadive Islands," dated 19 May, 1848, by W. Robinson, Esq., Madras, p. 76, 1874.

atoll to atoll; they then set a course about 12 miles to east or west of the atoll they subsequently hope to reach. With the south-west monsoon comes a change of current, which is experienced at Male about the middle of May, the set then being almost due east; the rate of the current varies with the wind of the previous day. During April and October little or no current is felt.

The currents in the northern part of the Laccadives are very irregular owing to the proximity of the Indian coast. This is especially the case in the south-west monsoon, a definite south-eastern set being often experienced almost reaching to Minikoi. However, the following data are given in the Admiralty Charts for the neighbourhood of the latter atoll:—

January	0—45 miles per 24 hours, N.W.
February......	Various, any direction.
March.........	Various, any direction, often due N. or S.
April	10—25 miles per 24 hours, S. varying 4 points to E. or W.
May...........	Various, always southerly.
June	0—45 miles per 24 hours, S.E.
July...........	5—30 „ „ „ S.E.
August	0—45 „ „ „ E.S.E.
September ...	0—25 „ „ „ S.E.
October	10—25 „ „ „ E.
November ...	Various, 0—35 miles per 24 hours, W.N.W.
December ...	„ 10—25 „ „ N.N.W.

The maximum currents above are undoubtedly current + wind. Many captains of the great passenger liners, running to the east, do not make any allowance, based on the charts, but consider only the winds of the previous days in setting their courses. The "West Coast of Hindustan Pilot" makes the following statement (p. 363) in respect to the "Eight-Degrees Channel" between Minikoi and the Maldives:—"It will be prudent to keep nearer to Minikoi than to the Maldives, as the current sets to southward between the end of September and the close of the year. In the strength of the south-west monsoon, mid-channel is the best track, or rather inclining to the Maldives." It is scarcely necessary for me to point out, that this statement is seriously in conflict with the data of the charts. It serves excellently to show that there are no definite currents in the Laccadives, all sides of the atolls and reefs being probably washed equally at different seasons of the year.

The currents through the atolls in the Maldives are of great strength, as also in the channels between the atolls. A current of three to four knots per hour is by no means uncommon in the passages on the east side of the atolls in the north-east monsoon, and this was even exceeded in the channels through the leeward reefs. In the lagoon of Miladumadulu we experienced in the middle of December a current of 2½ to 3 miles per hour, against which we could make no headway. With strong easterly breezes—hence at least eight points off our track in both atolls—we made a course along the east sides of N. Mahlos and Miladumadulu, which, if accurately plotted, would show a series of loops, losing opposite the passages and gaining our easting again to leeward of the islands and reefs. To test the rate of the currents, I adapted Messrs Negretti and Zambra's river-meter by fitting it with a larger vane. With currents over 2 knots per hour it appeared to give fairly reliable results. I took a series of observations on the currents near Male island during the third week of February, 1900, wind 2 to 4 Admiralty scale, regular never varying more than a point from north-east, depth 2 fathoms.

Position	Depth of bottom in fathoms	Number of Observations	Direction of Current	Current in miles per hour: Greatest	Least
Passage Male to Hulule	24	9	N. by W.	5·1	1·5[1]
" " Wilingili	10	9	S. by W.	5·3	2·3
" " Funadu	26	9	W.N.W.	7·3	3·1
Two miles due N. of Male	28	6	S.W.—W.	3·4	·8[1]
Channel N. to S. Male Atoll	245	4	W.	4·1	2·7

I also sailed twice up to the passage between Hulule faro and Furenafuri, finding currents of 3·7 and 2·1 knots into the lagoon. Of course all these currents were largely dependent upon the tide, but it is a most noticeable feature that the direction remained constant in spite of the latter, which hence only affected the rate.

The depth, to which the currents of the Indian Ocean extend, has never, so far as I am aware, been investigated. Yet in considering any theory of the formation of coral reefs it is a most important factor, requiring consideration. I may perhaps refer to a short paper by Admiral Sir W. Wharton on the "Foundations of Coral Atolls[2]," where he discusses in this connection the depth to which there may be motion sufficiently violent to move material.

I applied two methods of investigation to ascertain the directions of the currents, *i.e.* by examining the specific gravity and temperature of the water at various depths, and by means of a direction-indicator. Admiral Marakoff is the chief exponent of the first method, which he used to examine the currents of the Bosphorus[3]; the direction of the current is found purely by deduction[4]. I employed it in the channels round Male, mentioned above, but the differences were too small and variable for it alone to be a satisfactory criterion. It was useful merely as a check on my second method. In the latter I attempted to record the directions of the currents at any depth by means of a compass (made for me by Messrs Negretti and Zambra). The latter was quite open to the water at the side of its box, and could at any depth be jammed by a messenger. The whole was placed in the middle of a V-shaped vane, which swung freely on a central bearing, itself clamped on the sounding line. Immediately below the direction-indicator I placed my current-meter, which I fitted to swing freely, and at the end of the rope I attached a 20 lb. sounding lead. The compass gave uniform results, but the readings of the current-meter varied so greatly that I omit any further reference to them.

I carried out observations in the first place to ascertain, whether the currents were the same at all depths in the deeper passages of atolls, as from theoretical considerations I expected to find under-currents. I found as a result that there was no difference in

[1] Approximate only. I obtained my scale on the meter by means of timed floats, using for the purpose corked bottles, weighted with sand, with tiny flags, so that they should not be affected by the wind. It must be checked frequently as the amount of friction may alter greatly. Previously to this I had used the meter constantly in Minikoi lagoon.

[2] *Nature*, vol. LV. pp. 390—3, 1897.

[3] I had the pleasure of discussing this subject with Adm. Sir W. Wharton, Sir John Murray and Mr J. Y. Buchanan, before I left England. I am indebted to these gentlemen for much practical advice as to the work of the expedition. I am only sorry that I could not carry out their suggestions in their entirety.

[4] *Vide* "Le Vitiaz et l'Océan Pacifique."

any of the positions previously recorded round Male island, either at half-flood, or half-ebb from the surface to within 3 fathoms of the bottom, an observation I confirmed by the hydrometer. In the channel between N. and S. Male atolls the current was in the same direction down to 150 fathoms.

My second series of observations were to ascertain the depth to which the main oceanic currents extended and their behaviour on meeting with an obstacle. I made two examinations, the first at Minikoi and the second at Male[1]. A preliminary series of observations off the east side of Minikoi showed that the oceanic current was setting S.E. by E., and could be recorded usually down to a depth of at least 60 fathoms. Starting from Weli Gandola passage, I then ran a line of soundings out from the reef, on which I had affixed a pole. At the same time I took a series of observations on the direction of the current at the surface and at intervals of about 20 fathoms down to a depth of 120 fathoms. Fig. 5 shows my results graphically; it records my stations and the vertical

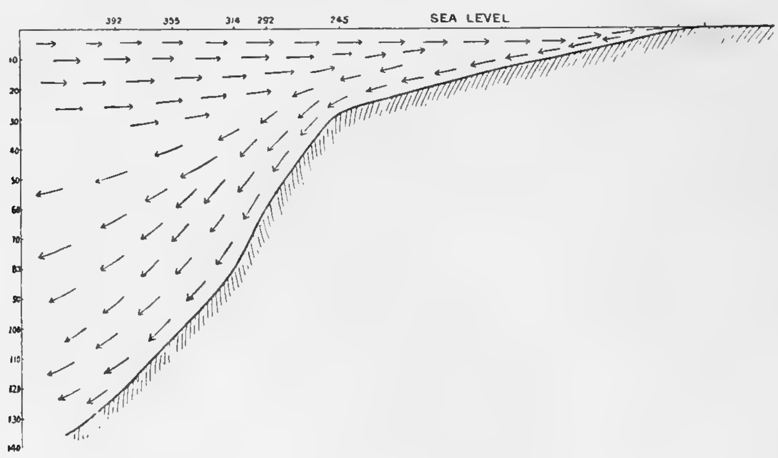

Fig. 5. Diagram to illustrate the behaviour of a current on striking a reef. The section is that of the outer slope off Weli-Gandola channel, Minikoi. Horizontal and vertical scales the same; the former is marked in yards, the latter in fathoms.

effects of the obstacle on the current. Horizontal plans would show the divarication of the upper current round the atoll, and the gradual merging into this of the lower current. I made two additional soundings between the reef and the first recorded in Fig. 5, but the rollers were so heavy that I did not attempt to use the indicator. A similar line, run off the reef of Hulule faro, the north point of Hulule bearing due west, gave similar results down to 80 fathoms, 500 yards from the edge of the reef. The records though were complicated by the proximity of the deep channel between N. and S. Male atolls.

[1] An apology is perhaps needed for offering these observations at all; they are not intended to be final, but may perhaps suggest to others, more happily situated than I am, the need of investigating the matter fully. My work, indeed, at Minikoi was meant to be experimental to test my apparatus. I proposed subsequently to investigate the point fully in the Maldives, but I was unable on account of illness to make more than a preliminary series of observations off Hulule.

I have in Fig. 5 represented the reef in its low-tide condition, when it is practically awash. Undoubtedly the surface current to some extent would be accentuated, and pass over the reef at high tide. It would be checked, however, by its friction on the reef, so that it would not probably gain greatly in strength, and hence the additional amount of water passing over any reef would be relatively small. In Minikoi during four nights, when I was anchored close to the reef, I never recorded a greater current than 2·4 knots per hour, although taking observations every hour. The backwash outside the reef, which appeared to be strongest close to the bottom, is of interest, as it might well carry out any coral or nullipore detritus from the reef and be the chief agent in extending its foundations further and further seaward. The depth, 20 to 60 fathoms, where the steep slope commences off most oceanic reefs, may well be the critical point for the oceanic currents off those reefs. Speculation is, however, premature until these observations have been confirmed, and more exact results have been obtained.

Tides are of course at all times largely influenced by the prevailing winds and currents; they are hence very irregular in the Maldives and Laccadives. At Minikoi I found a rise of about 5 feet 9 inches at springs and 3 feet 6 inches at neaps; at Addu the rise is only about 4½ feet at springs. In the south-west monsoon the flood commences extremely slowly, rises rapidly, and as slowly attains its maximum, at which it may hang for some time; the ebb, when it has once commenced, is more regular. In the north-east monsoon both flood and ebb pursue an even course. The flood always appears to set to the east and the ebb to the west. The latter at Minikoi in the south-west monsoon is almost invariably the longer in the proportion of about seven to five. There is, however, very considerable variation in accordance with the strength of the winds, and I have even observed the above proportion almost reversed; further it alters with the time of high water. The monsoon winds commonly moderate after the heat of the day during the night. Hence in the south-west monsoon the obstruction they form to the fall of the tide is not so great as in the daytime, with the result that the lowest tides occur in the early morning (high water, full and change, in the lagoon at Minikoi being about 10 h. 30 m.). In the north-east monsoon the winds assist the falling day-tide, and the evening tides are hence the lowest. This, however, is in no sense a complete explanation, as during dead-calm weather in the Maldives with no appreciable oceanic current I found that the same phenomena are nearly as strongly marked. The difference between the rise and fall of the morning and evening tides at springs is often in heavy weather as much as 2 to 2½ feet. On one occasion towards the north of the atoll of Minikoi the morning tide rose 7 feet 5 inches, while the evening tide did not show more than 4 feet 7 inches; it was blowing at the time a gale from the south-west.

The **rainfall** varies, increasing from the north to the south of the groups. At Minikoi its total is about 100 inches per annum, the greater part of which falls during the first month of the south-west monsoon. During the rest of the year, especially in December, heavy showers of short duration are not infrequent. Vegetation increases in luxuriance from north to south in the Maldives. At Addu there is no dry season, and the fall probably reaches a total of about 150 inches.

The **temperature** in the shade varies generally between 70° and 90° F., both day and night. For ten days at the end of February, 1900, it did not fall below 85° either by night or day; such temperature is, however, very exceptional. The wet and dry bulbs are never far apart, and they commonly approach within 1° of one another during the south-west monsoon. The temperature of the sea varies greatly from year to year. The Admiralty Charts for the region of Minikoi give February 82°, May 86°, August 81° and November 84°. My observations for the four months I spent in this atoll were, expressed in round numbers, June 87°, July 84°, August 83° and September 84°. The maximum and minimum daily temperatures seldom varied more than 4° at depths of 4 to 8 feet; the observations, recorded above, are the mean of these. The temperature outside the reef and within the lagoon never varied more than 2° F.

[Note. Mr Forster Cooper on reading over the above chapter has offered me the following observations in respect to his cruise in March and April, 1900:—"In my journey through the atolls of South Male, Felidu, Mulaku, Kolumadulu and Haddumati I experienced only north-westerly winds with the exception of a due easterly gale, lasting three days, while I was in the south of Felidu atoll (March 12—14).

"Little current was noticeable during the cruise within the encircling reefs of the atolls, but in the dividing channels it varied usually between 2½ and 3 knots per hour, setting westerly. In the channel between Kolumadulu and Haddumati of Veimandu island the current reached 6½ knots per hour. It appears in the north-east monsoon to be always very strong in this channel; a native boat was a few years ago carried completely away, eventually reaching the African coast near Zanzibar."

The currents of either monsoon tend to run very strongly up and down the Maldive chain. As above shown, they reach to a considerable depth, and naturally tend to be much impeded by the banks. A strong current would be expected in the Veimandu channel, the N.E. horn of Haddumati directing the down current in this direction.

Capt. Pigott, R.N.R., S.S. "Vasna," B.I.S.N. Co., informs me that on the night of June 25th, 1899, he experienced a set S. 51° E. of 34½ miles in 12½ hours off the east of Miladumadulu and Tiladumati atolls. The weather was fine and settled, with a light westerly breeze, the sea calm with a long low swell from the south-east. The course was N.b.W., Mafaro at 4·20 p.m. bearing 12 miles due west. In the middle of the "Eight and a Half Degrees Channel" the current was setting about ¾ knot per hour due E. This observation shows very admirably how the current washes around the banks.]

CHAPTER III.

The Atoll of Minikoi.

Section 1. General.

Minikoi atoll (Fig. 1) is of a more or less oval shape, somewhat pointed to the north-east, where there is a narrow channel into the lagoon with 2 to 2½ fathoms of water. This passage is further broken by a shoal in the centre, showing clearly the continuation of the reef. The latter is for the rest perfect, and can in moderate weather be traversed everywhere on foot at low spring-tides. Three boat-passages exist to the north-north-west, available at half tide, but the importance of these must not be magnified, as they are regularly cleared by the inhabitants. The greatest length of the atoll is 5 miles and breadth 2·9 miles; the circumference is nearly 13 miles and the lagoon occupies an area of about 6 square miles.

The position of the atoll has already been seen. It suffices here merely to draw attention to its isolation, arising as it does probably within two miles from a depth of 1100 fathoms on every side except to the south-south-west. In the latter position a ridge at a depth of about 950 fathoms appears from the charts to connect Minikoi atoll to the Maldive group. Unfortunately no proper sections were run when the atoll was re-surveyed in 1891, and I had not the means to make a proper series of soundings. Indeed the weather was too bad during the greater part of my stay for boats to get out except to the north and east. In these situations the slope commences with a sudden drop from the reef to 2 or 3 fathoms, the bottom consisting of rounded buttresses and masses of coral-rock. Local variations due to shallow platforms occur, but the fall is generally fairly even for 100 to 350 yards, where a steep commences at a depth of 30 to 50 fathoms. To the east-north-east of Kodi point this shelf is more extensive, the greater part having a depth of 35 fathoms, forming a possible anchorage in the south-west monsoon. The further slope here is more gradual, and the steep less defined, indicating the trend of the submarine elevation, on which the atoll is founded. The steep is probably similar to that of Funafuti and other atolls, a few yards giving no bottom at 120 fathoms (Fig. 5). I did not sound deeper, but the chart indicates that a more gradual slope soon commences down to the encircling depth. The first slope to about 40 fathoms is notably broader to the north and west than to the south and east; in the latter position no two sections are the same. In Fig. 5 a section off Weli Gandola passage is represented. The bottom would appear to be extremely rough, great masses of rock, off which the lead drops sometimes for an additional 3 to 5 fathoms.

The chief island, called Minikoi throughout this paper, extends from the north point right down the east and south sides of the atoll for a distance of six miles. It is only about 50 yards broad to the north, but gradually increases further south, attaining at its centre a breadth of 750 yards. In the latter position a prominent point, Mou-Rambu,

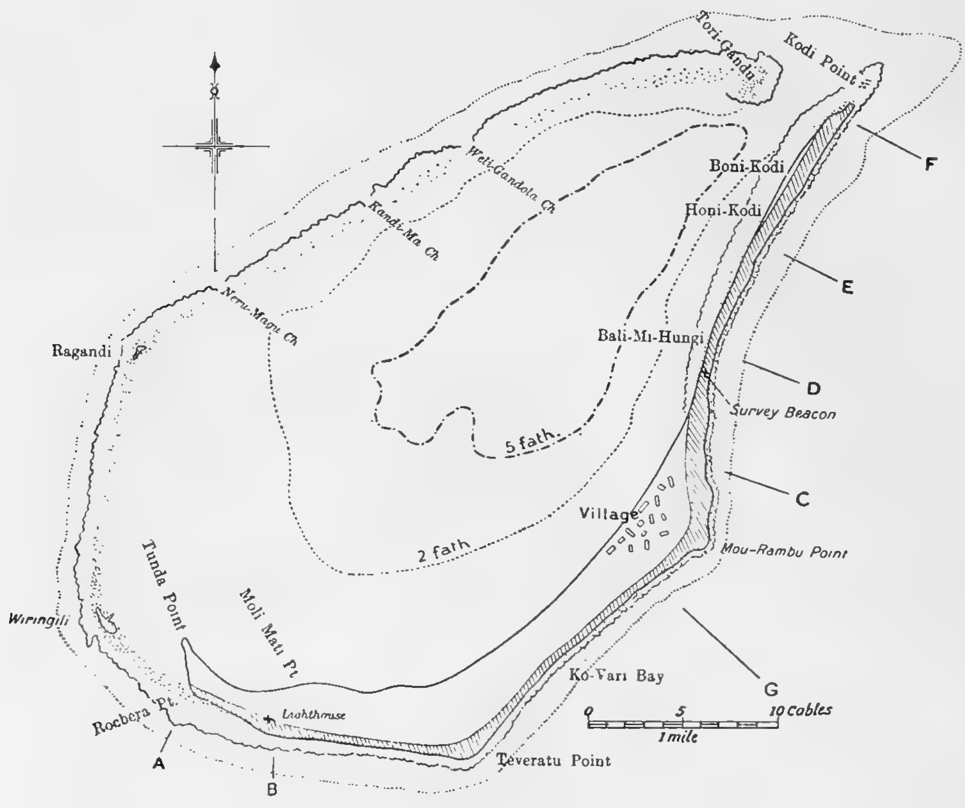

FIG. 6. Minikoi Atoll (*slightly altered from the Admiralty Chart*). The rocky area of the land is shaded, the boulder zone dotted, and the 100 fathom line is shown. *A—G*, positions of the sections in Fig. 7.

extends to the south-east, and on the opposite lagoon-shore the only village of the atoll is situated. Proceeding southwards Minikoi varies in breadth between 300 and 600 yards, ending with a small horn, extending north for 200 yards into the lagoon. This horn is the only bank in the atoll, which may be supposed to have been formed by sand and detritus swept over the reef.

On the seaward face from the north end to Mou-Rambu point the reef is very narrow, and indeed can scarcely be said to exist. It then gradually broadens to the west point of Minikoi island, where it passes into the reef-flat of the west and north sides of the atoll. The island itself merges into a well-marked boulder zone on the same reef, on which the small island of Wiringili arises at a distance of half a mile. The reef retains a characteristic broad reef-flat and rough zone for one and a half miles to a small rocky patch, Ragandi island, extending from thence in an east-north-easterly direction to the deep lagoon passage. In the latter part the reef is much narrower and considerably broken up, the boulder zone scarcely existing in some places.

SECTION 2. LAND.

The surface of Minikoi island (Fig. 6) is sharply divided into two areas, an outer, covered on the surface with large, loose, coral or rock masses, and an inner, with sand. The line of junction is quite distinct, in some places a slight dip, in others an abrupt step down to the sandy area. The rocky area fringes the island on its seaward face, varying up to 150 yards in breadth near the village. Where the island is less than 100 yards in breadth, it alone is traversed in a section. The whole of the northern two miles thus belongs to this area with the exception of a narrow sandy patch against the lagoon at Boni-Kodi. South of Mou-Rambu point the rocky area narrows somewhat, especially in Ko-Vari Bay and between Rocbera and Teveratu points, where it is in places only 70 to 80 yards broad, being indeed generally less than 100 yards.

In the rocky area the surface is covered with masses of coral or limestone, some round, others flat slabs, weighing up to 1 cwt. or even more. To the north of Mou-Rambu they are much larger than to the south, where blown sand also has to some extent intermingled. All the surface masses are pitted, and eaten into sharp points by the rain, which rapidly drains through them. No soil has formed, and layer after layer of blocks can be removed, until a firm bed conglomerate within tidal limits is at last reached. The whole is covered with timber, or woody herbage, the roots of which extend down even into the conglomerate. On the surface the masses have much the same appearance, allowing for rain, as they have on a tidal beach. If the outer blocks however be removed, *Madrepora*, *Pocillopora*, and other branching corals are found with their stems still unbroken, while massive species have their calicles and septa even yet entire, *absolutely negativing the possibility of a beach-origin for the rocky area.*

Speaking quite generally, the island attains its maximum height toward the seaward side, and slopes gradually to the lagoon. To ascertain the height accurately, I ran six sections across the island, leaving one broad gap between the lighthouse and the village, where the growth of coconut and other timber was too dense to allow of rides being cut. Even there, however, I obtained a few partial sections in from the seaward beach. The inner part of the reef-flat, where the latter exists, lies at the mean low-tide level, and all heights are taken as above this, since it must be regarded as the upward limit, to which the various organisms can build their reef. The sections give the following measurements (Figs. 6 and 7).

Section	Breadth of Island in yards	Greatest Height	Height at Centre of Section	Greatest Height near Lagoon
A	370	9 ft. 0 in.	3 ft. 11 in.	5 ft. 0 in.
B	495	12 „ 3 „	5 „ 11 „	5 „ 8 „
C	375	12 „ 8 „	3 „ 8 „	10 „ 3 „
D	103	14 „ 9 „	13 „ 0 „ [1]	10 „ 0 „
E	80	13 „ 6 „	9 „ 6 „ [1]	7 „ 4 „
F	107	14 „ 8 „	13 „ 1 „ [1]	12 „ 0 „

[1] Approximate only.

In most of the sections the greatest height is close to the top of the seaward beach, but in *F* it lies 66 feet back from this position. A seventh section *G* (Fig. 7), opposite the village in Ko-Vari bay, gave an elevation of 19 ft. 3 in., close to the sea, and heights up to 20 feet occur on both sides of Mou-Rambu point, decreasing northwards to a general height of 14 feet and to the south of 12½ feet. The abnormal height of the beach continues to Teveratu point right along Ko-Vari bay. At my first examination I did not deem this exceptional, since on this part, especially supposing the atoll at one time a reef awash,

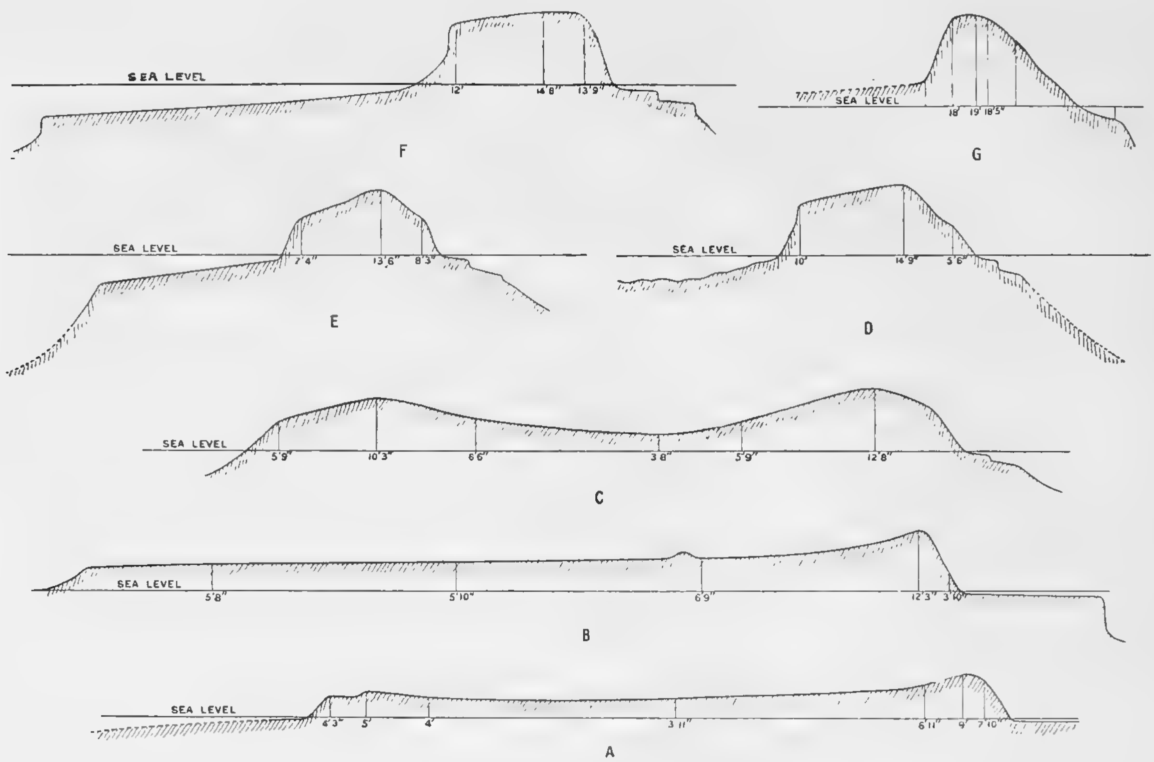

Fig. 7. Sections across Minikoi (see Fig. 6). In every case the seaward face is represented to the right. *Vertical scale 8 times the horizontal.*

masses of rock and coral would, I considered, naturally tend to be piled up in each monsoon. Inside this ridge the surface of the land had been, I saw, much lowered by previous generations of the natives for planting purposes, and also to form pits for macerating the coconut husks for coir[1].

My attention being especially drawn to this, I re-examined the whole carefully, and dug a number of pits, coming to the conclusion that the ridge may have been broadened by the above means, but that its height is due to absolutely natural causes. *An elevation then, allowing for rainwater denudation, of at least 24 feet demands explanation.*

[1] This hollowing out of garden land—*totam*, as it is called—is common throughout the whole of the Laccadives for *ragghee* (grain) growing, and also for bananas and yams. I did not meet with it in any part of the Maldives. Coir is rope made from the fibre of the coconut husk.

Fig. 1. Sea-beach at low tide near Kodi point, Minikoi, with S.S. Thrunscoe ashore

Fig. 2. Lagoon-beach at low tide near Kodi point, Minikoi

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A glance at the sections shows that the outer beach[1] increases in steepness from south to north of the island, from *A* to *F*. A certain amount of sand occurs at the base of the beach to the south, and the whole slope is quite regular.

North of Mou-Rambu there is no sand, and the beach is formed entirely of large blocks of stone (Pl. I. fig. 1). It cannot here be a formation simply piled up by the breakers, since its slope is gradual only at the base, ending above may-be precipitously, or even with a small overhanging cliff. Recently living coral masses are rare among the blocks; no pumice occurs; the greater part indeed is formed of the same weathered blocks, which strew the rocky area of the island, smoothed somewhat perchance by the waves and spray. The before-mentioned conglomerate crops out along the whole length of the seaward beach. Vegetation extends in many places right up to its summit; often the roots of the trees are exposed, and here and there the trees themselves have fallen. All these points are very marked along the eastern face, and further only the remains of a former wide path of flattened stones are now to be found. *Indeed there can be no doubt, but that the waves are slowly and surely encroaching on the land.* Between Mou-Rambu and Teveratu points the erosion is still visible, though the rate is less. On to Rocbera point the action is not so clear, but the masses of conglomerate at the base of the beach and the almost complete absence of reef masses, thrown up after the heavy gales of the south-west monsoon (which I saw), lead me to believe that the same action is still proceeding. From Rocbera towards Tunda point there can be no doubt as to the washing away masses of conglomerate of large size cropping up near the first point with a marked cliff on the beach above. It is, here, however, due mainly to the strong currents and continual rollers, which in the south-west monsoon at high-tide sweep across the reef and along the beach.

Round the north, or Kodi point, the beach has a definite cliff above of 4 to 7 feet, and indeed it is formed mainly of the masses which have slipped from this with a little sand below high-tide mark. The line of the island is shown by isolated masses of conglomerate, which extend northwards on the reef (Pl. II. Fig. 1). A break occurs first, the reef-flat extending across from the sea to the passage into the lagoon. Then follow the conglomerate masses, more or less in ridges, which gradually tail off to the point of the reef. Formerly a few coconut trees grew on these masses, but now all except one small peak are covered at spring tides.

Along the lagoon side of the island, from the north point to the Survey Beacon, the cliff continues. At the north it varies up to 10 feet in height above its detritus, which together with sand washed up by the waves adds about 3 feet more to the height of the land above the mean low-tide level (Pl. I. Fig. 2). Conglomerate crops out to a height of 2 to 3 feet in the face of the cliff, but the latter consists for the most part of coral masses, similar to those which cover the rocky area of the island. These blocks, following the usual mode of growth of most corals in shallow waters at any rate, tend to be flattened; they lie horizontally in the cliff, and have no trace of any dip in any determinate direction (Fig. 8). The rocky beach about a quarter of a mile from the north end is broken by coarse sand with a definite cliff above, the island itself

[1] I have throughout avoided the use of the term "hurricane beach," as I think that it is due to a misconception of the mode of origin of most islands of atolls.

broadening slightly. Southwards again the rock reasserts itself with smaller coral masses and a lower cliff (seldom more than 6 feet) with perhaps a tendency to form a greater talus. The basal conglomerate masses too are generally smaller and of lesser height. Coral slabs from the lagoon do not add at all to the beach, and even seaweeds and sand do not accumulate except in a small bay near Kodi point, protected by spurs of rock on either side. The shore especially at Boni-Kodi is strewn with fallen coconut and other timber. An old pilgrimage path, extending to the shrine of a *Said,* close to Kodi point, only exists now here and there. The end wall of a long house, which formerly stood at Bali-Mi-Hungi, the leper settlement, alone stands. *The sea is rapidly regaining its sway.*

FIG. 8. Cliff against the lagoon near Kodi point, showing conglomerate masses at base. (*From a photograph*).

Along the sand area the cliff retains its position almost down to the village, and the beach is strewn with coconut trees. Gradually however the slope broadens, and its summit opposite the village is almost washed by the succeeding waves of the high spring tides. At Moli-Mati point its breadth reaches a maximum, 50 yards across between tide-marks, the land above gradually attaining a height of 2 feet more. The high-tide limit is shown in the south-west monsoon by a line of green algae and sand washed up by the waves. Shells in the beach are rare, the whole being formed of extremely fine, almost impalpable white sand, the washings of many reefs. No decaying vegetable matter is seen to relieve the whiteness, save the single line left by the preceding high tide, all such being quickly seized by Ocypod crabs and drawn into their burrows.

Above the high-tide limit the height of the land is gradually increased by sand blown up the beach at low tide. A few yards back herbaceous plants commence to grow, soon giving place to the typical bushes. The natives quickly follow, and plant coconuts, which may be seen gradually rising in height further inland. *The land, indeed, is here rapidly gaining on the lagoon.* Still further on, towards the inner side of Tunda point, the cliff and fallen trees reappear, where, if anywhere, it would be most natural to expect a backwash and a piling up of sand to form fresh land.

Here in Minikoi we have a typically situated island, of an atoll with the reef continuing unbroken at its west end, round which the tide surges with considerable force. The current should sweep sand and mud off the reef, should build up a shoal into the lagoon, and should carry the point of the island along this. It is essential to see if this is what is really happening, since Dr Guppy[1] has brought forward a great mass of circumstantial evidence to show that it is in this way that secondary atollons are formed reclaiming ultimately large areas from the sea. The southern half of Minikoi too would seem to be absolutely similar to that of the Cocos-Keeling atoll described by Guppy. The rocky seaward rim of Minikoi extends at Rocbera point directly into the boulder zone of the reef, many long masses of rock more or less undermined marking its transition. The rocky area before this had from the lighthouse westward been gradually narrowing, and at the point the beach has a small cliff above with undermined or fallen bushes, which conclusively prove its washing away. Just behind Rocbera is a small marsh or *kuli*[2], covered with reed, its floor below the high-tide limit. Tunda point does not extend directly into the lagoon, but a little to the north-west. Round it the water is deeper close to the shore than further out towards Wiringili, and the greater part of the bottom here is covered with a branching species of *Porites*, right to the base of the beach, some being thrown up at the point. North of the *kuli* all is sand, the same indeed as forms the lagoon beach at Moli-Mati point. If some of the beach sand between Rocbera and Tunda points (not a mere surface scraping) be sifted to remove the smallest particles, it will be seen to be essentially the same. The sand carried over the reef in this position is largely foraminiferal, while that on the beach is formed of finely triturated coral particles. *It follows then that Tunda point must originally have been a lagoon formation. Behind this point on each side the shores show a marked loss. The land is gradually narrowing, the sea will sooner or later break across, the corals round the point will be silted up and killed; finally the whole will be washed away. Moli-Mati will probably, unless man interferes, form such another point in the not very distant future.*

Before discussing the formation of the conglomerate, it is important to consider the action—as deduced from observation—of the various agencies, to which a reef-rock, such as I consider this rock to be, may be subjected above and below the sea. A reef, freely exposed to the sea, may be compared in structure to a sponge, a series of hollow cavities joined together by canals. Corals grow leaving cavities and spaces, which become silted up to some extent with sand, composed of their own fragments and Foraminifera. These spaces are next bridged over partially by means of the corals themselves, but more particularly by *Lithothamnion* and *Polytrema*[3] (Foraminifera). When the cavities are once completely closed in from the sea by organic growths, there is practically no circulation of water in them, causing any change; boring and other organisms are killed, or depart for the more surface growths. As long as there is a circulation of water, a continual solution and redeposition of the lime[4] goes on. The sand, being loose, is ground down into fine particles, which naturally, presenting a relatively greater surface, would be first dissolved. The deposition would tend to occur within the pores of the corals, where the change of water is less, and there is a fixed support; the lime deposited follows the crystalline form of the coral. So long as the coral skeletons are protected by organic growths, none of these changes can go on, but boring

[1] "The Cocos-Keeling Islands," *Scot. Geo. Mag.* (1889).

[2] I propose to employ this term for all such marshes of atoll islands, borrowing the name from the Maldivan, whence is also derived the name *atolu* or atoll. The term appears to me preferable to *barachois*, which is used for such by G. C. Bourne in speaking of Diego Garcia (*P. R. S.*, vol. 43, p. 442, 1888).

[3] This form gradually increases in importance to a limited depth.

[4] For the sake of brevity I use this term throughout instead of calcium carbonate, or bicarbonate.

organisms, especially sponges, may work destruction. If the growth of the reef be vigorous, the whole action of the latter may be neglected, the corals not being seriously weakened. If on the contrary the conditions are unfavourable, whole masses of coral may collapse with the slightest superincumbent weight into small grains, giving, with the solution and redeposition of the lime, great bricks, as it were, of structureless rock. Other skeletons suffer with those of corals, but the solvent action is invariably more and the boring action less pronounced.

Above the sea- and tide-marks the first action on the same reef-rock is the solution by the rain of the softer parts, sand, nullipore, etc.[1] Some of the water escapes carrying its lime, but a considerable portion percolates into hollows and is dried up, its lime serving to consolidate the sand, etc. The water attacks the corals from the base, where they are weakened by boring organisms, breaking them off and causing a sinking of the whole surface, portion by portion. This continues until the crevices below are to a large extent filled up with sand and fragments, more or less consolidated together. There results finally a solid surface, strewn with coral blocks, which have less rapidly dissolved. A few chambers may remain in the rock; they either existed as such from the original reef, in which they were closed in, or were subsequently dissolved out owing to the rain having ready means of access and escape.

Between tide-marks the action is more complicated by the wetting and partial drying of the rocks by water, containing a large amount of calcium sulphate in solution, and further charged with lime from the neighbouring shore and reefs. First the surface, exposed to the tide, has its pores to some extent filled up by sand particles. It further hardens, and becomes thoroughly indurated with lime, precipitated from the water, which dries on the surface after each ebb. Yet withal solution is quite marked; the waves stream off by tortuous channels worn in the sand and nullipore formations between the harder corals, which, if branched, are left as an upstanding forest of stems. Behind the surface loose sand becomes more consolidated than where there is rain-water action alone. The solvent action within the masses, save a little due to the rain, is inconsiderable, and the whole differs very little from the original reef, except in its better consolidation and the filling in of some of its interspaces.

The conglomerate in Minikoi is found everywhere at the base of the outer beach, especially at the points. Immense masses occur in the beach on the lagoon side of Kodi point (Pl. I. fig. 2), and continue in smaller pinnacles along the same shore, as far as the rocky beach extends. The masses are much pitted and very rough on the surface and of a slate-grey colour; they consist of a consolidation of corals, nullipores, shells, etc. Between tide-marks the scour, sweeping the sand and pebbles to and fro, undermines and finally precipitates the masses, to wear themselves beds perhaps in the rock beneath, to which they may become consolidated. It follows then that no results can be obtained by the examination of the smaller masses in respect to the position of the corals, etc., of which they are composed. The large lagoon masses near Kodi point are of rough surface with their corals freely exposed (Fig. 9). *Madrepora* is by far the most abundant genus

[1] These deductions are largely based on my observations on indubitably raised rocks in the Fijies, but more particularly in the northern districts of Ceylon, the Jaffna Peninsula and the adjacent islands. See *Report Brit. Ass.*, p. 400, 1900.

represented, but *Pocillopora*, *Euphyllia*, *Pavonia*, *Astraea*, *Galaxea* and *Montipora* were also found. The modern facies or species of *Madrepora* grow from a central mass with branches radiating out over their upper surfaces. The central stems grow straight upright, vertically indeed, and are packed all over with corallites, possessing more or less raised calicles, which

FIG. 9. Conglomerate mass near Wiringili at low tide, showing the rugged appearance and undermining by tidal action. (*From a photograph.*)

give them a very rough appearance. The branches extend more and more horizontally from the centre outwards, but none grow downwards. The upper surfaces of the horizontal branches are similar to the central stems, but their lower are smooth, corallites distant from one another, calicles with no raised rims. The basal mass, in which the branches appear to be rooted, is formed by a filling up of the interspaces between the branches by a lighter corallum of open texture, a kind of coenenchyma. Such being the mode of growth of *Madrepora* it follows that this genus forms an excellent criterion by which to judge whether the conglomerate masses originally grew as such, or were otherwise formed, as by a beach consolidation (Pl. II. fig. 2).

On the pinnacles and masses the branches of the different facies of Madrepora *are much worn but generally still entire. Some of the colonies seem to be a little tilted, but most are clearly in the absolute position in which they originally grew*[1]. *Other genera of corals amply confirm the evidence of elevation, which this fact implies, and imbedded* Tridacna *shells with their open mouths in a horizontal position lend their support.*

It remains to consider the position in which the conglomerate was originally formed. The fine-grained structure of some parts shows the presence of nullipores, but the latter are never in sufficient quantity, allowing amply for denudation, for the whole to have formed part of the surface of a reef awash. At the same time spreading nullipores, of which there are indubitable traces, show that the rock must have been formed in a reef, freely exposed to the sea, and cannot have been built up in a lagoon. At Minikoi I was

[1] It occurred to me that the specific gravity of the basal mass might be such that the *Madrepora* would naturally tend to take up this position. I hence had a large number of colonies (about 30) placed on the reef near Teveratu point. The branches were broken off, the basal masses alone were left. They lay in every conceivable position, more indeed on the upper surface, as without its branches it became almost flat.

never able to approach a typical part of the reef from seaward[1], but in the Maldives at about three fathoms the bottom consists of great buttresses and masses with branching *Madrepora* and *Pocillopora*, massive corals here and there, and a considerable nullipore growth between. These coral colonies are for the most part small, the branches short and stout,—the usual condition near the surface, or in any strong current,—and somewhat resembling those of the conglomerate masses. Between the buttresses sand and a few boulders of coral, broken off the higher parts of the reef and rolled smooth, are seen, themselves perhaps to be built into the reef. Such boulders I have not found in the conglomerate, and their absence would indicate that the latter was formed both deeper and before the existence of any reef-flat to the atoll. *Indeed the conglomerate would seem to have constituted part of the original reef (which by subsequent growth fashioned the atoll of Minikoi) at a time antecedent to the formation of any definite reef-flat, and at a depth of at least three fathoms. The conglomerate then may be considered to prove conclusively an elevation of the atoll. Its summits are 6 feet above the reef-flat (the low-tide level) and, allowing 18 feet for the depth at which it was formed, there must have been an alteration of level of at least 24 feet.*

Returning to the condition of the whole reef at the time of elevation, if there were a broad reef-flat, no additional upheaval to that suggested above would be required to explain the height of the island in different positions. The boulders, which form the rocky area, lie more or less horizontally on one another, and are much rain-worn. If they had been piled up by the waves, they would show a definite dip, but their position is more in accordance with their being formed by the simple sinking of the surface owing to the solvent action of the rain, removing nullipores, sand and the softer parts. The height of the land-sections *D* and *F* is about 14 feet[2], and the elevation based on other considerations 24 feet, giving a sinking of 10 feet to the surface. Considering the heavy rainfall, the spongy nature of a reef, and the almost complete absence of evidence of nullipore growth in the boulders, this erosion of the surface would seem to me but reasonable. Allowing an average loss of half an inch in a century, ample even if the original reef were not solid, only 24,000 years since the elevation would be required. This period is perhaps more than sufficient for all the changes which have taken place in the atoll since its elevation, but is not synchronous with any known upheaval, such as might naturally be expected in the Hindustan continent, if such a change of level has taken place, as I believe, more or less at the same time throughout both the Laccadives and Maldives.

Let us proceed however to an examination of the sandy areas, so as to see whether they lend any support to the changes that have so far been deduced. I have already described the surface characters of this area with the exception of a small patch at Boni-Kodi, similar sand to which indeed forms a belt everywhere against the rocky area. It consists of coarse particles of all the organic skeletons, which assist in forming a reef, with larger rounded pieces of coral. It thus differs entirely from the fine sand of the lagoon shore elsewhere, resembling somewhat closely the sand at the base of the sea-beach of the south half of the island. I investigated its distribution by digging pits in section across

[1] For the reef characters in different positions see Sec. III. Such reef as exists between Mou-Rambu and Kodi points is not typical.

[2] I have not taken the greater elevation—19 feet—as found in section G, as I consider that there may have been along the ridge here a piling up of boulders, even land, at a time antecedent to the elevation.

the island and by examining all wells and native excavations. North of the village it practically extends from the old raised reef to the lagoon, but southwards it gradually decreases in breadth, giving place to the regular lagoon beach sand. Towards the rocky area more coral fragments occur, but the junction is sharply defined, while on its lagoon side it merges very gradually into the finer sand. The patch at Boni-Kodi forms a soft, very friable sandstone on the surface with loose sand beneath, apparently the crowbar finally fetching a hard rock. The amount of consolidation elsewhere is very varied, but at the mean high-tide level it commonly forms a loose sandstone, increasing gradually in hardness to the low-tide limit, below which soft sand succeeds and water is obtained, varying in sweetness with the distance from the sea.

Reef-flats without islands generally slope towards their lagoons for some distance, the hard rock gradually giving place to a coarse sand, which has been swept across the flat by the waves[1]. *The origin of this belt of coarse sand at Minikoi must have been, I think, the same, and its occurrence hence supports the view that the rocky area at one time formed part of a regular reef-flat.*

Remembering that the remainder of the sand is certainly of lagoon origin, it is of interest to remark that in some of my pits in it I found alternations of harder and softer sandstone, or loose sand. It was impracticable to trench across, but my pits were sufficiently numerous to warrant me in the belief that there is an irregular series of lines of sand-rock, more or less parallel to the lagoon shore with areas of loose sand between. I shall have occasion subsequently to point out that the formation of sand-rock is characteristic of beaches, which are washing away, or at rest. *Hence it may perhaps be deduced that there have been periods at Minikoi, when sand was being actively heaped up from the lagoon, alternating with periods of rest, or even of washing away.*

Beach-sand-rock at the present day crops out nowhere on the lagoon shores of the island. A little only is found at the west end and on the outer beach to the south. In Ko-Vari bay it fringes the beach against the reef, but it is doubtful whether its constituents did not rather form part of the original raised reef. The same remark perhaps applies to its presence elsewhere, but the point is immaterial, as no deductions are based on its occurrence.

The island of Wiringili is formed almost entirely of rock, much of its surface being bare. It is situated at one of the most exposed parts of the atolls, for the south-west gales are always those of the greatest force, and the reef outside it is narrow. The conglomerate rock forms a broad belt of masses and pinnacles at the inner part of the reef, many of them much undermined (fig. 10); they reach a maximum height over the reef-flat of 8 feet, and loose masses add an additional 2 or 3 feet to the altitude of the land. On the lagoon side of the island is a collection of small fragments of rock and sand. The erosion on the seaward face is very marked, but the rest of the island is protected by the conglomerate band.

Ragandi is a bare islet of conglomerate close to the edge of the reef. It is covered usually with loose boulders, thrown up by the waves, but the sea occasionally sweeps it quite clean, generally carrying away at the same time a wooden beacon, which crowns its summit. It is probable that in a few years no trace of the land will remain.

[1] Submerged reefs on the other hand are generally precipitous on all sides, and do not hence show such or indeed any transition to a sandy area.

CHAPTER IV.

The Atoll of Minikoi (*Continued*).

Section 3. The Atoll Reef.

The encircling reef of Minikoi in its different aspects may be considered as typical of the whole of the Maldive and Laccadive atoll-reefs. In a section three parts may be distinguished—the reef-flat, the rough or boulder zone, and the inner slope. The two former are to some extent sharply separated off, as their basis is a solid flat of rock, while the third may be entirely formed of loose sand. There is also the outer slope to the depths of the sea, but I have already referred to this in my general account of the atoll (Sec. 1, p. 27). I shall, however, recur to its characters in any position where it may appear different from the previous descriptions. On account of the variation it will be most convenient to sketch in the characters of the reef in several different situations in a traverse of the whole circumference of the atoll. In my account of the Maldives I shall as far as possible for description merely refer to the reef in different situations at Minikoi atoll.

Kodi point is essentially a sharp projection, the breadth being less than 100 yards from a depth of $1\frac{1}{2}$ fathoms on either side. Owing to its situation by the lagoon passage the currents in and out of which, meeting with those along the seaward reef, form a whirl round the point, the sea breaks heavily on either side almost independently of the quarter from which the wind may happen to be blowing. Hence the two sides, experiencing almost the same conditions, resemble one another closely. The point of the reef projects about 1 cable (200 yards) from the land, and in its centre lies a series of conglomerate masses, 40 yards long, running parallel to the outer edge of the reef on either side. Taking a section across the centre of the point, one finds two or three little terraces on the outer or east side, each perhaps 12 yards broad and rising by a 2-feet step at its outer edge. They are studded with low pinnacles of the conglomerate, which also form a broken line at the outer edge of each. These masses increase in size and height inwards, and are of smooth contour, exhibiting externally no trace of their constitution. The whole surface between is covered with low green algae, and is completely destitute of sand and boulders of any sort; no corals grow, and only a few low incrusting nullipores are found towards the seaward edge of the outer terrace. Further seaward the whole bottom could be seen at the backwash, preceding each breaker, to be spread with red, white and pink *Lithothamnion* together with a few corals, principally small colonies of the most massive facies of *Pocillopora* and *Madrepora* (Pl. II. fig. 1).

Fig. 1. Reef from Kodi point, Minikoi, looking north

Fig. 2. Conglomerate mass at base of beach

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In the centre of the reef the rock masses are all much eroded underneath by the seas, which at high tide, breaking on either side, meet one another in the middle of the reef to rush along and escape at its north point. This central pinnacled flat is about 30 yards broad, and in places a few coral masses lie, some perhaps thrown up by the sea, but most eroded out of the conglomerate. Between the masses a few pits are found, from which the water does not escape, and in these flourish colonies of *Porites arenosa* and *Psammocora plicata* (or similar facies). The lagoon face against the passage is similar to the seaward, but the terraced arrangement is less noticeable. The pinnacles are fewer and smaller, and the breadth is only about 30 yards. The drop outside is more abrupt, the reef ending in a cliff of 1½ to 3 fathoms against the passage. The surface is smooth, but various larger foliaceous and calcareous algae (*Halimeda*, etc.) flourish; neither nullipores, nor corals are found even at the extreme edge. Round the end of the point the conditions of the two sides merge into one another, but the terraces are broader; the outer is not marked with pinnacles, and slopes gradually to the depths below.

A series of large table-topped dead rocks are seen on the backwash of the breakers outside the cliff against the lagoon passage; they extend up from the level of the central conglomerate masses in a line to the point of the reef. Owing to the heavy seas I never succeeded in making good my footing on any of these, but they appeared to be pitted and bare of all organic growth except a few, low, green algae. They are apparently being eroded underneath, subsequently to topple over and to be completely removed in a similar manner to the conglomerate masses of the shore. I cannot find any record of such bare masses in the numerous accounts of coral reefs. In those, which I have seen, I can only compare them to the table-topped, raised reefs in some of the Lau islands of the Fijies; the erosion of the latter, however, is mainly between tidal limits. They may be the tables of much taller mushrooms, the stalks of which have given way, while the tables have not yet been cut down by the sea to the regular level in this position. *I am, however, rather inclined to believe that they are due to a broadening of the passage, and that they show the maximum effects which can be produced by the combined current and breaker actions on the reef.* A reef-flat consists of buttresses and masses which by organic growth have become joined together. The water has got behind some of these, and the present table-shape results. The force of the waves would cause a rapid denudation of the consolidating sand, and the constant change of the water, due to the currents of the passage, an equally quick solution. The out-rushing water, carrying a large amount of dirt of all sorts in suspension, would prevent any organic growth, so that the former actions would be unimpeded.

Between Kodi and Mou-Rambu points the reef is very similar to that eastwards of the former. There is a steep, boulder-strewn beach, and below this a series of terraces—usually three with a step of 1 foot to each—before the regular outward slope commences. The pinnacles of conglomerate are sparser, but usually a well-defined row marks the outer limit of all except the most seaward, which is never uncovered at any tide. The latter terrace is not well defined, being a flat for a certain distance and then tailing off seaward into the outer slope. Its inner part is completely covered with low, green algae, which to seaward give place to large nullipore areas with occasional colonies of *Madrepora*, *Pocillopora*, *Coeloria* and *Psammocora* in the hollows. The inner terraces are to some extent covered with green algae, but neither nullipores nor corals are found except very rarely in shallow pits. *Often bare patches of rock occur, the pinnacles are constantly falling, and there is no doubt but that they are being rapidly eroded to the level of the outer terrace.*

Off Mou-Rambu there are four terraces, the most seaward with the same characters as the outer of those described above, but about 35 yards in breadth. The second has only a very few pinnacles, mostly at the outer edge. The third is studded with blocks, the outer limit being marked by an almost complete line, and the fourth, or innermost, is a rocky mass of conglomerate with top awash at ordinary high tide, broken up by a number of fissures, through which the water escapes after each successive wave.

In Ko-Vari bay the inner terrace forms a ridge at the base of the beach, 3½ feet above the low-tide limit. It is quite smooth, and formed of a conglomerate of sand and coral fragments. Parts consist of the ordinary coral conglomerate, but most is of beach formation (see page 37). It is being worn away on the surface, eroded underneath, and great slabs are constantly being broken off, the action nevertheless being much slower than on the coral-rock. The reef outside this inner terrace varies in breadth to 45 yards. Two terraces, each 10 to 12 yards across, occur, the inner smooth and bare of organic growth with a well-marked line of pinnacles on its outer edge, the seaward 1 foot lower, somewhat hollowed out in the centre, edge marked only by an occasional pinnacle and the surface covered with green algal growths with nullipores to seaward. An outer flat starts 1 foot lower; it varies up to 25 yards in breadth, and slopes gradually to a depth of about 5 feet, where it gives place to a succession of coral and nullipore masses. Its surface is covered with green algae, nullipores and corals of the usual genera in addition to massive and branching facies of *Porites*.

From Ko-Vari bay westwards the terrace formation disappears, giving place to a broad reef-flat. Masses of conglomerate, however, crop out at the base of the beach right round to the end of the island. Off Teveratu point the beach is very steep,—being formed of large boulders from the conglomerate,—and merges below into the reef, which is about 80 yards across. Three parts may be readily distinguished; an inner 20 yards broad, bare with a few rock masses, the remains of the terrace formation; a middle part, 40 yards across, never completely uncovered at low tide, the typical reef-flat; and an outer part, which slopes for about 1 foot in a breadth of 20 yards, consisting of great buttresses, perhaps divided across, the fissure zone. The reef-flat is noticeable in this position for the remarkable abundance and luxuriance of coral growth, as compared with the same part to the south and west of the atoll, and generally with the Maldivan reefs. Three or four facies[1] of *Madrepora* abound, with low branches and spreading masses, in places covering over 20 per cent. of the surface. Other corals spread over an additional 20 per cent., *Coeloria daedalea, Pocillopora coespitosa, Leptoria tenuis, Orbicella* (two or three species), *Pavonia repens. Psammocora plicata* and *Porites palmata* being the most numerous[2]. The fissure zone is simply a part

[1] By the term facies I imply simply a mode of growth. I cannot use the term species in referring to *Madrepora*; it is too precise, as I am uncertain whether all, while appearing distinct, are not really the same species. The determinations of the species, while usually accurate, are only intended to convey an idea of the facies of the genera represented. More massive species of *Pocillopora* and *Porites* were also obtained in addition to specimens of *Prionastraea, Hydnophora, Goniastraea* and *Astraea*.

[2] I am at a loss for a complete explanation of this great luxuriance of coral growth, unparalleled in my experience of similar reef-flats, both for quantity of coral and variety of genera and species. Teveratu point projects to the south-east, eight points from either of the prevailing winds, the

of the reef-flat, which is broken into buttresses and masses by the channels along which the superincumbent water escapes. The fissures vary enormously, some being only a few inches across, others many yards, serving perhaps as boat-channels, the waves surging through and not piling up as breakers. The channels gradually slope from the reef to a depth of about $2\frac{1}{2}$ fathoms at the ends of the buttresses. The latter may be of almost any size, and are often much intersected. The rollers break just outside their seaward ends, which in any one position lie approximately in line with one another. Off Teveratu the buttresses are smooth on the top, covered with seaweeds, with all the species of corals of the true reef-flat, together with many stunted colonies of some massive facies of *Pocillopora.* To seaward they end more or less precipitously, but towards the fissures often overhang from 1 to 2 feet; their edges and sides—except where they are overhung—are completely covered with encrusting nullipores. Some of the channels extend right into the true flat, but none are large enough for boats. They have no coral growth, but boulders of recent coral origin may lie in them, generally more or less bedded in sand, perhaps being consolidated to the rock by nullipores.

The reef off the lighthouse and the western parts of the island exhibits the same divisions as at Teveratu, but the true reef-flat is about twice as broad. The beach is formed of small boulders and sand, tailing off into a rough area, 20 yards broad, which represents the inner zone of Teveratu. It has the same characters as the latter but less intensified, and further is strewn with coral masses, some thrown up by the waves, but the majority washed down from the land behind. I could find no trace of any consolidation going on at the present day, the loose masses usually lying bedded in a little sand, which may have a few crustaceans and worms, perhaps also a holothurian or two and some actinians. The under sides of the blocks, where exposed freely to the water, are bare, or covered in patches with thin sponge and Tunicate colonies. The broad flat is almost devoid of life of any sort; its surface has a somewhat slimy appearance from the mud and dirt. Such algae as grow on it are small and filamentous, silted at their roots with mud. A few small pits are found, having perchance a boulder or two bedded in sand, the whole of the rest of the hollow obliterated by Halimeda, or some similar alga with calcareous leaves. The fissure zone is the same breadth as off Teveratu, but it is higher, and resembles more the same zone, described by me at Funafuti and Rotuma[1]. Its surface is pitted, and almost completely covered with low green algae and nullipores. In larger pits corals may grow, but the colonies are of small size[2], a species resembling *Pocillopora coespitosa* being the most common; an incrusting *Montipora* alone attains any magnitude, although most of the genera found at Teveratu may be represented. The seaward edge of the zone forms

ordinary currents caused by which would be bound to sweep round it. Probably the seas always break on it heavily, keeping the water of the reef-flat cool, and practically at the lowest tides preventing any drying up of the coral polyps. The whole reef, too, having a rocky shore, is singularly free from mud and dirt of all sorts. On the whole I am inclined to think that this luxuriance only dates back for two or three seasons, which have been peculiarly favourable. The small size of most of the coral growths lends this view some support.

[1] "The Coral Reefs of Funafuti, Rotuma and Fiji, etc." *Proc. Camb. Phil. Soc.*, vol. IX., pp. 417–503. (1898.)

[2] This is a most remarkable feature along the whole reef in this position, few of the colonies being more than a few inches across. At the commencement of the much delayed south-west monsoon in August, 1899, the beach was strewn with small coral fragments, and there seemed to be considerable death among the reef corals, owing to dirt and mud. I am inclined to think that most of the branching coral colonies had been formed since the last south-west monsoon (in this case 10 months), and that few or none survive it.

a marked line, and the fissures are small, many closed over by nullipores, which may perhaps leave small blowholes.

The reef between the last two positions described gradually varies from the one to the other. In one place for about 200 yards the whole of the seaward face of the buttresses and for some distance up the channels is singular in being absolutely covered over by a yellow zoanthid actinian. Off Wiringili and Ragandi islands the reef is nearly the same as off Teveratu point, but the conglomerate zone is broader, more marked, and very rugged (Fig. 10). Between Wiringili and Minikoi the reef outside the boulder zone is

Fig. 10. Seaward beach of Wiringili with masses of conglomerate. (*From a photograph.*)

intermediate between the reef off the end of the large island and the reef of the whole of the west and north sides of the atoll. The latter does not differ materially in different parts, and the description in one position will serve for the whole.

In a cross section between Wiringili and Ragandi three zones are well defined, the fissure, reef-flat, and boulder. The fissure zone does not very materially differ from that off the end of Minikoi island, but its edge against the sea is more irregular, some masses dropping with a cliff to two or three fathoms, others tailing off gradually. It varies in breadth up to 30 yards, and slopes about two feet in this distance from its crest; the latter is a slightly higher part just exposed at low springs, six or eight yards across. Further outside the slope quickly attains a depth of four or five fathoms, slowly increasing for some distance. The bottom is fairly smooth, covered with spreading nullipores and studded with round masses of the same and coral colonies, the former always with a coral core. There is no appearance of the great masses found off the reef to the south of Minikoi island. The seas break just outside the edge of the zone, which except the crest is swept by the waves in all weather. The fissures seldom have overhanging sides, or any accumulation of coral blocks or sand in their channels. They generally start in the crest and slope to about $2\frac{1}{2}$ fathoms outside; few reach through to the reef-flat, from which at low tide the water cannot readily escape seaward. The water at low tide rushes up the fissures and a certain amount wells over on to the reef-flat, though most, being thrown back by the crest, escapes with great force down the channels. The buttresses are pitted on the surface into small rounded hollows, which are often filled with algae, allied to *Halimeda*, or with small coral colonies, mostly branching facies of the usual genera. Generally, however, the hollows are empty, the rock beneath merely covered with a nullipore, or a flat green alga of some sort. If the surface be broken, a nucleus, usually of coral, is reached after several inches of a light concretion of worm tubes and *Lithothamnion*. The walls and floors of the fissures are usually smooth, and encrusted completely with nullipores. Free animal life of any sort is rare; a few thick-spined Echinoids and large crabs wedge themselves into the hollows; brilliantly coloured fish wash to and fro with the waves in the fissures; between the branches of corals and weed a few Alphaeids find a refuge with an occasional Cyprid and Stromb. The crest of the zone is not always present in such a marked manner, though an inner part, densely covered with green algae, in which the fissures mostly end, can always be distinguished. Its surface has the regular worm tube and nullipore structure, only in greater thickness; corals are rare, a few mammillated nullipores being the only calcareous organisms.

The reef-flat is about 50 yards in breadth, presenting almost the same characters as in the last position described. The greater part of its surface, being situated about 6 inches below the crest of the outer zone, is at any state of the tide covered with water, in which there must be some change through the fissures. Its surface is absolutely free from loose coral boulders, and is for the greater part bare save for low algal growths. It is clean, with no dirty appearance from mud or sand, and, if broken into, is seen to be formed of hard coral rock. Small incrustations of nullipores are found, but they are never of any real importance, nor can they in any way affect the general height of the whole. The same genera of corals grow as are found on the fissure zone; spreading forms of *Montipora* alone attain any size, their colonies sometimes covering 2 or 3 square yards. The most abundant genus is *Pocillopora*, of which two forms, finely and coarsely branching, are numerous; *Coeloria daedalea* also is of considerable importance. Corals attract the eye, and hence tend to assume an undue signification. It is very unusual for them to cover more than 10 per cent. of the surface of any reef, sufficient for wastage, but not enough to alter the general level. Towards the exterior masses of hard rock, 2 to 3 feet high, are found irregularly about every 40 yards. They are pitted on the surface and rotten, perhaps the outside a mass of worm tubes, surrounding a solid rock core. Although I passed along this reef in the beginning of September, 1899, after very heavy south-west gales, I failed to find any large masses thrown up by the seas (negro-heads), nor did I ever find any rocks on the flat in process of cementation on to the reef. Blocks added thus usually can be easily split off with chisels along the line of cementation, but I failed to break any of these. *I am hence driven to the conclusion that these masses are true pinnacles, that they once absolutely were part of the reef itself and were left, while the rest was completely washed away.* Of free animal life, other than that found on the fissure zone, Holothurians alone are prominent.

Of these two zones as far as the north passage into the atoll little further need be said. They have nearly the same characteristics, but the fissure zone increasingly becomes more broken and less defined at its outer edge, which tails off very generally by similar masses to the seaward depths. The crest is in many parts absent, and the two zones merge into one another; pinnacles are scarcer. In three places between Ragandi and the passage the reef is lower, forming boat channels, which are used above half-tide in the north-east monsoon. These passages are merely extra large fissures, which run further into the reef-flat; they are kept open mainly by the scour of the tide, preventing coral and other calcareous growths.

The boulder zone (Fig. 11) is an area of rough blocks of rock, separating the reef-flat from the lagoon. It is about 30 yards broad, moderately sharply defined on both sides;

some of its masses attain a height of 3 feet above the reef-flat, but the general level is 1 to 2 feet less. What appears to be the inner part of the reef-flat forms the foundation; it is to some extent worn into holes, in which the larger loose masses lie, imbedded in sand. The three islands merge at their ends into this zone, masses of the conglomerate extending out from each for 100 yards or more along it. It has a twofold origin, consisting of boulders cast into this position from the reef and lagoon, and also of masses of the conglomerate, some loose and some attached to the solid platform below. Relatively little of the whole, however, consists of masses attached to the reef, the greater part being formed of loose blocks of the old coral-rock. Towards the outer side a certain number of coral blocks are thrown up from seaward, and on the lagoon side also a few may be washed

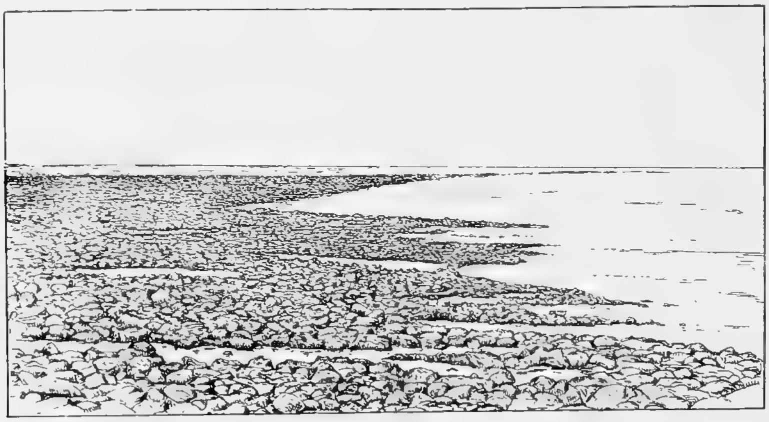


Fig. 11. Boulder zone and reef-flat between Wiringili and Ragandi. (*From a photograph.*)

up. The sand beneath is coarse, consisting of fragments of the conglomerate and the washings of the reef. The boulders are singularly free from all boring and other destructive organisms; their exposed surfaces are absolutely bare of any animal or plant life. Little can grow on the basal reef on account of the sand, and indeed no fixed organisms of any sort are found save on the undersides of boulders, which may be almost covered with thin sponge, Tunicate or Polyzoa colonies in numerous small incrustations with possibly a little Hydroid and Actinian growth as well. Brilliantly coloured Turbellaria and similar looking Nudibranchiata browse on these. Crabs of thin compressed genera and Ophiurids hurry to escape on every side; numerous Macrurans dart for shelter. Under the boulders a few sharp-spined Echinids, thin-skinned Holothurians and large Cyprids lie free on the surface, and in the sand may be found an occasional Polychaet and Sipunculid. In places the boulder zone may be lower, where the water of the rising tide finds its earliest access to the lagoon, and its surface practically smooth and bare.

While the boulder zone has the above enumerated characters as far as Ragandi, it ceases further north to be nearly so well defined. Indeed it is merely the inner part of the reef-flat, sparsely strewn with boulders with a few masses of the conglomerate here and there. The latter do not exist opposite the boat channels, and are most numerous intermediate to these. Close to the north passage there are a large series of such masses, many of great size, forming almost a bare conglomerate flat, covered with about a foot of water at high tide.

Section 4. The Lagoon.

The distribution of the fauna in the lagoon of an atoll is dependent on the currents, which bring food and water to the various organisms. To ascertain their force and character I anchored for five nights in different situations, taking serial observations on the directions and rates of the current, temperature and surface fauna[1]. For rate of current I used Messrs Negretti and Zambra's current meter[2].

To summarise my observations, the tide sets in mainly over the south and west reefs of the atoll, carrying with it weed and dirt from the reefs together with a certain amount of plankton, but in any situation relatively little as compared to the quantity which enters by the north passage. At first the tidal effects were felt in the latter channel, but about half-tide, when the boulder zone began to be covered, a reversal of this current was experienced; a previous current inwards of 1 to $1\frac{1}{2}$ knots gave place an hour before high tide to an outward current of $\frac{1}{2}$ knot, increasing to 1 knot at high tide. With the ebb a slight inward set over the reef still continued, and was felt until the boulder zone began to be uncovered. The current in the north passage increased up to 4 knots at a depth of 1 fathom, the surface nets catching a mixture mainly of weed and mud with some few Crustacean larvae. Away from the immediate neighbourhood of reefs I never recorded a current in the lagoon of more than 1 knot, but incidentally I proved that the water is to some extent changed by admixture in every part except perhaps immediately opposite the lighthouse. The advent of the water from without was shown by a slight change (lowering) in the temperature and the specific gravity of the lagoon-water, and in the arrival of the true sea-plankton. The latter was mainly noticeable in its Medusae, Diphyids and Sagittae; Appendicularia and Salps were also found. Crustacean constituents were not relatively numerous. Minikoi is a small atoll with a relatively very large reef surface as compared with the lagoon. The fact that there should be a thorough circulation of water is hence of great importance and perhaps accounts for the richness (in quantity, not in species) of the fauna, which the lagoon contains[3].

The shore of Minikoi as far north as the village slopes gradually into a broad sand-flat, but beyond this a level reef commences and continues up to the north point. This reef varies up to 300 yards in breadth, and no part of it is exposed even at low-tide springs. It slopes absolutely from the base of the beach, and has about 3 feet of water at its edge, where it drops steeply into 2 fathoms of water. Masses of conglomerate, such as are found in the beach, may occur on its surface for some distance, gradually further out decreasing in size. At Boni-Kodi the reef is 216 yards broad from the base of the beach, and pinnacles extend 170 yards out. Its appearance in this position bears a close comparison with the reef outside the island, in that it is very obviously a solid

[1] The situations were opposite points, where the reef is low near Wiringili and Ragandi Islands, opposite the channel of Neru-Magu, the centre of the lagoon, and just inside the north passage. The last was not very satisfactory, as the night was stormy, and my boat was twice filled with water by breaking seas.

[2] *Vide* p. 22. For slow currents, such as I wished to record, a lighter and larger form of instrument is desirable. The screw should have three or four blades, and great attention should be paid to its bearings to avoid friction of every sort.

[3] My observations were made in the south-west monsoon. From general considerations I cannot see why there should not be nearly as good a circulation of water in the north-east. The main island would be a barrier to some extent, but the currents in the north passage would be probably profoundly modified and stronger inwards, changes which could not fail to be advantageous.

mass of rock and not a sand formation. Its surface is muddy, slimy and worn into holes more or less filled with sand; it is bare and smooth for the greater part, and boulders are practically non-existent. The whole area is singularly devoid of animal or plant life, sessile or free. A few species of coral grow at the very edge, but on the surface I only found a few small colonies of *Porites arenosa*; delicately branching nullipores may exist and also *Halimeda*, but weed is generally scarce.

The sand-flat at the south of the main island extends up round the reef to the west and north, covering about half the total area of the lagoon. The whole, except a small part near the lighthouse, is completely covered even at low-tide springs, the greater part having 2 to 3 feet of water. Around the sand-flat, wherever the reef exists, an outer zone, 100 to 150 yards broad, may be separated, characterised by its abundant growth of corals, the rest of the sand being absolutely bare. The slope from the reef to the general level of the flat occurs entirely in this area. The principal coral is a species of *Madrepora* with massive branches, which is everywhere abundant in this situation. Other more delicate Madrepores occur as well, mostly in isolated colonies, but a stag-horn species with branches up to 1 inch in diameter forms in places close to the boulder zone regular groves. *Porites arenosa* is found everywhere, in masses up to 20 feet across, dead in the centre, but living at the edge, and places where the currents are not greatly felt are often almost completely covered by it; the masses are always free, their stalks having been destroyed, and are very generally somewhat hollowed out in the centre. *Pavonia repens* crops up anywhere, while the species of *Pocillopora*, of which there appear to be several, are found only opposite breaks in the boulder zone. Locally extremely common, especially near the western and northern reefs, are great masses of *Millepora*, *Heliopora* and *Psammocora*, while colonies of *Goniastraea*, *Astraea*, *Orbicella*, *Prionastraea*, *Siderastraea*, *Mussa* and *Euphyllia* are often met with, frequently growing in the hollow masses of *Porites arenosa*. On the under-surfaces of any of the above *Agaricia* may grow, and various species of *Fungia* are very abundant on the bare sand. *Halimeda* abounds, growing among the basal branches of *Madrepora*, but other algae can scarcely be said to occur. A mere glance at the above list of the more important genera serves to show the richness of the area, and the bold growth of the colonies themselves proves that the position on the whole is one eminently favourable to them. The parts poorest in corals lie immediately behind the boulder zone, where it is especially high or low, the stillness of the water and the too rapid currents both being unfavourable. Surveyed from a boat at high tide the presence of breaks in the boulder zone can be assuredly told by the white, sandy bottom continuing up to it. Over the richer areas at the sides of these, heavy boots and putties are required, as one literally breaks one's way through groves of coral. The skeletons of living corals (*i.e.* covered by the living polyps) from the area are singularly free from destructive organisms of all sorts, no Polychaets nor Sipunculids; even sponges, which pervade the hard parts of most or all reef corals, do not exercise much sway. The growth is hence probably extremely rapid, and yet the decay must be as quick. The area is certainly not increasing in height. Dead corals are found bored through and through; they soon rot away, and break down into sand, or are dissolved.

The reef of the boulder zone can at its edge be very distinctly traced under the sand, which varies between that of the former zone and the fine mud of the centre of the atoll.

Indeed with a short crowbar the presence of such a reef is indicated often for 30 to 40 yards, and it would appear to underlie a not inconsiderable part of the sand-flat. Attached organisms, other than those which have been already mentioned, are rare in this outer area, but nearly all the free forms of the boulder zone with the exception of Ophiurids are found in as great, or even greater abundance. The black beche-de-mer is extremely numerous, and myriads of small fish dart between the branches of the corals. Annelids and Sipunculids are rare, but generally free life on the coral reefs of the deep sea is nowhere as abundant nor varied as on tropical continental coasts, or on even moderately rich ground of the Mediterranean and English seas.

The rest of the sand-flat is nearly bare of all organic growth. Opposite Minikoi island two small green algae are found in patches, and here and there clumps of a finely branching nullipore grow, nearly imbedded in sand. Surface-living Holothurians are very common in places, and a small species of *Ptychodera* occurs locally under the weed in great abundance. Living in the sand are large numbers of a white Holothurian, a large Sipunculid and two *Synapta*, besides vast numbers of smaller species of the same groups. In addition heaps of sand, 4 to 5 inches high, in a calm sea stud the whole, the castings of an immense Enteropneust, the end of the body of which is often 1½ inches in diameter when distended with sand.

The sand ends about 100 yards outside the line, marked 2 fathoms in the chart, opposite and to the north of Minikoi island, the intermediate area generally being covered with coral shoals, intersected by channels with about 2 fathoms of water. These shoals are usually flat on the top, bare or hollowed out in the centre, with perpendicular, or overhanging sides—especially towards the deeper part of the lagoon—covered with coral growth. On their summits the chief coral is *Porites arenosa*, but all the previously mentioned lagoon genera are represented; massive Astraeids tend to be the dominant forms on the sides. All are much infested with boring organisms, *Lithodomus*, Cirripedes and a Gastropod as well as the usual Sipunculids and Polychaets. The patches decrease in size towards the sand area, on which they seem on the whole to be encroaching. To the south-west and north of the atoll coral patches may occur near the edge of the sand-flat, but there is no definite broad line. This is especially the case by the boat channels and northern passage. By the side of the latter I found what appeared to be the remains of a patch, which for some cause or other had been killed the previous year. It was a round mass, standing in 3 fathoms with 1 foot of water covering it at low tide, sides precipitous, diameter about 18 yards. Its surface was rotten, its sides extremely sparsely covered with living corals—the greater part dead at the base—with much dead and rotting coral. Four other patches seemed to be in the same condition, but they had a certain amount of weed, and would appear to have been killed some time previously. Several other reefs in the vicinity had also been affected, but none to the same extent; some, however, had had in places quite sensible slips at the sides. Free animal life on all the shoals, it may be noted, is extremely scarce.

The slope from 2 or 2½ fathoms, the general depth of the edge of the surrounding flat and reef, to the deepest waters of the lagoon is gradual and regular. Coral patches occur everywhere but much more sparingly in the deeper waters and towards the north; indeed the centre of the lagoon is fairly clear. The patches all reach within a couple of feet of the surface. With the lead I failed to find any incipient patches, and I lined the whole lagoon with dredgings without finding any trace of such. In its southern half this deeper area is covered with extremely fine sand with delicate shells and Halimeda leaflets. This gradually gives place northwards to an area of broken coral fragments in process of decay, studded perhaps with small colonies of Polyzoa. Towards the passage *Polytrema* and nullipores begin to appear, and the bottom consists largely of their rounded masses, 1 or 2 inches in diameter, each on a coral core. The depths in the Admiralty Chart are to all intents accurate, but the 2 fathom area is greater, as also is the 5 fathom. The latter indeed occupies the whole centre, and in the middle of it is an elongated pit with 7 to 9 fathoms. Dredging in this part of the lagoon is extremely unproductive. No fixed organisms other than those already mentioned were obtained. For the rest 2 Gastropods, 1 Lamellibranch, an Asymmetron, a Carib and a few sand-loving Macrura alone were obtained in any considerable numbers.

Section 5. The History of Minikoi as an Atoll.

In the foregoing I have been at some pains to show that an elevation of at least 24 feet must be allowed for the whole atoll. I do not myself consider that the change of level has been much greater than this. Therein I am supported by the general appearance of the corals in the conglomerate, which indicates a formation in shallow water. The point may seem a small one, but it gains in importance from the wide distribution of absolutely similar conglomerate on the atolls both of the Indian and Pacific Oceans. Yet I cannot maintain that an ocean reef at a depth of 10 or even 15 fathoms, swept, as is probable, by a strong current, would not if elevated to the same height have in its conglomerate a similar structure. The sea has now been quite sufficiently explored in the tropics to show that relatively few reefs exist of such a character, most having at least grown into true atoll reefs awash. The reef, too, would have had to have been caught by the elevation at just the right period, for with pure oceanic conditions—the most favourable, if judgement may be based on the more perfect forms of atolls, afar from land,—it could only take a relatively very short time for the reef to rise from 10, or even 20 or 30 fathoms to the surface. The rocky area of the land lies obviously on reef. Remembering both this fact and the regularity of the existing reef, I may point out that such deep shoals have not usually perfect rims, but merely here and there peaks and banks approaching the surface.

It appears to me then a fair assumption that the atoll existed as such when the change of level took place. In further support of my contention that the elevation has been but small, I would point out that the conglomerate appears to have been of very recent formation, a character fully supported by the same rock in the whole of the Maldive Archipelago. Coral-rock, when elevated in any great thickness, soon loses its distinct, organic structure, assuming a hard, uniform, crystalline character by rain-water solution and the reprecipitation of its line. This may be seen in the Fijies, Tonga, Pelews, Solomons, Christmas island and West Indies, indeed wherever reefs of any considerable thickness have been elevated above the waves. The island of Viti Levu, Fiji, is perhaps an exception, but the conditions are peculiar here, in that there must have been several elevations and subsidences, in which the coral-rock was covered with the practically impervious so-called "soapstone[1]." Of course the argument depends on the assumption with which I started,

[1] *Vide Proc. Camb. Phil. Soc.*, vol. IX., p. 453. (1898.)

but with each additional inch eroded the condition of the rock should differ further from that of the modern reef, while there is actually little or no change.

It remains then to consider the form of the atoll, when first elevated, as far as may be deduced from the evidence before us. I have already pointed out that gain and loss are both taking place in respect to the land, and the distribution of these two factors. *First it is obvious that the atoll has been stationary for a considerable period of time* on account of the broad reef-flat round most of its circumference, together with the lagoon-reef off Minikoi island and the broad sand-flat everywhere. Further there are the same actions of gain and loss in respect to the reef. Without entering into detail no one doubts, so far as I am aware, that a reef in a stationary area, exposed to the sea, would gradually grow seawards. The buttressed edge of the reef of our atoll, all covered with calcareous organisms, the masses growing on to it, and the further masses seaward, covered with nullipores and corals, give indubitable presumption of gain from the sea. *On general grounds and from experience I consider that the sea gains on the reef in lagoons, where the circulation of water is considerable.* Specifically I may at Minikoi point to the dead reefs near the north passage, and to the similar character of the whole surface and edge of the reef, extending along from the village to the north point[1].

Seeing the changes taking place I summoned all the old men of Minikoi to my aid, and by their assistance I am enabled to reconstruct to some extent the appearance of the atoll at the commencement of the last century. First there has been little apparent change, either in the seaward part of the reef, or in the outer beach, save only that the outer paved path was at that time perfect from the village northwards and separated by shrubs from the sea. The rocks at Kodi point further were crowned with coconut trees, and joined to the main island. Belts of coconut trees existed right up from the village to the north of the island along the lagoon shore, while now only a few are found at Boni-Kodi. Indeed the natives add an average breadth from memory (60 years) of 30 to 40 yards, an amount which seems incredible in a closed lagoon, but is fully supported by the strewn coconut and other trees on this beach as well as the house remains at Bali-mi-Hungi. The action continually goes on, but hurricanes are especially destructive, causing slips everywhere along both lagoon and outer beaches. Against this must be recorded an extensive gain—60 to 70 yards it is stated—between the village and Moli-Mati point, but Tundu point has retreated almost a like distance, the intermediate area varying. An island, Tori-Gandu, on the reef to the west of the north passage existed with 4 or 5 coconut trees, while Ragandi at the same time had as many as Wiringili now, *i.e.* about 30, but the latter island is only slightly smaller. Lastly it was stated that the north passage has broadened greatly, but views as to its deepening, though held by the majority, produced an acrimonious discussion, from which and on other grounds I am not inclined to credit any considerable difference.

The presence of conglomerate masses I can only regard as indicating the existence of former land in any position, where they now occur. The land then must have at one

[1] My soundings, as compared with the chart, gave evidence of such inconsiderable change in the same direction that I do not care to lay any emphasis on them. A small miscalculation in the state of the tide, or in the positions of the various points taken for fixation, might explain the differences of the two sets of soundings.

time extended round the whole atoll with only a single break perhaps to the north with lower parts here and there, where boat channels across the reef now exist. The seaward shore must at that time have been relatively steep, like that between Kodi and Mou-Rambu points at the present day but without terraces. The old reef must have had extensive sand-flats, extending out from it into the lagoon on every side, and the lagoon on change of level, if it existed at all, must have been at most a mere small, central pool with a slight ebb and flow of the tide through a single inconsiderable channel to the north. Indeed save for this small channel Minikoi cannot at one time have been far different from the low coral islands such as Oaitupu (Ellice Group), Mulaku (Maldives) and Tromelin, which exist in considerable numbers in both the Pacific and Indian Oceans. Supposing the land in the present atoll to be entirely swept away, the condition at the present day cannot be far different from that of the atoll before the change of level, allowing for its then smaller size.

(*To be continued.*)

HYMENOPTERA.

By P. CAMERON.

THE Hymenoptera taken by Mr Stanley Gardiner in the Maldives and in the Minikoi Atoll number 25, of which two are parasitic (*Ichneumonidae*), the others belonging to the Aculeate section of the order. The number of species captured on the Maldives is 20; in Minikoi 10; 5 species are common to both groups. The known species are Indian forms of wide distribution in the Oriental Zoological region; and some of them, *e.g. Ceratina viridissima, Xylocopa aestuans, Polistes stigma,* and *P. hebraeus,* extend also into Africa and the Malay Archipelago. All the species, new and old, belong to genera of universal distribution in temperate and tropical countries. The genus *Megachile,* for example, ranges from the boreal districts of Europe and America to Australia, and few of the Pacific Islands are without a representative of it.

The Minikoi species were captured from June to September during the south-west monsoon, which is usually the wet monsoon; but in 1899 during the period of Mr Gardiner's visit the weather was abnormally dry, the rain not commencing until the second week in August. The Maldive species were taken in November and December, which were very dry months; but in October heavy rain fell. Hulule Island was visited in January and February, 1900.

HYMENOPTERA PARASITICA.

Fam. **Ichneumonidae.**

1. *Zanthopimpla appendiculata,* sp. nov.

Long. 11; terebra 4 mm.

A species closely allied to the doubtful *Z. punctata* Fab.; and which is certainly different from *Z. punctata* Krieger.

Hab. Minikoi, Laccadives.

Scape of antennae pale yellow; the flagellum brownish. Head yellow, except the ocellar region, where there is a mark longer than broad, which extends to the end of the vertex and is rounded in front. The face is strongly and closely, the clypeus less strongly, punctured. The head is not much developed behind the eyes, and is roundly, obliquely narrowed there. On the base of the mesonotum are three black marks touching each other;

the central is about as wide as long, transverse at the base and apex, and with the sides bulging out roundly; the lateral marks are larger; their base is straight and slightly oblique; their outer side is rounded outwardly; on the inner they are obliquely narrowed. On the base of the median segment are two black, ovoid marks, placed transversely, the broad end on the outer side; the basal area is wider than long; it becomes gradually, but not greatly, widened towards the apex, which is transverse; the outer basal areae are wider than long; the area next to it, in front, is triangular, oblique, and longer than the width of the base, where the bounding keel bulges out. Pleurae smooth and shining. Wings clear hyaline; the nervures and stigma are black; the areolet is distinctly appendiculated. Legs coloured like the body; the hinder tibiae are black at the base. On the abdomen are twelve black marks; the pair on the petiole are broader than long, and have a short, sharp projection on the inner side at the base; the second pair are small; the third are the largest; are about as wide as long and rounded on the inner side; the fourth pair are smaller and somewhat similar in shape; the fifth distinctly wider than long; the sixth are still wider, but not so long; there are no marks on the sixth and apical segments. In the ♀ there are no marks on the second segment; that on the fourth is very small; in the middle of the last segment are two curved oblique furrows.

2. *Enicospilus reticulatus*, sp. nov.

Luteo; abdominis apice nigro; metanoto reticulato; alis hyalinis, stigmate fusco. ♀.

Long. 14 mm.

Hab. Hulule, Male Atoll, Maldives.

Antennae luteous, darker towards the apex. The sides of the face and the clypeus have a yellowish tinge. The face is finely wrinkled in the middle and punctured on either side; the clypeus is smooth and indistinctly punctured at the base; the labrum wants the yellow tint of the clypeus; the vertex and the eye orbits have a distinct yellowish tint. Mandibular teeth black. Mesonotum fuscous, except at the base and sides. The scutellar keels are stout; the apex is closely, longitudinally striated. The base of the median segment is smooth, with the sides irregularly striated; the rest of it is irregularly, distinctly reticulated; on the apex the reticulations are oblique and less distinct in the middle below. Pro- and meso-pleurae closely punctured, the middle of the pro- and the lower part of the meso- closely striated. The metapleurae above shagreened; the lower apical part bears some striae. Wings clear hyaline; the stigma and nervures fuscous; the basal abscissa of the cubitus is thickened, the basal two-thirds being thicker than the apical part; there are two distinct horny points; the lower one is dilated and rounded behind; its upper part forms a somewhat triangular shape; the apical point is somewhat oval in shape. Legs coloured like the body; the hinder tarsi are shortly but distinctly longer than the tibiae; the anterior twice their length.

The transverse median nervure is received shortly behind the transverse basal; the recurrent nervure is bullated on the top; the disco-cubital nervure more widely in front of it.

HYMENOPTERA ACULEATA.

Fossoria.

Fam. **Crabronidae.**

3. *Crabro idrieus*, sp. nov.

Niger, mandibulis, scapo antennarum, linea pronoti, basi scutelli, apice femorum, tibiis tarsisque flavis; alis hyalinis, stigmate fusco. ♀

Long. 7 mm.

Hab. Goidu, Goifurfehendu Atoll, Maldives.

The scape of the antennae bright yellow; the flagellum is black, fuscous towards the apex; it is covered with a white pile and is distinctly thickened towards the apex. Mandibles bright yellow; the teeth black, with a piceous band behind them. Front and vertex opaque, the front is strongly, but not very closely, punctured; the vertex is less strongly and not so closely punctured. The frontal depression, the face and the clypeus, are thickly covered with silvery pubescence; the face is distinctly keeled in the centre; at the apex this keel slightly projects and is smooth and shining.

Pro- and mesothorax opaque, the mesonotum and scutellum are sparsely punctured; the mesopleurae less distinctly punctured. Propleurae shining; on the basal half are three or four irregular keels; on the apex two longish oblique keels, with two shorter ones behind them. The middle of the metaplurae is depressed and is, especially in the middle, obliquely striated. The following are yellow: an interrupted line on the pronotum, the tubercles, the scutellar keels, two large marks, rounded behind on the base of the scutellum. Abdomen black, except for an oblique, yellow mark on the sides of the second and third segments. The petiole is as long as the second and third segments united; the base above is flat, shining, and furrowed in the middle at the base; this part becomes acutely narrowed at the apex.

The tubercles are fringed behind with white hair; the part behind them is keeled; from the top of this keel an oblique smooth furrow runs; the keel behind the middle is obscurely striated. The "enclosed space" on the base of the median segment is stoutly, obliquely striated; in the middle at the apex reticulated; the apical slope on either side of the furrow is transversely striated, the striae becoming weaker towards the apex; the four anterior tibiae are lined with black behind, the anterior in front.

Comes nearest to *Crabro orientalis* Cam.

4. *Crabro musaeus*, sp. nov.

Long. 9—10 mm. ♀

Hab. Mahlos Atoll, Maldives.

Similar in coloration to the preceding species, except that the third and fourth segments are lined with black laterally above and with a mark on the sides behind; it is easily known from it by being longer, by the "enclosed area" on the median segment not being stoutly striated, and by the upper abscissa of the transverse cubital nervure being almost in a line with the lower, and of almost equal length to it: in *idrieus* the lower is longer than the upper, which is on a different angle with it, it being only slightly oblique.

The lower part of the head, inside and out, is thickly covered with silvery pubescence; the clypeus is stoutly keeled. The scape of the antennae, the mandibles, except at the apex, an interrupted line on the pronotum, the sides of the scutellum, the scutellar keels, the tubercles, a mark on the upper side of the mesopleurae, between the two furrows, a longish line on the sides of the third segment at the base, an oval mark on its sides at the apex, and a shorter line on the sides of the fourth segment at the base, yellow. The furrow bordering the scutellum is crenulated; the post-scutellum is closely, longitudinally striated. The area on the metanotum is furrowed down the middle and is finely and closely, obliquely striated. The propleurae bear curved, not very stout striae. The narrowed basal part of the petiole is shining and obscurely striated; the nodose (and larger) apical part is opaque. The stigma and alar nervures are fuscous; the apical abscissa of the radius has a sharp, straight, oblique slope. The four anterior femora are for the greater part, the hinder are entirely, black; the four front tibiae are yellow, lined with black behind; the posterior yellow, black at the base behind, the tarsi are yellow.

5. *Trypoxylon erythrozonatum*, sp. nov.

Nigrum, abdominis medio rufo; tarsis anterioribus albis; alis hyalinis; nervis stigmateque nigris. ♀.

Long: 15—16 mm.

Hab. Hulule, Male Atoll, Maldives.

Scape of antennae brownish beneath. Face, clypeus, and the lower part of the eye incision densely covered with silvery pubescence. Mandibles for the greater part ferruginous. The upper part of the front bears a narrow longitudinal keel; the lower is raised, the raised part becoming gradually wider towards the apex. Thorax thickly covered with rather longish white hair; the furrow below the tubercles is smooth; there is a shallow central furrow on the basal region of the median segment, which becomes gradually wider and deeper towards the apex; the apical furrow is wide: the sides have an oblique slope. Legs black; the basal two joints of the four anterior tarsi and the calcaria are white; there is a narrow pale band near the base of the hinder tibiae. The wings are slightly infuscated at the apex. The apex of the petiole and the second and third segments are rufous.

6. *Trypoxylon melanurum*, sp. nov.

Nigrum, tarsis, tegulisque fuscis, alis hyalinis, stigmate fusco. ♂.

Long: 10 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives; Minikoi, Laccadives.

Antennae black, fuscous towards the apex; the last joint is as long as the preceding three united; on the underside it is dilated at the base, narrowed towards the apex; the middle joints are slightly dilated beneath. Front and vertex closely punctured; on them is a large area; its upper part is rounded and encloses the lower ocellus; its lower is more narrowed towards the apex; the part occupied by it is raised and reaches near to the antennae, where it is prolonged as a short, stout keel; from the junction of the two parts a curved keel runs to the eye incision. The lower part of the eye incision, the face and clypeus are covered with silvery pubescence. Pro- and mesothorax smooth and shining. The base of the median segment bears stout, longitudinal keels, the two central of which are more widely separated; the rest of the segment is stoutly, irregularly, transversely striated; the basal half has two longitudinal keels which form a central area, rounded at the apex; there are two longitudinal keels on the apical slope, which unite near the apex of the segment, this second area being more sharply pointed at the apex than the basal one. On the base of the mesopleurae is a wide, deep, crenulated furrow, bisected above by a smooth, curved one. Legs black, the tarsi testaceous, darker at the base. Wings hyaline, the nervures fuscous. Abdomen entirely black.

Fam. **Scoliidae.**

7. *Elis thoracica* Fab.

This family is represented only by the above, a common Eastern species. Its ♂ has not yet been described with any degree of certainty (cf. Saussure, *Catalogus Specierum generis Scolia*, p. 188, and Bingham, *Fauna of Brit. India, Hymen*, p. 99) but, in the collection, there are some males which can only be connected with *thoracica*. They are densely covered with longish cinereous pubescence: the sides of the clypeus broadly from top to bottom, the apex of the pronotum, the yellow extending laterally to near the tegulae, two broad marks on the base of the scutellum and a mark on the centre of the post-scutellum, yellow. The hair on the median segment is denser than on the rest of the thorax; the oblique furrow on the flat apical half of the mesopleurae is distinct. The wings are hyaline, violaceous in tint at the apex; the radial cellules smoky. Legs black; the apex of all the femora, the outer side of the tibiae and of the base of the front tarsi yellow. Abdomen violaceous-black; the basal three segments above have the apices broadly yellow; the black dorsal parts are dilated in the middle and laterally, the basal projections being narrowed at the apex; the fourth segment is more narrowly yellow at the apex; the black band there is also dilated, but only slightly in the middle.

Hab. Common in Minikoi, Laccadives; one ♂ from Goidu, Maldives.

Fam. **Sphegidae.**

8. *Sceliphron madraspatanum* Fab.

Hab. Goidu, Goifurfehenḍu Atoll, and Fainu, Mahlos Atoll, Maldives.

9. *Sceliphron violaceum* Fab.

Hab. Hulule, Male Atoll, and Mamaduwari, Mahlos Atoll, Maldives. Minikoi, Laccadives.

Both these species of *Sceliphron* are of universal distribution in the Oriental region.

10. *Bembex maldivensis*, sp. nov.

Long. 17 mm.

Hab. Goidu, Goifurfehendu Atoll, Hedufuri, Mahlos Atoll, and Hulule, Male Atoll, Maldives.

Belongs to Bingham's Section A, and comes near *orientalis* and *borreri*. ♀. Antennae entirely black. Head densely covered with long, white hair, the clypeus also with silvery pubescence, the edge of the pronotum narrowly, the labrum and the mandibles to the teeth, pale yellow. Thorax densely covered with silvery pubescence; the prothorax, except behind, two narrow lines on the centre of the mesonotum, two broader, shorter, almost united, transverse ones near the apex, the apex and sides of the scutellum, the apex of the post-scutellum; a broad curved line on the centre of the median segment; the sides broadly from near the middle, the base of the mesopleurae, the mark dilated at the top so as to enclose the tubercles, a large vertical mark in the centre, which becomes gradually wider from the top to the bottom, a smaller, more irregular mark on the apex behind, a crescent-shaped mark on the metapleurae behind the spiracles and the apex broadly—the mark below extending backwards beyond the middle—sulphur-yellow; legs yellow; all the coxae and trochanters; all the femora broadly in front and behind; a line on the fore tibiae behind and a shorter one in front, black; the spines on the fore tarsi are long, stout, and, except the basal one, black. The basal joint of the fore tarsi is not very broad, and becomes gradually narrowed, but not much, towards the apex; the second becomes gradually narrowed, on the outer side from the base to the apex, which is transverse and three times the width of the base; the two following are smaller and are not so broad at the apex compared with the base. The basal abdominal segment is broadly black at the base and apex; the two bands are united in the centre by two black marks which become gradually narrowed towards the apex; the apices of the second, third, and fourth are broadly black; the black bands dilated backwards in the middle, and have, at their base, two black marks, which are broader than long; the fifth segment is black, with the sides broadly yellow; the sixth is entirely black, with its sides straight. The ventral segments are black, except the first and second at the sides of the apex; the yellow marks there are obliquely narrowed towards the apex.

The ♂ is similarly coloured; the clypeus is pale yellow, black at the base and with a broad band on the apex; the seventh joint of the antennae is slightly dilated near the apex; the eighth has a stout tooth, which becomes gradually raised from the base to the apex; at the apex is a small one; there is a blunt basal and a smaller, sharper apical one on the ninth; the tenth is broadly dilated behind, as is also, to a less extent, the eleventh. The middle femora are serrate beneath; the joints of the fore tarsi are not so much dilated, especially towards the apex; the spine on the second ventral segment is larger than usual; its downward length is distinctly greater than its length at the base and it is curved and slightly hooked at the apex. The pygidium is sparsely and distinctly punctured on the sides; the epipygium becomes gradually raised in the middle to shortly beyond the centre of the segment, there curves downwards, the top slightly projecting. The last joint of the hinder tarsi is thickly fringed at the base with stiff longish spines, which being longer at the base and apex of the fringed part give it an incised appearance.

11. *Bembex handlirschi*, sp. nov.

Long. 11 mm. ♂.

Hab. Hulule, Male Atoll, Maldives.

This is one of the smallest of the Oriental species. It belongs to the group of *Orientalis*.

Antennae entirely black; the seventh and eighth segments are dilated towards the apex on the underside; the ninth has a small sharp spine; the tenth and eleventh are hollowed; the tenth is narrowed at the base. Head black, thickly covered with white hair; the clypeus, except at the base, and the apex in the centre, the outer orbits, the labrum, the mandibles, except at the apex, two small central and a longer, pyriform mark outside below the ocelli, pallid yellow. Thorax thickly covered with white pubescence; two narrow lines on the centre of the mesonotum and probably a transverse apical one, a narrow line on the pronotum, the base and apex of the propleurae, a curved line on the upper half of the mesopleurae in the centre; this line becoming dilated gradually, but not very much, towards the centre, a small mark on the base of the metapleurae, a large oblique one, narrowed at the base, on the apex and extending on to the apical slope of the segment; the apex of the scutellum and postscutellum and a broad curved interrupted line on the apex of the basal slope of the median segment, pale yellow. Legs coloured like the body; the coxae, trochanters, the base of the femora narrowly and the upper part broadly and the lower parts of the anterior pair and the hinder knees, black; the middle femora are serrate, but not strongly; the joints of the fore tarsi are slender and not much dilated towards the apex; the spines are long and pale. The basal black band on the first abdominal segment is broadly and roundly dilated in the middle at the apex; there are two black marks, broader than long, on the base of the second, two less distinct ones on the third; the apical bands are dilated backwards in the middle; the band on the fifth is united by a narrow line to the base; the 6th and 7th segments are entirely black. There is no spine on the second ventral segment; the last is broadly depressed on the either side of the middle; the outer edge is curved and narrowed towards the apex. Wings clear hyaline; the costa and stigma testaceous; the nervures darker. Tegulae black, lined with black on the inner side.

Fam. **Vespidae.**

12. *Polistes hebraeus* Fab.

Hab. Hedufuri, Mahlos Atoll, Maldives.

The Maldives form is *macaensis* Fab.

13. *Polistes stigma* Fab.

Hab. Minikoi, Laccadives. The common Indian variety.

14. *Rhynchium Maldivense*, sp. nov.

Long. 11—13 mm.

Hab. Hulule, Male Atoll, Goidu, Goifurfehendu Atoll, Maldives. Minikoi, Laccadives.

This species agrees so very closely with *R. argentatum* Fab., *sec.* Saussure, *Stett. Ent. Zeit.* XXIII. p. 187 (cf. Cameron, *Ann. and Mag. Nat. Hist.*, Dec. 1900, p. 531), that it might readily be mistaken for it. It may be known from it by the pronotum behind being sharply keeled, by the propleurae being bordered before and behind by flat, shining keels; the third cubital cellule at the bottom is broader, being as wide there as the space bounded by the first recurrent and the second transverse cubital nervures, whereas in *argentatum* it is not half the length.

♂. Antennae covered with a pale down; the hook is brownish, stout, slightly curved; with its pedicle it is fully longer than the joint. The front, the eye incision, and the lower half of the outer orbits are thickly covered with silvery pubescence; the vertex with griseous hair. The front and vertex are closely and strongly punctured; the space between the antennae bears a narrow, but distinct, keel. The clypeus at its greatest width is nearly as long as its length; above it is transverse and bordered with a yellow band; the upper half is distinctly punctured; the lower is alutaceous and impunctate; the apex is broadly and roundly incised; its sides have an oblique slope. Thorax strongly and closely punctured, except on the apex of the meso- and on the basal half of the metapleurae. The prothorax at the base all round is bordered by a sharp keel; the furrow above the middle of the mesopleurae is distinct; the base below is smooth. The sides of the median segment are broadly rounded and bear neither teeth nor spines; its apex has an almost perpendicular slope and is almost transverse; above in the middle it is very slightly developed; it is smooth, except round the edges; the central furrow is deep and distinct on the upper half. Legs densely pruinose, as is also the abdomen. The basal segment of the abdomen is clearly separated from the second.

The ♀ has the clypeus punctured all over and it wants the white line on the top; it is more convex above and is more broadly and, not quite so deeply, incised at the apex; the median segment is more fully developed, and in the centre it is finely, transversely striated. The wings in both sexes are deeply violaceous.

ANTHOPHILA.

Fam. **Apidae.**

15. *Halictus minikoiensis*, sp. nov.

Niger, dense griseo piloso; tarsis longe fulvo pilosis; alis hyalinis; stigmate testaceo, nervis fuscis. ♀ et ♂.

Long. 8 mm.

Hab. Minikoi, Laccadives.

Antennae black; the flagellum tending to brownish near the apex and covered with a pale pile. The ocellar region is smooth and shining; the rest of the vertex and front closely and distinctly punctured. The face is roundly convex in the middle and is clearly separated from the clypeus; and is there almost impunctate. Clypeus rather strongly, but not very closely punctured, except at the apex, which is transverse; the extreme apex is depressed, brownish in tint and slightly projects at the ends. The hair is griseous, long and moderately thick on the front and face; sparser and shorter on the other parts. Mandibles brownish in the middle. Mesonotum shining, minutely punctured; in the centre of the basal half is a shallow, narrow furrow. Scutellum punctured on the sides and apex. Post-scutellum thickly covered with long griseous pubescence. The striae on the basal area of the median segment are irregular; at the base they are stouter and longitudinal; at the apex finer, closer and transverse; on the sides they are narrow, close together and longitudinal. The hair on the pleurae is longer and thicker than it is on the upper surface. The hair on the legs is long and white; on the outer side of the tibiae it is shorter and darker, almost black; on the tarsi it is long and bright fulvous; the claws are pale testaceous. Wings clear hyaline, iridescent; the stigma is testaceous; the nervures are blackish; the first recurrent nervure is interstitial. Abdomen shining, impunctate; the segments are edged with white pubescence; there is a narrow transverse furrow on the second and third segments; the anal rima is brownish.

The eyes distinctly converge above; the head is not very elongate in front; the lower half of the front bears a distinct keel; the apex of the median segment has a semi-perpendicular slope, is smooth and shining and deeply furrowed on the lower part; the tegulae are piceous.

16. *Ceratina viridissima* (Dalla Torre) (*viridis* Guer.).

Many of the specimens are golden above.

Hab. Common in the Maldives.

17. *Ceratina appendiculata*, sp. nov.

Nigra, capite thoraceque supra viridis; abdomine late flavo-lineato; clypeo flavo, nigro bilineato; alis hyalinis, nervis stigmateque testaceis. ♀.

Long. 4 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

Scape of antennae broadly yellow beneath; the flagellum brownish. Head dark green, smooth, thickly covered with white pubescence; the clypeus and an oblique, somewhat conical, spot close to its lower side, yellow; in the centre of the clypeus are two large marks, longer than broad and rounded above. Mandibles yellow, black at the apex. The mesonotum and scutellum are green; there is a broad yellow line on the pronotum, extending to the tubercles, which are similarly coloured, as are also the post-scutellum and a curved line at the side of the scutellum. The median segment is black and is, at the base, closely obliquely striated. Wings clear hyaline; the stigma and nervures are pale testaceous; the second and first transverse cubital nervures are united at the top. Legs thickly covered with long, white hair; the knees, tibiae and tarsi are bright yellow; the middle tibiae are lined behind with black in the middle; the hinder are black, except at the base and apex. Abdomen smooth and shining; there is a short yellow line on the first segment on either side; on the second and third the yellow lines extend nearly to the middle; on the fourth they are almost united; on the fifth and sixth they are continuous.

Characteristic is the union of the first and second cubital nervures at the top; the third is straight and oblique to near the bottom, where it curves sharply backwards, thus forming a sharp angle, from the apex of which a short nervure issues; the second recurrent nervure is received at the base of this angle.

A distinct species.

18. *Allodape picitarsis*, sp. nov.

Niger, nitidus, facie, clypeo, maculaque inter antennas flavis; alis hyalinis, stigmate fusco. ♀.

Long. 5—6 mm.

Hab. Minikoi, Laccadives.

Antennae black; the flagellum with a brownish tinge towards the apex. Head smooth and shining; the vertex is obscurely punctured. The front ocellus is surrounded by a wide, deep furrow; the front is broadly dilated in the middle; the dilatated part becomes gradually wider towards the apex. The yellow mark on the face is slightly and roundly incised on the top; the sides curve slightly outwardly; the yellow mark is continued to the end of the clypeus, on which it is narrower and slightly longer. On the apex of the pronotum is a broad, white band, narrowed at the sides; the tubercles and the greater part of the tegulae are yellow. Mesonotum and scutellum aciculated; the basal area of the median segment is strongly and closely punctured; the rest of it is smooth and shining. Legs thickly covered with long, white hair; the hair on the tarsi is more testaceous in colour, and their apices are testaceous. Abdomen shining, smooth; the apices of the segments are testaceous; the basal segment at the base is hollowed, but not deeply. Wings clear hyaline; the stigma fuscous; the nervures slightly darker.

19. *Megachile otriades*, sp. nov.

Long. 13 mm. ♀.

Hab. Hitadu, Mahlos Atoll, Maldives.

Has the hair coloration of *M. lanata*, with which it is closely related; it is smaller; the mandibles are differently formed, their second tooth is longer compared to the first and not so widely separated from it; the middle part is broadly and distinctly dilated, the posterior part being also dilated and separated; it is more rounded than the middle portion, which has the base and apex straight and oblique.

Scape of antennae black, opaque, closely punctured and covered with pale hair; the flagellum is brownish. Head as wide as the thorax, closely, almost rugosely, punctured except for a T-shaped mark on the clypeus and face, the end of which extends to the apex of the clypeus. The front is thickly covered with long, dark, rufous hair; the vertex with shorter, dark, fuscous hair; the face and clypeus with long, dark hair. The mandibles are furrowed along the edge to near the base; on the inner part they bear long, curved punctures; the outer tooth is sharply pointed, becoming gradually narrowed to the apex, which is rounded; the second tooth is triangular; the inner is broadly rounded; the middle and the second are bordered behind by a smooth, flat part, which is clearly separated. Thorax closely and distinctly punctured and thickly covered with dark, rufous hair; the sides and breast with shorter pale hair. Legs thickly covered with pale hair; the hair on the hinder tarsi on the inner side is dark rufous. The basal segments of the abdomen are covered with dark rufous, the other segments are fringed with pale, fulvous hair; the scopa is pale, almost white, except on the last segment, where it is black.

20. *Megachile cinyras*, sp. nov.

Long. 15—16 mm.

Hab. Minikoi, Laccadives.

Belongs to Bingham's Section "F. Abdomen with transverse bands on all segments above of white pubescence" (*Hym. of India*, p. 472), in which it would form a new section: Pollen-brush white, black at the apex.

Head closely and rather coarsely punctured; the lower part of the face and the middle of the clypeus broadly and irregularly smooth and shining. Mandibles closely and strongly punctured; the apical tooth is bluntly rounded; the second shorter and more triangular in shape, but not sharply pointed at the apex; next to it is a rounded depression, followed by a longer, straighter one. Thorax closely and strongly punctured and without any striations; the hair above is rufous, on the upper part of the pleurae fulvous; on the lower white. The hair on outer side of the legs is white, on the inner rufous. The basal half of the wings is fulvous; the apical smoky, with a violaceous tinge. The abdominal segments are fringed with pale pubescence; the pollen-brush white, slightly tinged with fulvous; on the apical two segments it is black. The back is shining and has a distinct violet and blue iridescence.

What I consider to be the ♂ has the apical tooth of the mandibles narrower and more sharply pointed; and it is followed by two shorter triangular ones; the hair on the front and vertex is white; the clypeus is fringed with bright, rufous hair; the antennae are long and slender; the apex of the last joint is obliquely narrowed and smooth and shining on the lower side; the last segment is broadly incised, the sides of the incision are straight and oblique; the last ventral segment is irregularly, coarsely, rugosely punctured; its hinder edge is raised and is irregularly toothed.

21. *Xylocopa tenuiscapa* West.

Hab. Goidu, Goifurfehendu Atoll, Maldives. One example.

22. *Xylocopa esica*, sp. nov.

Nigra, nigro pilosa; alis violaceis ♀.

Long. 23 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

Scape of antennae narrow, not dilated at the apex; the flagellum covered with a fuscous down. Eyes parallel, only very slightly converging above. Head shortly, but perceptibly, narrower than the thorax; densely covered with black pubescence; closely and rather strongly punctured. The anterior ocellus is surrounded by a smooth furrow, which is widest below, where it is produced downwards for a short distance; the space below it is smooth and shining and ends in a smooth tubercle, which has a small fovea above it. The face and clypeus are closely punctured, are flat, and, at the apex, the clypeus is smooth and shining and almost transverse with the sides rounded; a deep, oblique furrow runs from the base of each antenna, downwards. Mandibles smooth and shining; the base in the middle bears some deep, irregular punctures, below which is a distinct fovea, which is oblique, straight on the inner side, rounded ou the outer, and narrowed beneath; the lower tooth is broadly rounded; the lower somewhat triangular. The labrum in the middle is smooth and shining, bare and broadly keeled, the keel being broadest on the top. The sides and base of the mesonotum are closely punctured, as is also the scutellum, except at the base. The median segment is more closely and strongly punctured; the basal area is clearly defined; its base is longer than the sides; it is aciculated and obscurely furrowed down the middle. The hair on the legs is long, dense and deep black. Wings uniformly deep violaceous, with some blue tints at the base and apex; the third transverse cubital nervure is obliquely sloped at the top and bottom; the two parts are of equal length and form a sharp angle in the middle; the lower part has a more sharply oblique slope. Abdomen smooth and shining; sparsely punctured, except at the base where the punctuation is closer and stronger; there is a smooth furrow down the middle of the apical segment; the middle of the last apical segment is smooth and keeled towards the apex.

This species comes near *X. gardineri*, but is not, I feel sure, its ♀; as, apart from the difference in the coloration of the base of the wings, it differs from it in some structural points; the area on the median segment is longer, much broader compared to its length and it is glabrous and impunctate; the thorax wants the white pubescence; it is smaller and the abdomen at the base is not hollowed: it is distinctly longer than the head and thorax united. The spine on the outer side of the four hinder tibiae is broad at the base, bluntly pointed at the apex; that on the front pair is smaller, more curved and more sharply pointed.

23. *Xylocopa aestuans* Lin.

Hab. Common in the Maldives.

24. *Xylocopa latipes* Drury.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

A common Oriental species.

25. *Xylocopa gardineri*, sp. nov.

Nigra, nigro pilosa, alis violaceis, basi hyalinis. ♂.

Long. fere 25 mm.

Hab. Mamaduwari, Mahlos Atoll, Maldives.

Scape of antennae not dilated towards the apex, slender. Head opaque, thickly covered with short black hair and closely and distinctly punctured, except at the sides of the hinder ocelli and the apex of the clypeus. Eyes not converging on the top, parallel. The front ocellus is surrounded by a deep furrow. Clypeus flat; the oblique lateral furrows are not clearly indicated. The base of the mandibles is sparsely punctured; the apical tooth is broadly rounded at the apex; it is short, not much longer than broad. Labrum obliquely depressed, closely and rather strongly punctured and with a smooth furrow down the centre, which is broadest at the top. The sides and base of the mesonotum are covered with pale hair; the centre is bare. Except in the middle the mesonotum is closely and minutely punctured. The scutellum is sparsely punctured at the base, closely and more strongly towards the apex. Pleurae and sternum closely punctured and thickly covered with black hair. Wings deep violaceous, except at the base, where they are narrowly hyaline. Legs thickly covered with black hair; the outer side of the hinder tibiae is smooth and projects in the middle into a triangular tooth; the inner spur is broadly, triangularly dilated at the base. Abdomen shining; above sparsely punctured at the base, much more closely at the apex. The last ventral segment is bare and smooth and bears a stout tooth on either side, these teeth are straight on the inner side, rounded and narrowed towards the top on the inner; below it is smooth and depressed at the apex. The cubitus beyond the second recurrent nervure is straight, it then turns up straight and obliquely towards the apex of the cellule; it then turns obliquely backwards, this upper abscissa being shorter and having a more rounded curve; the second recurrent nervure has the upper abscissa slightly, the lower (and longer) one is more sharply, oblique. The basal area on the median segment is small, opaque, sparsely punctured; its length is as long as its width at the base.

LAND CRUSTACEANS.

By L. A. Borradaile, M.A., *Lecturer in Natural Sciences of Selwyn College, Cambridge.*

(With Plate III. and text-figures 12—23.)

CONTENTS.

I. Introduction.

In the economy of a coral island no group of animals is of greater importance, from the biological point of view, than the land Crustaceans. Their numbers, their ubiquity, their activity combine to give them a prominence, which is all the more marked from the absence of so many of the other land animals of continental areas. They are the chief scavengers of the island, play a great part in the destruction or disintegration of fruits, and probably aid in the distribution of seeds. The work done by them in burrowing along the sandy lagoon shore has a possible importance not hitherto noticed[1]. And it is likely that their omnivorous appetite renders them enemies of many animals, which cannot be specified in the present state of our knowledge: indeed it is highly improbable that the foregoing paragraph exhausts the list of instances in which their behaviour is a factor of importance in the economy of the island[2]. No study of a coral island, in fact, would be complete without an account of this constituent of its fauna.

For five weeks, in the months of June and July, 1899, I was with Mr Stanley Gardiner in the Atoll of Minikoi. During this time I gave considerable attention to the structure and habits of the land crustaceans of the island. My observations form the bulk of the present paper, but there is included a report on the forms collected by the expedition in the Maldives. In treating of Minikoi I shall begin with a short enumeration of the various species to be found there, and the situations in which they respectively live, and then pass on to some remarks on the structure and habits of the land hermit-crabs (*Coenobita*), and the habits of the true crabs of the genus *Ocypode*. The report on the Maldive collection ends the article.

In the section dealing with the genus *Coenobita* I have thought well to enter into some detail, and this for two reasons. First, that the peculiar habits of these animals give them an interest of their own, and thus lend an importance to the investigation of their anatomy, and secondly that, in spite of several excellent descriptions of separate systems of organs to be found in the series of elegant and accurate works on the comparative anatomy of the Decapods which we owe to various French observers, there is still need of an account of the organization of a hermit-crab. In that *Coenobita* presents the Pagurine type in its most highly developed form (at least as regards many of the organs), it is the most suitable genus for this purpose. In that it contains land animals only, and is not found in Europe or temperate North America, it is less so. I have endeavoured to overcome this difficulty by indicating, in the course of the article, those points in which, to my knowledge, *Coenobita* differs from the hermit-crabs of the sea (Paguridae). My dissections have been made on fresh and spirit specimens of the Minikoi species[3] only, and principally on *C. clypeatus* and *C. perlatus*, but, in the few cases where other information has been available, it has been used to check the dissections. Except in a few instances, the musculature has not been dealt with, and histological details have been entirely avoided.

The introduction to this paper would not be complete without an acknowledgment of the generosity of the Drapers' Company of London and of the Managers of the Balfour

[1] See below, p. 95.

[2] See *e.g.* Alcock, *Sci. Mem. Med. Off. Ind.*, XII, p. 59 (1901).

[3] See below, p. 68.

Memorial Fund, by which I was enabled to visit Ceylon and join Mr Stanley Gardiner's expedition, and to undertake, among other pieces of work, that which is here set forth. My best thanks are also due to Mr Stanley Gardiner for much kind advice and assistance, and to Mr Edwin Wilson for the care which he has bestowed upon the illustrations.

II. The Land Crustaceans of Minikoi.

1. General.

The dozen crustacean species living on land in the Island of Minikoi more than make up in number and activity for their comparative poverty in kinds. They are certainly the most conspicuous, as they are probably the most numerous, animals in the island. The Crabs are represented by six species only. Living in burrows, close along the high-water mark of the sandy shore of the lagoon, the sage-green and yellow coloured *Ocypode ceratophthalma* (Pallas) is very numerous. Inland, the place of this species is taken by the brownish *Ocypode cordimana* Desm., whose underground galleries are plentiful in the sandy soil, especially along paths and open spaces. Two species of *Geograpsus*—*G. grayi* (H. M.-Edw.) and *G. crinipes* (Dana)—are common, the former more so than the latter, which seems to like damp spots by the side of pools and tanks of fresh water for which *G. grayi* shows no great preference. These active and conspicuous species, though they are rather hard to distinguish as spirit specimens, are perfectly distinct in life, their colour alone serving to separate them, were there no other differences. *G. grayi* gives the impression of being black and white (in point of fact the back is purple and the legs and underside yellowish), while *G. crinipes* is of a bright orange colour[1].

Another small Grapsid belongs to Kingsley's subgenus *Orthograpsus*[2], which is included by Alcock[3] in the genus *Geograpsus*, Stimps. Unfortunately, a part of the Minikoi collection was damaged on the way home, and there are left of this crab only two badly mangled specimens. So far as can be seen from these, it is near to, but not the same as, Dana's *Grapsus longitarsis*[4]. The points in which the two forms differ are as follows (fig. 12):—1. In the Minikoi specimens the teeth on the underside of the outer end of the meropodites of the walking legs are low and blunt, and much less marked than in Dana's figure. 2. The same is the case with the tooth at the end of the upper edge of this joint. 3. The hairy line along the dactylopodites of the walking legs is wanting. 4. The tooth at the outer angle of the orbit is shorter than in *G. longitarsis*. It shields only about a fourth of the cornea, instead of more than a half, as in Dana's figure. The colour of the crab when alive is a dull brownish-green, and is not much altered by preservation in spirit. The length is about half an inch.

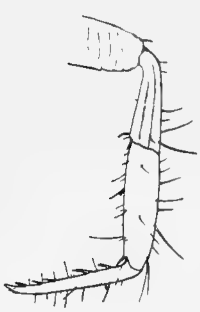


Fig. 12. Second walking leg of right side of *Geograpsus longitarsis*, var. *minikoiensis*.

In the absence of better material, I am unwilling to give any opinion as to the specific distinctness of this little crab. In the list below[5], it will appear as a variety (*minikoiensis*) of Dana's species.

The last of the crabs, the little *Metasesarma rousseauxi* H. M.-Edw., is

[1] For a careful discussion of the differences between these species, see De Man, *Zool. Jahrb. Syst.* ix. pp. 80 ff. (1895).

[2] Kingsley, *P. Acad. Philad.* 1880, pp. 180, 194 (1880).

[3] Alcock, *Journ. As. Soc. Bengal*, lxix. ii. 3, p. 394 (1900).

[4] For references to literature see below, p. 68.

[5] p. 67.

found in various situations, generally taking advantage of the shelter of some object. It often hides under timber, where, as Dr Alcock remarks[1], its greenish mottled coloration is protective. De Man records[2] some examples of this species from a stream in Flores, but it is certainly not restricted to the water, nor even to particularly damp spots. With the exception of *Geograpsus longitarsis*, all the above crabs are included by Major Alcock among the Indian Fauna[3].

The land hermit-crabs (genus *Coenobita*) are no less numerous than the true crabs on Minikoi. Three species are found—*C. perlatus* H. M.-Edw., *C. rugosus* H. M.-Edw. and *C. clypeatus* Latr. Of these the first two show a preference for the neighbourhood of salt water, while the third is chiefly to be found in the jungle. I shall return, later on, to the subject of the genus *Coenobita*.

Three species of Isopod make up the tale of Minikoi land Crustaceans to twelve. Two woodlice, belonging respectively to the genera *Cubaris* and *Philoscia*, are found, as might be expected, in rotten timber and loose earth, while a *Ligia* (*L. exotica* Roux) lives in certain localities along the lagoon shore, and is chiefly conspicuous in running about on boats drawn up on the beach.

The following is a complete systematic list of the land Crustacea of Minikoi:—

DECAPODA, BRACHYURA, CATOMETOPA.

Family **Ocypodidae**. Genus *Ocypode*, Fabr., 1798[4].

1. *Ocypode ceratophthalma* (Pallas), 1772.
   Cancer ceratophthalmus, Pallas, Spicilegia Zool. IX. p. 83, pl. V. figs. 7, 8 (1772).
   Ocypoda ceratophthalma, Ortmann, Zool. Jahrb. Syst. X. p. 365 (1897) [synonyms]; Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 345 (1900).

2. *Ocypode cordimana* Desm., 1825.
   Ocypoda cordimana, Desmarest, Consid. gen. Crust. p. 121 (1825); Ortmann, Zool. Jahrb. Syst. X. p. 362 (1897) [synonyms]; Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 349 (1900).

Family **Grapsidae**. Genus *Geograpsus*, Stimps., 1858.

3. *Geograpsus grayi* (H. M.-Edw.), 1853.
   Grapsus grayi, H. Milne-Edwards, Ann. Sci. Nat. Zool. (3) XX. p. 170 (1853).
   Geograpsus grayi, Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 395 (1900) [synonyms].

4. *Geograpsus crinipes* (Dana), 1851.
   Grapsus crinipes, Dana, Proc. Ac. Philad. 1851, p. 101.
   Geograpsus crinipes, Alcock, Journ. As. Soc. Bengal LXIX. ii. 3, p. 396 [synonyms].

[1] Alcock, *op. cit.*, p. 428.

[2] De Man, Max Weber's "Reise O. I." II. p. 350 (1892).

[3] Alcock, *op. cit.*, *passim*.

[4] Ortmann [*Zool. Jahrb. Syst.* X. p. 359 (1897)] states that Fabricius spelt this name *Ocypoda*. In the copies of the *Ent. Syst. Suppl.* in the Cambridge University and Zoological Society's libraries the spelling is *Ocypode*.

5. *Geograpsus longitarsis* (Dana), 1851, var. *minikoiensis* n. (fig. 12).
Grapsus longitarsis, Dana, Proc. Ac. Philad. 1851, p. 249; U.S. Expl. Expd. Crust. I. p. 339, pl. XXI. fig. 4 (1852).
Orthograpsus longitarsis, Kingsley, Proc. Ac. Philad. 1880, p. 195.

Genus *Metasesarma*, H. M.-Edw., 1853.

6. *Metasesarma rousseauxi* H. M.-Edw., 1853.
Metasesarma rousseauxi, H. Milne-Edwards, Ann. Sci. Nat., Zool. (3) XX. p. 188 (1853); De Man, Zool. Jahrb. IX. Syst. p. 138 (1895); Alcock, Journ. As. Soc. Bengal, LXIX. ii. 3, p. 427 (1900).

ANOMALA, PAGURINEA.

Family **Coenobitidae.** Genus *Coenobita*, Latr., 1826.

7. *Coenobita perlatus* H. M.-Edw., 1837.
Cenobita perlata, H. Milne-Edwards, Hist. Nat. Crust. II. p. 242 (1837); Id. Atlas to Crust. Cuvier's R. An. pl. XLIV. fig. 1.
Cenobita perlatus, Ortmann, Zool. Jahrb. Syst. VI. p. 319 (1892) [synonyms].

8. *Coenobita rugosus* H. M.-Edw., 1837.
Cenobita rugosa, H. Milne-Edwards, Hist. Nat. Crust. II. p. 241 (1837).
Coenbita rugosus, Ortmann, Zool. Jahrb. Syst. VI. p. 317, pl. XII. fig. 22 (1892) [synonyms].

9. *Coenobita clypeatus* Latr., 1826. (Fig. 13.)
Coenobita clypeata, Latreille, Fam. Nat. R. An. p. 277 (1826).
Coenobita clypeatus, Ortmann, Zool. Jahrb. Syst. VI. p. 315, pl. XII. fig. 20 (1892) [synonyms].

ISOPODA, ONISCOIDEA.

Family **Armadillidiidae.** Genus *Cubaris*, Brandt, 1833.

10. *Cubaris murinus* Brandt, 1833.
Cubaris murinus, Brandt, Consp. Onisc., Bull. Soc. Nat. Mosc. VI. p. 190 (1833).
Armadillo murinus, Budde-Lund, Crust. Isop. Terrestr. p. 27. Hauniae, 1885 [synonyms].

Genus *Philoscia*, Latr., 1803.

11. *Philoscia*, sp.
Near *P. gracilis* Budde-Lund, 1879, but cannot be more accurately determined, as the single specimen now available for examination is in a somewhat damaged condition, and has lost both uropods.

Family **Ligiidae.** Genus *Ligia*, Fabr., 1798.

12. *Ligia exotica* Roux, 1828.
Ligia exotica, Roux, Crust. Médit. 3, pl. XIII. fig. 3 (1828); Budde-Lund, Crust. Isop. Terrestr. p. 266. Hauniae, 1885 [synonyms].

2. Some points in the structure and habits of the land hermit-crabs (*Coenobita*).

i. **External features.**

The genus *Coenobita* contains those hermit-crabs which have left the sea and taken to a life on land, but have not, like *Birgus*, lost the habit of shielding the abdomen with a shell, or some such covering. In their outer, as in their inner organisation, the members of the genus closely resemble the hermit-crabs of the sea, and even present many

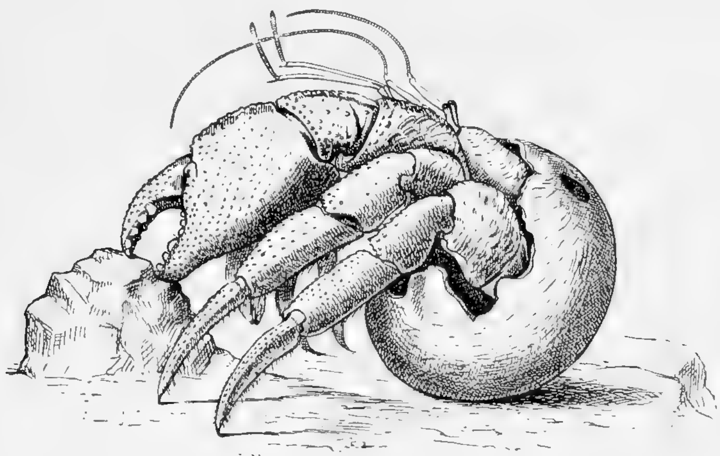


Fig. 13. *Coenobita clypeatus* using a broken coconut as shell.

characteristic features of Pagurine[1] structure in a more highly developed form than any other branch of the group. The most striking of these features are, of course, those connected with the habit of sheltering within the empty shell of a gastropod mollusk, and it is perhaps worth while recapitulating them, even at the risk of ploughing the sands of well-known fact.

Physiologically, then, the body may be divided into three regions as regards its outward aspect: (1) a *fore-part* carrying the complex of organs—sensory structures, legs and jaws—by which the animal enters into relation with the outer world, and containing internally the central nervous system and stomach, both intimately connected with the external organs just mentioned, and the excretory organs. This part of the body can be completely extruded from the shell, while the animal still retains a firm hold on the latter. (2) A *mid-part*, which, when the fore-part is thrust out, fills the mouth of the shell, and is provided with limbs, which help in retaining a grasp of it. This region carries the main respiratory apparatus—delicate organs which need a certain amount of protection and yet should be in free communication with the surrounding medium—and the heart. (3) A *hind-part*—the abdomen—which contains the bulky liver and the generative organs, and carries on its appendages the eggs, which thus obtain the shelter provided by the shell. This division of the body, which is at all times completely protected by the shell, is also provided with an apparatus by means of which, in normal circumstances, the latter is retained. This apparatus consists of an anchor, formed by the sixth abdominal segment and its appendages (fig. 18), and a broad band of muscle—the cable of the anchor—along the ventral side of the abdomen, serving roughly the same purpose as the columella muscle of the original maker of the shell.

[1] In the present article, the term "Pagurine" will be used to include the most typical members of the Pagurinea—the Paguridae and the Coenobitidae. The word "Pagurid" will be applied to the former of the two families alone.

The *fore-part of the cephalothorax* is strongly compressed, having a narrow, vaulted roof and flat vertical sides. Its compression extends also to the antennae and the first three pairs of legs, enabling the whole complex, including the limbs, to be withdrawn into shelter when necessary. The absence of the rostrum is, no doubt, an adaptation to the same end. The cuticle over the whole of these exposed structures is strongly calcified.

The *eyestalks* are narrow and elongated and directed straight forwards above the antennules; the eyes themselves are small. Some rather abnormal features appear in the *antennules* (fig. 14). By the lengthening of their joints, the stalks of these appendages far outreach those of the antennae, bearing at their ends each a long and a short flagellum, the whole being able to be folded up lengthwise and concealed under the body. The long flagellum, which is the more dorsal of the two, is compressed and club-shaped, with a blunt, rounded end. Its lower edge is covered, in the distal two-thirds, with a close fur of short "olfactory" hairs[1]. The short flagellum tapers at the end, and bears on the penultimate joint a long bristle, which looks as if it were adapted for cleaning the olfactory hairs of the long flagellum. The opening of the otocyst is small, but situated in its usual position on the dorsal side of the basal joint of this limb. The antennules of the Pagurids (fig. 14), on the other hand, are relatively short, and bear each two short flagella, like those of the crabs. The dorsal (outer) flagellum tapers to a point and bears below a fringe of olfactory hairs much longer than those of *Coenobita*. These peculiarities of *Coenobita* are perhaps in connection with the habit of exercising the sense of smell in the search for food[2], and that in a different medium from the one in which the Paguridae live, while at the same time it is necessary that the organs be able to be withdrawn into a small space.

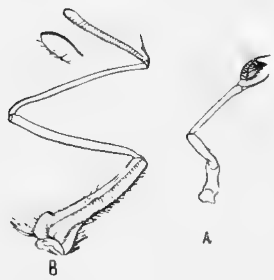


Fig. 14. Left Antennules. A. *Eupagurus bernhardus*; B. *Coenobita clypeatus*.

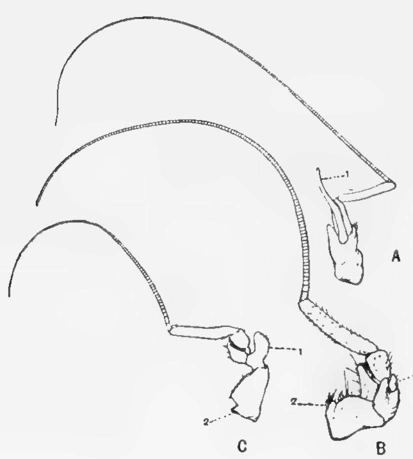


Fig. 15. Left Antennae. A. *Eupagurus bernhardus*; B. *Coenobita clypeatus*; C. *Coenobita perlatus*. 1. Antennal scale. 2. Tubercle with opening of green gland (not seen in A).

The scale of the *antenna* (fig. 15), which in the Pagurids is well developed and moveable, is, in *Coenobita*, reduced in size and, except in one instance[3], fused with the second joint of the flattened stalk of the limb. The flagellum ends bluntly instead of tapering to a point like those of most marine Decapods—a feature, which must probably be attributed to the same cause, which has shortened the sensory hairs of the antennule. The *mouth-limbs* (fig. 16) present no remarkable features. They are all stout and show a tendency to develope tufts and fringes of strong, close set, hairs. The powerful cutting edge of the mandible is not toothed, and the lash of the exopodite of the first maxilliped is wanting.

[1] The statement of Ortmann [Bronn's *Thierreich*, v. 2, p. 1146] that these appendages "langen Sinneshaare entbehren" is thus somewhat misleading, though strictly true. The shortness of the hairs, which would be apt to become matted in the absence of a supporting medium such as water, is no doubt an adaptation to terrestrial life.

[2] See below, p. 92.

[3] *C. clypeatus*, Latr.

The *legs* (figs. 13 and 17) of the first pair are unequal, though both are chelate. The larger, left chela, used for seizing and holding the food and as a weapon of offence and defence, serves, when the animal is withdrawn into the shell, as a very perfect lid or operculum, for which purpose its stout, rounded shape is clearly adapted. It may also (*C. rugosus* A, fig. 17) bear a stridulating organ in the form of a series of parallel ridges on its outer surface. The smaller chela is used for tearing the food and conveying the fragments to the mouth. The second and third pairs of legs are adapted for walking.

The *hinder part of the thorax*, forming the middle of the three regions alluded to above, may be said to begin at the level of the transverse portion of the cervical groove and to include the two hinder pairs of legs. It is distinguished from the preceding region by

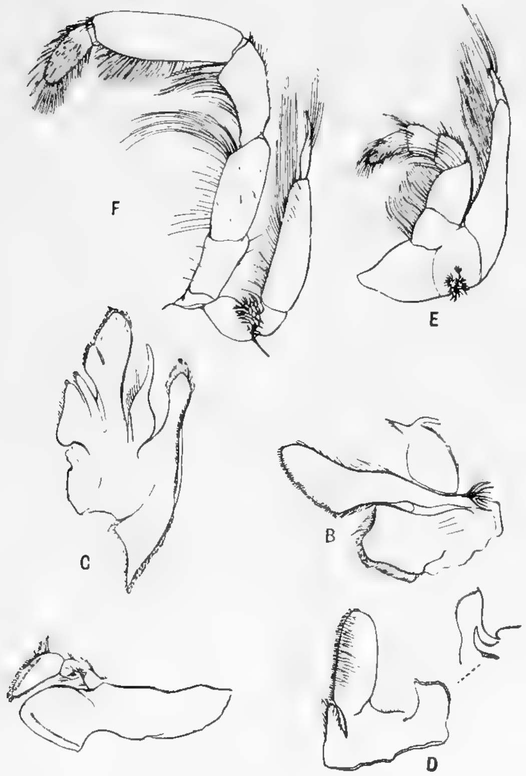


Fig. 16. Mouth-limbs of the left side of *Coenobita clypeatus* from behind. A. Mandible; B. 1st maxilla; C. 2nd maxilla; D. 1st maxilliped; E. 2nd maxilliped; F. 3rd maxilliped. A small portion of the anterior side of D is attached to show the endopodite.

In *Pagurus* the maxillipeds bear on their exopodites long, slender, curved lashes, fringed with fine hairs and much resembling those of many crabs. The absence of these structures in *Coenobita* is perhaps due to the loss of their functions in the absence of water. The little backward hook on the first maxilla is wanting in *Pagurus*.

being rather depressed than compressed and by less strong calcification of its integument. The branchiostegites, which anteriorly share in the general compression and calcification of the body, are here soft and tend to be depressed. But the legs of the fourth pair are carried pressed up against the sides of the body in such a way that the soft branchiostegites are indented by them and only project dorsally and posteriorly where they overhang the limbs in question. Behind, the branchiostegites gape widely from the body, and leave an opening, through which the legs of the fifth pair can be thrust into the gill chamber.

The *fourth and fifth legs* (B—E, fig. 17) of each side are markedly smaller than the preceding ones. Each of them is chelate after its own fashion, and each bears a part in the work of holding the animal into its shell. This is accomplished by means of a definite patch on the propodite of the limb, which is covered with a fine sculpture in the form of rounded scales, overlapping one another so as to produce a surface capable of friction. In cases, which often occur, when the animal, either from its size, or from the lack of suitable gastropod shells, is forced to content itself with some other receptacle for its abdomen[1], these limbs have to take a larger share of the work in which they ordinarily assist the sixth abdominal appendages, of keeping on the "house." It is probably by their means also that the animal is able to emerge from the shell when it is inverted. The chela of the *fourth leg* is of a peculiar nature. The propodite, on which the above-mentioned patch is developed, is a broad, discoidal structure. Against this disk fits a little sickle-shaped dactyle. In *Pagurus* the limb more nearly approaches a normal chela, in *Eupagurus* it is sub-chelate. The *fifth leg* has a chela which is clumsy, but of the ordinary shape, with two approximately equal fingers. As in the other forms (Anomala) in which it is a gill-cleaning organ, it is covered with hairs and usually carried under the branchiostegite during life, though upon occasion it can be used to assist in retaining hold of the shell.

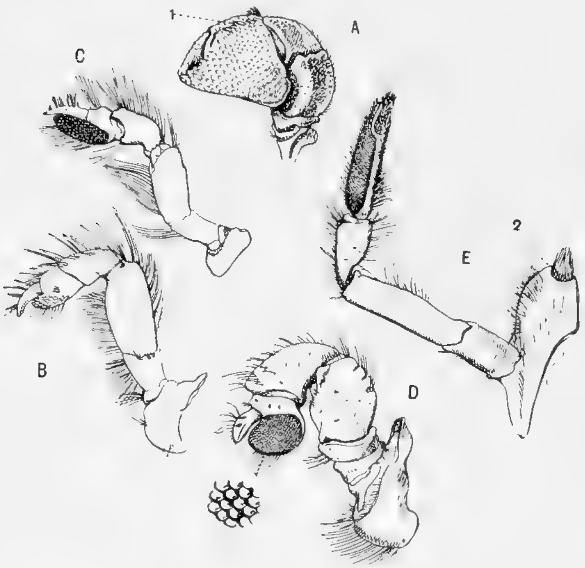


FIG. 17. Legs of hermit-crabs from left side. A. 1st leg (cheliped), *Coenobita rugosus*; B. 4th leg, *Eupagurus bernhardus*; C. 4th leg, *Pagurus deformis*; D. 4th leg, *Coenobita clypeatus*; E. 5th leg, *Coenobita clypeatus*. 1. Stridulating organ. 2. Male generative opening.

The *abdomen* is connected by a narrow waist with the thorax. It is covered with a soft, flexible skin, save for a narrow transverse ridge representing the tergite of each of the first five abdominal segments, and broader plates on the sixth segment and telson. The whole is spirally twisted to the right, to fit in with the dextral twist of an ordinary gastropod shell. In correspondence with this twist, the appendages are also asymmetrical. In the male they are absent from the first five segments[2], but in the female the second, third and fourth are provided, on the left side with long, biramous limbs, covered with hairs and used in the breeding season for carrying the eggs. The sixth pair of abdominal limbs (fig. 18) are present in both sexes, but that of the right side is larger than that of the left. The exopodite is sickle-shaped and longer than the endopodite; both are provided, on the outer surface, with friction organs like those of the last two thoracic legs, and the function of the whole limb is obviously to anchor the animal into its shell.

[1] *e.g.* the shell of the fruit of *Calophyllum* or of the coconut. See p. 92.

[2] *C. clypeatus* has short, uniramous limbs on the left side in the 2nd, 3rd and 4th abdominal segments of the male.

The family Coenobitidae, containing besides *Coenobita* the Robber-Crab *Birgus*, differs from the Pagurids, or hermit-crabs of the sea[1], in the following external features:—1. The structure of the antennules (*see above*). 2. The structure of the antennae (*see above*). 3. The greater compression of the fore-part of the body. 4. The habitat—on land.

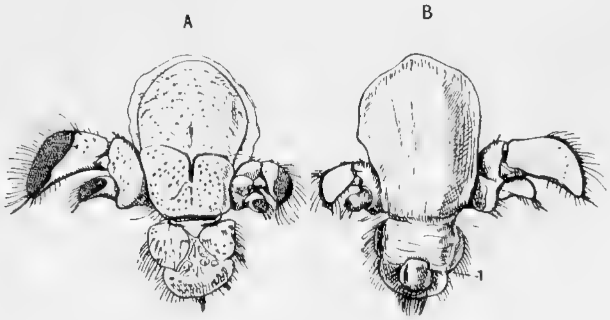


FIG. 18. Last two abdominal segments of *Coenobita clypeatus*. A. Dorsal view; B. Ventral view. 1. Valve guarding the anus.

The genus *Coenobita* differs from *Birgus* in the form of the abdomen, which in *Birgus* is short, untwisted, provided with broad terga, and not carried in a shell. The points in which the outward features of *Coenobita* vary from species to species are small and unimportant. The most interesting is perhaps that which separates *C. clypeatus* Latr. from the rest of the genus. In this species the vestige of the antennal scale is still loosely articulated with the stalk. In all the others it is fused. *C. diogenes* (Catesby) is distinguished by its cylindrical eyestalks from the other species, in which these structures are always compressed. Of the remaining four forms, *C. rugosus* H. M.-Edw. and *C. perlatus* H. M.-Edw. are distinguished from *C. compressus* Guérin and *C. spinosus* H. M.-Edw. by the elongation of the basal joint of the fifth leg of the male into a genital process, and by the presence of stridulating ridges on the outside of the hand (propodite). The small grey or purple *C. rugosus* is very variable (Bouvier[2] enumerates several varieties), but may be easily distinguished from the larger, scarlet, *C. perlatus* by the greater development in the latter of the genital process. *C. compressus* is recognisable by its small size, grey, or purple colour and less hairy integument from *C. spinosus*, which is larger, of a brown colour, and considerably hairy in parts. The last revision—and the one adopted in this paper—is to be found in Ortmann's well-known work on the Decapods of the Strassburg Museum[3]. It differs in several points from that of Bouvier[4], but has the merits of simplicity and clearness, and has satisfactorily accounted, so far, for every one out of the many specimens that have passed through my hands.

The distribution of the genus would appear, from the data in Ortmann's paper and others since published, to be as follows:—*C. diogenes* is found in the West Indian region alone, and is the only representative of the genus there. The other species are all restricted to the Indo-Pacific area, but are there of almost universal distribution, *C. rugosus* being perhaps the most widespread.

[1] See footnote to p. 69 above.

[2] Bouvier, *Bull. Soc. Philem.*, Paris, (8), II. p. 143 (1890).

[3] Ortmann, *Zool. Jahrb. Syst.*, VI. p. 315 (1892).

[4] Bouvier, *loc. cit.*

ii. **The Alimentary Canal.**

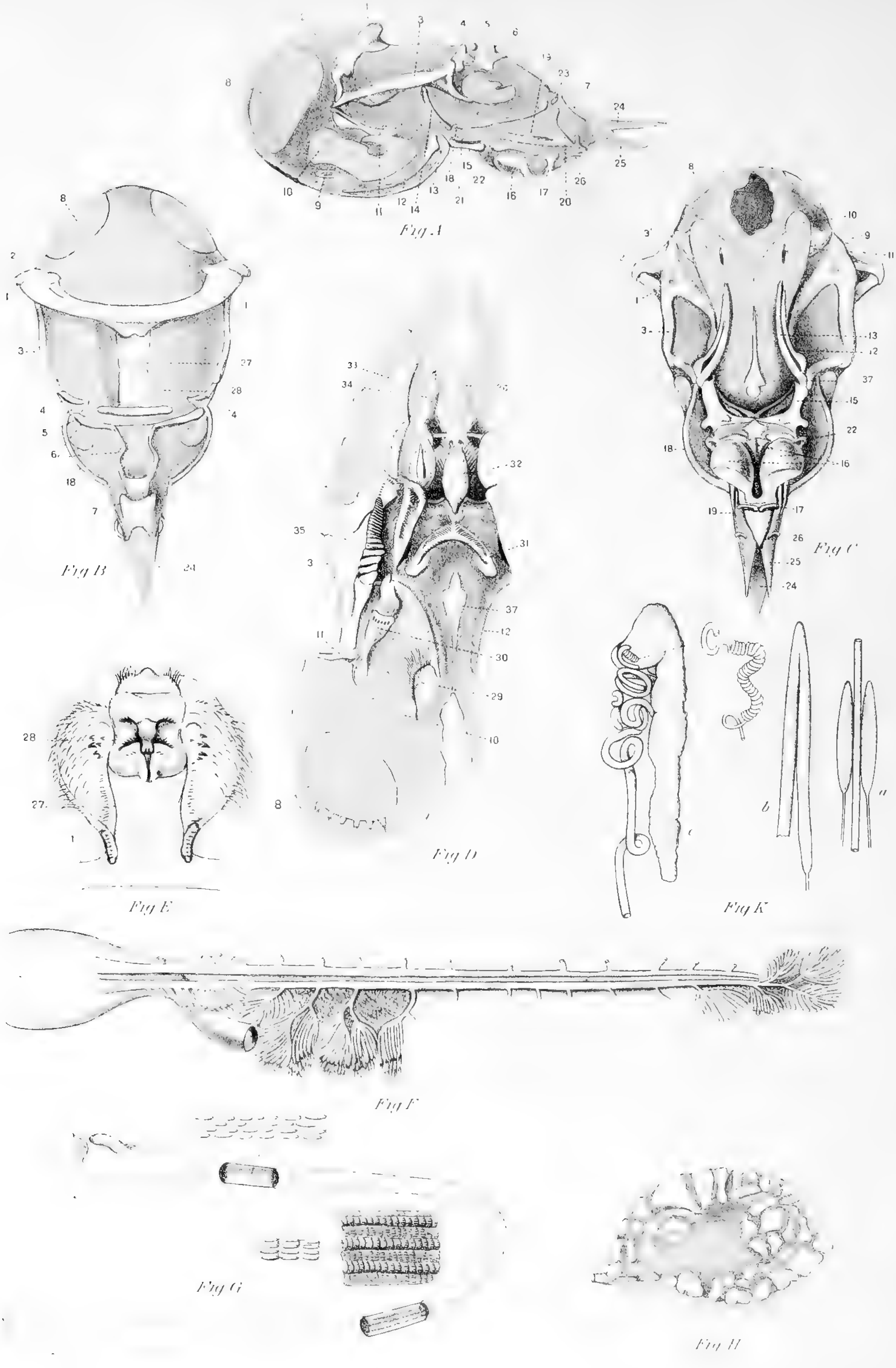
A. The Fore-gut[1]. (Pl. III. figs. A—E). The short, wide *oesophagus* presents no feature of special interest. In correspondence with the compression of the fore-part of the cephalothorax mentioned above[2], the *Maw* or "*Stomach*" is narrow and elongated. The hinder or "pyloric" division is nearly horizontal, and is sundered from the anterior "cardiac" portion by the usual deep hollow on the dorsal surface of the stomach. The *cardiac sac* is narrow, rounded in front and somewhat flattened above. The walls of its thin fore-part show on each side the thickened "cardiac disk" found in other Pagurinea (8, Pl. III.). Internally, this disk bears seven or eight tufts of long hairs, placed on pointed prominences arranged along its lower edge.

The *gastric mill* is strong, no doubt in connection with the nature of the food, which is chiefly vegetable, and often consists of such tough substances as the fruits of the screw-pine (*Pandanus*). In the *mesocardiac ossicle* (1, Pl. III.), the most prominent part is a strong band across the roof of the cardiac division of the stomach, bent in the form of a bow, and lying with the hollowed side forward; its ends are broadened. In front of this is a thinner portion, which merges gradually into the thin wall of the fore-part of the stomach. Behind the ossicle the roof of the stomach falls away into the hollow between the two divisions. The rounded hinder edge of the bow projects somewhat over this gap, and overhangs a wide, triangular process from its own underside, which forms part of the hind wall of the cardiac portion—the anterior wall of the hollow. The apex of this triangular plate, by which it joins the fore end of the urocardiac ossicle, is not pointed, but ends in two rounded lobes, of a bright white colour and strongly calcified. The *pterocardiac ossicles* (2, Pl. III.) are triangular or rather three-lobed structures in the side wall of the cardiac division, at the outer ends of the bow of the mesocardiac. One lobe is directed outwards, one inwards, and one downwards. Between the outward and the inward lobes lies that edge of the ossicle which articulates with the broadened outer end of the meso-cardiac bow. The *zygocardiac ossicles* (3, Pl. III.[3]) also lie in the side walls of the stomach, but behind the mesocardiac. Each is a roughly diamond-shaped plate of large size, placed so that its longer diagonal runs fore and aft. There are thus an anterior and a hinder angle. The latter is directed somewhat downwards, so that, of the two edges of the diamond which are uppermost, the hinder slopes downwards, while the more anterior is almost horizontal. This latter edge is much thickened and curled inwards, towards the cavity of the stomach. The other edges are also thickened, though not to the same extent. The *lateral tooth* (35, Pl. III.), borne internally by the zygocardiac ossicle of each side, is strong, and bears a series of transverse ridges which grow smaller from before backwards. The first three or four of these are much larger than the hinder ones, and are set farther apart.

[1] In writing the following account of the fore-gut and its armature in *Coenobita*, I have been much helped by Mocquard's work on these organs of the Decapoda [*Ann. Sci. Nat.* (6) *Zool.* XVI. i. (1883)], and especially by the numerous allusions to this genus scattered through his section on the Pagurinea. Though he figures no *Coenobita*, Mocquard had dissected three species—*C. compressus*, *C. spinosus*, and a third whose name he did not know. The present account is based on the information given by Mocquard and on dissections of the three Minikoi species. Thus the total material available has reference to at least five out of the six species of the genus.

[2] p. 70.

[3] This ossicle is so placed that it overhangs and presents one face downwards and an edge (the horizontal one) outwards. Its shape is therefore not properly seen in a full side view and cannot be made out in fig. A, Pl. III. but may be seen in the ventral view (fig. C).



Figs A-F. F.W. del.

E. Wilson Cambridge.

Borradaile - Coenobita

The *exopyloric ossicles* (4, Pl. III.), which lie in the roof of the pyloric division of the stomach to the outside, and rather in front, of the medium pyloric ossicle, bearing to this latter much the same relation that the pterocardiacs bear to the mesocardiac, are stout, broad, and roughly diamond-shaped. One diagonal runs transversely and the other fore and aft. The hinder angle is rounded. The whole ossicle has a saddle-like double curvature, and its outer surface is roughened. The *pyloric ossicle* (6, Pl. III.) consists of two parts—an anterior expansion, and a hindward median process from this. The anterior expansion lies with its long axis across the stomach. Its outer ends are thickened, and so shaped as to embrace the ends of the prepyloric ossicle. These thickenings each send backward a very narrow strip to border the hindward process of the ossicle. The whole middle region of the ossicle, between the thickenings, is thin, and of a membranous, or, in the hinder part, cartilaginous consistency.

The *urocardiac ossicle* (27, Pl. III.) is an oblong, semi-transparent plate, of simple form, lying in the anterior wall of the dorsal hollow of the stomach, with its long axis fore and aft. Its anterior end abuts on the mesocardiac ossicle, from which, however, it is

EXPLANATION OF PLATE III.

Reference Numbers.

1. Mesocardiac ossicle
2. Pterocardiac ,,
3. Zygocardiac ,, horizontal (upper) edge
3′. Zygocardiac ,, anterior angle
4. Exopyloric ,,
5. Prepyloric ,,
6. Pyloric ,,
7. Uropyloric ,,
8. Cardiac disk ,,
9. Opening of invagination to bear postoesophageal brush
10. Cardiac side plate
11. Prepectinate ossicle
12. Pennate ,,
13. Inferolateral cardiac ossicle
14. Subdentary ossicle
15. Auricular ,,
16. Ampullar ,,
17. Posterior subampullar ossicle
18. Anterior pleuropyloric ,,
19. Middle pleuropyloric ossicle
20. Posterior ,, ,,
21. Anterior subampullar ,,
22. Middle ,, ,,
23. Posterior mesopyloric ,,
24. Dorsal terminal valve
25. Lateral ,, ,,
26. Ventral ,, ,,
27. Urocardiac ossicle
28. Median tooth
29. Postoesophageal brush
30. Comb
31. Median inferior tooth
32. Interampullary process
33. Upper pyloric side-valve
34. Lower ,, ,,
35. Lateral tooth
36. Interampullary valve (overlying ventral terminal valve)

Fig. A. Stomach of *Coenobita perlatus* from the left side.

Fig. B. Ditto, from above.

Fig. C. Ditto, from below.

Fig. D. Ditto, with roof of cardiac portion removed and the pyloric portion opened along the middle of the roof, the side walls being reflected.

Fig. E. Median tooth of same from within.

Fig. F. Liver of *Coenobita clypeatus*, ventral view.

Fig. G. Mid- and hind-gut of same species; portions opened to show texture of lining.

Fig. H. Green gland of same species from above.

Fig. K. Generative glands; *a*, ovaries of *Coenobita clypeatus*; *b*, ovaries of *C. perlatus*; *c*, testis of *C. clypeatus*. Anterior end towards bottom of plate in each case.

sharply marked off. The *median tooth* (28, Pl. III.), is large and well-developed. It is an oblong plate, somewhat shorter than the urocardiac ossicle, at the hinder end of which it is placed, and with concave sides. The inner surface bears a median longitudinal and four or five pairs of lateral transverse ridges, of which the two hindermost are the stoutest. The details vary considerably in different species[1]. The *prepyloric ossicle* (5, Pl. III.) is a **T**-shaped structure, placed vertically in the front wall of the pyloric division of the stomach, *i.e.* in that wall which faces the hollow between the two divisions. The stem of the **T** has concave sides and broadens considerably, where it joins the cross-piece. The latter is slightly concave on its anterior side.

The ossicles described in the foregoing paragraphs constitute the gastric mill, and, with the muscles which move them, are the apparatus by which the food is triturated. To complete the account of the skeleton of the stomach it is now necessary to mention certain less important pieces, by which the organ maintains its shape, and which support internally the various tufts and fringes of hairs with which it is provided. We may consider these in four groups:—

(1) Those of the cardiac region, all of which lie in the ventral, or ventro-lateral wall. They comprise the cardiac disks (described above), the post-oesophageal brushes, the cardiac side-plates, the prepectinate ossicles, the combs, subdentary, pennate and inferolateral cardiac ossicles, and the cardiopyloric valve.

(2) Those on the ventral wall of the pyloric region; comprising the auricular, anteroinferior pyloric, preampullar, and posterior subampullar ossicles.

(3) Those at the sides of the pyloric region; comprising the anterior, middle, and posterior pleuropyloric and anterior and middle subampullar ossicles.

(4) Those in the dorsal wall of the pyloric region; comprising the mesopyloric and uropyloric ossicles.

Group 1. *Postoesophageal brushes* (29, Pl. III.). A patch of hairs on each side of the stomach, situate on a lobe formed by invagination of the wall on the ventral side, a little behind the oesophagus. The outer opening of the invagination is surrounded by a calcified ring.

Cardiac side-plates (10, Pl. III.). Large thickenings of the ventrolateral wall behind the oesophagus. They are covered internally with tufts of hairs, especially long towards the hinder end.

Prepectinate ossicles (11, Pl. III.). Elongated plates in the side wall of the stomach, above the cardiac side-plates. The fore end of each is thin and expanded and the upper edge thickened along its whole length, but especially at the hinder end.

Combs (30, Pl. III.). An invagination of the wall of the stomach at the hind end of the prepectinate ossicle of each side, producing internally a cushion on which are a number of short, stout spines.

Pectinate and post-pectinate ossicles are wanting.

Subdentary ossicles (14, Pl. III.). A slender bar running backward and downward on each side from the zygocardiac ossicle to the fore end of the anterior subampullary ossicle, with which and not with the inferolateral cardiac ossicle, it articulates.

Pennate and inferolateral cardiac ossicles (12 and 13, Pl. III.). Two slender bars running parallel with one another along the line of junction of the ventral and lateral walls of the stomach, which line is defined by their presence. At their hinder ends they curve upwards, in corre-

[1] See Mocquard, *op. cit.*, p. 131.

spondence with the diminishing height of the cardiac division. Each of them grows gradually broader from before backwards, and is expanded at its posterior end. The ventral surface of the stomach, between the two inferolateral cardiac ossicles, is thickened on each side into a plate of cartilaginous consistency. In the middle line these two plates are sundered by a strip of thin chitin, in which lies a median ossicle having the shape of a dagger, placed lengthwise with the blade forwards. The pennate ossicle, which is the more dorsal of the two, bears internally a fringe of long hairs.

Cardiopyloric valve (31, Pl. III.). This has the form peculiar to the Pagurinea and Galatheinea; that is to say, it bears a **V**-shaped elevation composed of close-set lamellae not unlike the ridges of a file. The lamellae are flexible and the point of the **V** is backwards. The whole structure is known as the "median inferior tooth."

Lateral cardiopyloric ossicles are wanting.

Group 2. *Auricular ossicles* (15, Pl. III.). A pair of stout troughs, running backwards and inwards from the hinder ends of the inferolateral cardiac ossicles, on the ventral side of the stomach. The hollow of the trough is towards the inside of the stomach, and the hind end of each is expanded and less stout than its fore-part. There are no auricles.

Anteroinferior pyloric ossicles. A semi-transparent, four sided, median plate with a triangular projection from the middle of its fore edge. Behind it, and separated from it by the inner ends of the preampullar ossicles, are two small, semi-transparent, triangular plates, one on each side of the middle line.

Preampullar ossicles. Semi-transparent, transverse plates, just in front of the ampullae on the floor of the pyloric division.

Posterior subampullar ossicles (17, Pl. III.). Stout transverse bars, one on each side just behind the ampullae. Their inner ends are expanded and meet, but do not fuse.

Group 3. *Anterior pleuropyloric ossicles* (18, Pl. III.). Each of these starts at its hinder end by a roughly triangular expansion, with the apex directed downward and forward. From this apex proceeds a stout ridge on the side wall of the stomach, which, running forward, ends by articulating with the ventral end of the subdentary. The lower side of the ridge bears a triangular expansion. In the space between this ossicle and the pyloric, the wall of the stomach is thickened to form a cartilaginous plate.

Middle pleuropyloric ossicles (19, Pl. III.). A slender horizontal rod, behind and below the preceding ossicle on each side.

Posterior pleuropyloric ossicles (20, Pl. III.). A short, curved bar, with the convexity forwards, behind the middle pleuropyloric of each side.

Anterior subampullar ossicles (21, Pl. III.). An elongated calcified strip, hollowed on the outer surface, lying above the auricular ossicle of each side.

Middle subampullar ossicles (22, Pl. III.). Thickenings of irregular form, bearing to the ampullae the same relation that the anterior subampullars do to the auricular ossicles.

Group 4. *Uropyloric ossicle* (7, Pl. III.). A broad median plate in the pyloric roof, with the anterior edge very concave, and the anterior angles produced and strongly calcified.

Mesopyloric ossicles. The anterior pair are wanting; the hinder ones (23, Pl. III.) are present as a small oval plate on each side, in front of the uropyloric and outside its produced fore angles.

Internally the pyloric division presents the usual filtering apparatus of valves and fringes without any remarkable features. Of the *terminal valves* the dorsal and lateral are much elongated and pointed.

It will perhaps be of interest here to indicate the bearing of the gastric armature just described on the systematic position of the genus[1]. The following characters belong especially to the fore-gut of the Pagurinea:—(i) The long, narrow shape of the stomach. (ii) The slight inclination of the pyloric region. (iii) The form of the mesocardiac ossicle. (iv) The longitudinal direction of the dorsal edge of the zygocardiac ossicle. (v) The elongation of the cardiac side plates. (vi) The almost horizontal direction of the pennate and inferolateral cardiac ossicles.

Within the Pagurinea, the following characters separate the Coenobitidae[2] from the Paguridae: (i) The lower edge of the cardiac disk has its hairs arranged in tufts on pointed projections of the body of the disk. (ii) The lateral tooth has no notch on its lower edge. (iii) The median tooth carries transverse ridges. (iv) The exopyloric ossicles have a strong saddle-shaped curvature. (v) The pyloric ossicle is expanded and strengthened at its anterior angles.

The differences which separate *Coenobita* from *Birgus* are small, but the following may be mentioned:—(i) The anterior tubercle of the lateral tooth is wanting in *Coenobita*. (ii) The hinder edge of the mesocardiac ossicle is rather more convex than in *Birgus*. (iii) The anterior edge of the cross-piece of the prepyloric ossicle is more concave. (iv) The calcified ring round the opening of the invagination on which the post-oesophageal brush is borne, articulates, in *Birgus*, with an elongated triangular strip in front of the pennate ossicle. (v) In *Birgus*, the cardiac disk and the arrangement of hairs on its lower edge are more developed than in *Coenobita*, and form the "suboesophageal valves" of Mocquard[3].

The *gastric musculature* shows no important difference from that of the Pagurids as figured and described by Mocquard. The strong gastric mill is provided with a correspondingly powerful set of muscles to work it. The *anterior gastric muscles* are a pair of stout strands inserted on the mesocardiac ossicle and diverging slightly as they run forward thence to their origin from the under side of a low, rounded, transverse ridge of the carapace, situated above the bases of the antennae and eye-stalks. This ridge is the "procephalic apophysis." The posterior gastric muscle of each side is divided into two bundles—an inner one, inserted on the thickened plate at the outer end of the pyloric ossicle, and an outer one, somewhat broader than the inner, inserted on the exopyloric ossicle. The origin of the inner bundle is partly from the anterior side of a thin, flat, triangular apophysis, which projects inwards and somewhat forwards from the cervical groove a short distance from the middle line, and partly from the carapace in front of this apophysis[4]. The outer bundle arises in front, and a little to the outside, of the other. The *cardiopyloric* or *superior cardiac muscles* consist on each side of three bands running backwards from the hind edge of the mesocardiac to be attached to the exopyloric ossicle. Of these three,

[1] For the facts on which the following paragraph is based I am indebted to Mocquard (*op. cit.*).

[2] The family Coenobitidae includes the genera *Coenobita* and *Birgus*.

[3] *Ann. Sci. Nat.*, (6), XIII. 3 (1883).

[4] Such an apophysis seems, from Mocquard's remarks on the gastric musculature of *Pagurus*, to be wanting in that genus. It is however present in *Eupagurus bernhardus*, where it is directed *forwards*.

that which is outermost at its origin from the mesocardiac ossicle passes under the middle one and is attached posteriorly between this latter and the inner band[1].

The cardiac disks are provided, as in the other Pagurinea, with *dilator muscles*, running forward to the cephalic wall. Mocquard[2], discussing the working of the gastric musculature of the Decapoda, concludes that the function of the dilators of the stomach[3] is, by enlarging its cavity, to draw into it fluids, carrying with them the solid particles of the food. On the relaxation of the dilators, the constrictors[4] of the stomach will drive out the liquid, while the solid matters will be caught on the filter provided by the hairs on the cardiac disks or elsewhere near the opening of the oesophagus. This theory is very plausible, but there are considerable difficulties in the way of its acceptance in the case of the genus *Coenobita* at least. For the great majority of the food is by these creatures eaten absolutely dry, with only such juices as it naturally contains. If, for instance, an individual be watched in the act of consuming one of its most common articles of food —the fruit of the *Pandanus*—it will be seen to hold the food firmly with the great chela, while the smaller one is employed in stripping off the fibres of the fruit and placing them between the maxillipeds of the third pair, which open to receive them, and then pass them on towards the mouth. They are not immediately rejected, and presumably are sent into the stomach after having undergone a first crushing by the mandibles. In any case the powerful gastric teeth argue a mastication of some part of the food there. Now the *Pandanus*-fibres, and indeed the majority of the food of all sorts, cannot be supposed to contain enough moisture to convey the solid part to the stomach, however much it may be broken up by the mandibles. And the fact that the stomach, when opened, contains but little fluid, precludes the suggestion that its watery contents, passing backward and forward, continually perform the same function of carrying solid food from the mouth to the stomach.

These considerations appear to conclusively negative Mocquard's theory of swallowing in the Decapods. For, although the same difficulty does not exist in marine forms, the similarity of the mechanism in the two cases makes it difficult to suppose that a different method is adopted in each. The subject is at all events worthy of further investigation. It may prove to be the case that the more liquid part of the food is swallowed in the way described by Mocquard (and suggested before him by Parker[5]) while the more solid portion is either rejected or swallowed by some other mechanism, as, for instance, by the constrictors of the oesophagus.

B. The Mid-gut[6]. (Pl. III. figs. F, G.) As in other Decapods, the stomach of *Coeno-*

[1] The mode of action of the gastric mill of Decapoda is discussed in Mocquard's paper and in Huxley's "Invertebrates." Briefly put, it is as follows:—The contraction of the anterior and posterior gastric muscles has the result of bringing the three teeth (median and lateral) together. On their relaxation the ossicles return to their normal position by the elasticity of the stomach-walls, and also partly by the action of the cardiopyloric muscles.

[2] Mocquard, *Ann. Sci. Nat.*, (7), XIII. 3, p. 3 and XVI. 1, p. 255.

[3] Of course the above-mentioned dilators attached to the cephalic disks, though they are the chief, are not the only ones. Setting aside the dilators of the oesophagus and those of the pyloric division, the following, attached on the cardiac half of the stomach, are described by Mocquard; the anterosuperior (on the cephalic disk), the anteroinferior, the anterior and the posterior lateral.

[4] Of these there is one on each side—a band of fibres inserted on the cardiac wall at the front end of the side-plate, and running downwards and a little forwards to the oesophagus.

[5] T. J. Parker, *Journ. Anat. Phys.* XI. p. 59 (1876).

[6] Bouvier, in a short article "Sur la Respiration et quelques dispositions organiques des Paguriens terrestres du Genre Cénobite" [*Bull. Soc. Philomath.*, Paris, (8) II. p. 194 (1839)], remarks briefly on this and other internal organs of *Coenobita*. His observations were made on *C. diogenes*, and it is interesting to find that, so far as they go, they support mine, which relate to the Indo-Pacific species.

bita is followed by the *mid-gut* or *mesenteron*—a short, soft-walled tube, which grows gradually narrower from before backwards in consequence of the difference in width between the pyloric division of the stomach and the hind-gut. Through the roof of the mid-gut there opens on each side a short, curved coecum of simple form with its blind end directed forwards. Through the floor open the two bile ducts.

The Liver (Pl. III. fig. F). The same compression of the thorax, which has affected the shape of the stomach, has brought about the displacement of the liver of the hermit-crabs backwards into the abdomen. Starting from the underside of the mid-gut, one close on each side of the middle line, the bile ducts may be traced backwards below the hind-gut, gradually diminishing in calibre all the way. On its outer side each duct bears, at almost regular intervals, about a dozen stout tubes or primary ductules, the first of which enters nearly at the level of the last thoracic leg. Each of these ductules curves upwards and inwards over the hind-gut, diminishing in diameter by giving off secondary ductules along its outer side. These in turn give off ductules of a third order, and the latter bear the terminal tubules of the system arranged in tufts. Each tuft opens by a short tube (ductule of the fourth order) on the outer side of the tertiary ductule. The terminal tubules are long and usually cylindrical, though some of them show bead-like swellings at intervals. The whole of the tubules borne on a secondary ductule form, in the natural position of the organs, a well-marked secondary lobule, and all the secondary lobules of a primary ductule form a primary lobule. These lobules, though they are placed at fairly regular intervals along the bile-duct, and roughly correspond on the two sides of the body, are not segmentally arranged in the abdomen. Moreover, owing partly to the fact that the primary ductules run, not straight upwards round the hind-gut, but also somewhat backwards, the lobules come to overlap one another on the dorsal side of the gut, and their arrangement appears at first less regular than it really is. Besides those arranged on the above system, each bile-duct bears, on its anterior portion, a certain number of tubules directly sessile upon it. These gradually diminish in size from behind forwards, till a short stretch of the bile-duct, just behind the opening, is left quite free from them. Hindwards the bile-duct begins by the junction of two primary ductules.

We may speak of the whole of the lobules of each side as forming a right and a left liver respectively. The left liver, then, is somewhat smaller than the right, though the difference is not very marked. At the hind end of the abdomen the left liver passes dorsal to the right. The whole of the structures just described are bound together by strands of connective tissue carrying blood vessels. This circumstance, combined with the soft, easily-breakable texture of the liver, makes that organ rather difficult to unravel.

C. The Hind-gut. (Pl. III. fig. G.) Behind the mid-gut, and stretching from it to the anal opening in a direct course, runs the chitin-lined hind-gut. Its width is even for the first three-fourths or so of its length and then it increases gradually to a greater diameter. There are no rectal coeca.

Outwardly, the surface of the hind-gut is smooth, but within it is thrown into ridges. These ridges, which are twelve in number, are most marked at the hind end, grow gradually lower forwards, and finally fade away in the middle of the first abdominal segment, some distance from the end of the mid-gut. They are not all of equal size, being alternately large and small, or rather high and low, for there is not much difference in breadth. Each bears a series of small transverse ridges, and each of these is again made up of a row of four or five minute oval beads set with their long axes lengthways in the intestine, that is transversely to the ridge which each row of them composes. The whole of these structures are, of course, covered with a delicate chitinous pellicle. In the anterior region of the hind-gut, where the ridges are wanting, the inner surface is covered with similar small beads, less regular in shape, set in longitudinal rows. The transition from the mid- to the hind-gut is hardly visible outwardly in fresh specimens, but in a gut which has been for a few hours in spirit it is very easy to see, owing to the difference in calibre brought about by the shrinkage of the mid-gut. Internally, the beaded appearance of the hind-gut makes the distinction a sharp one. In the natural position of the organs in the body a great part of the hind-gut is hidden by the overlapping lobules of the liver, but more or less of the hinder part usually comes into sight amongst the lobules.

The *anus* (fig. 18) is situated on the under side of the telson. It is guarded by a strong valve in the form of an oval calcified convex plate (1, fig. 18), attached to the soft ventral wall of the telson in front of the anus, and projecting back under it. If this plate be parted from the body of the telson, the anus is seen as a longitudinal slit at the bottom of the hollow between it and the telson. Between these two structures, then, there is a sort of cloaca, into which the anus opens. The aperture of the cloaca is surrounded by a thick growth of hairs. The result of this arrangement is that the opening for the discharge of faeces is directed, not ventralwards, in which case it would be liable to be pressed against the columella of the shell and thus obstructed, but backwards, and is further protected from pressure by the stout plate beneath it. Possibly the object of the hairs round the opening is to prevent the entrance of faecal matter as the animal shifts in its shell, though it is remarkable that the shells of these voracious creatures contain quite a small quantity of dung. In the Galatheinea and Brachyura, groups whose members carry the abdomen pressed more or less strongly against the underside of the thorax, the same arrangement is found in a less complete form, the anus being usually prominent and directed more or less backwards.

(iii) **The vascular system** (fig. 19).

The rather large, muscular *heart* (19, fig. 19) lies, as usual in the thorax, close under the dorsal carapace behind the cervical groove, surrounded by the thin-walled pericardial sinus, in which it is suspended by the three pairs of fibrous *alae cordis*, and with which it communicates by the usual three pairs of ostia. In shape it appears roughly four-sided from above, the anterior end being drawn out into a low prominence from which arise the three anterior arteries. The hind end has also a low, rounded, median bulge. At about a third of its length from the hind end there is on each side a notch. The dorsal surface is slightly convex; the sides slope inwards to the ventral surface, which is flat, and is raised, at the hind end, into a round, median lobe, from which the sternal and abdominal arteries arise.

Arteries. Seven vessels are given off from the heart. At the front end there arises a group of three—a median *ophthalmic* and two lateral *antennaries.* A short distance behind these the paired *hepatics* are given off from the ventral surface of the heart; and at the hind end the ventral lobe bears two median arteries, a more anterior, ventrally directed *sternal*, and a more posterior, terminal *abdominal.*

The *ophthalmic artery* (1, fig. 19) runs straight forward over the roof of the stomach without giving off any branches, and finally divides into two vessels which diverge forwards at an acute angle, to supply the eyes. There is no swelling, or median prolongation beyond the bifurcation. The *antennary arteries* (2, fig. 19) run forwards and outwards from their origin on each side of the ophthalmic artery. On the inner side each gives rise to

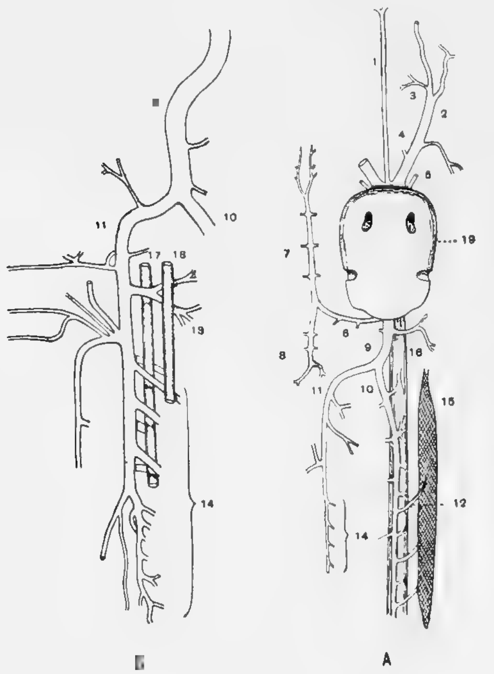


Fig. 19. Arterial system of *Coenobita clypeatus*. A. Arteries of female from above; B. Left or lower branch of abdominal artery of male (enlarged). 1. Ophthalmic. 2. Antennary. 3. Anterior gastric. 4. Posterior gastric. 5. Hepatic. 6. Sternal. 7. Ventral thoracic. 8. Ventral abdominal. 9. Dorsal abdominal. 10. Right branch of abdominal. 11. Left branch of abdominal. 12. Ovarian. 13. Spermatic. 14. Branches to liver. 15. Ovary. 16. Hind-gut. 17. Right bile duct. 18. Left bile duct. 19. Heart (represented too large).

an anterior and a posterior gastric artery, which supply the musculature of the stomach. At about the level of the anterior gastric artery there is given off on the outer side a stout branch, which runs downwards and forwards to the green gland. At a short distance in front of the posterior gastric artery a less important outer branch arises, to be distributed to the muscles of the adjoining part of the thorax. In front of the stomach the diminished artery is continued forwards to supply the antennae. Besides the above, there are other smaller and more variable branches.

The hepatic arteries (5, fig. 19). The position of the liver in the abdomen deprives these arteries of the function which gained them their name in other Decapods. It is perhaps best, however, to retain it, rather than add to an already overladen terminology. The hepatic arteries, then, in *Coenobita* do not supply the liver, but run downwards and forwards from the heart to supply the sides of the stomach. *The sternal artery* (6, fig. 19) on leaving the heart runs directly downwards, passes on one side or other of the intestine, and ends by going through the oval hole in the thoracic ganglion and dividing immediately underneath the latter into two branches, one of which passes directly forwards in the middle line and is known as the ventral thoracic artery, while the other runs directly backwards. This latter is the homologue of the ventral abdominal artery of other Decapoda. It has here very little right to the name, but to avoid confusion, and also because it does actually send two small branches into the abdomen, may be allowed to retain it. The sternal artery, in its vertical course, that is before its bifurcation, gives off two or three small branches backwards towards the abdomen. The *ventral thoracic artery* (7, fig. 19) gives off branches right and left to the third, second and first pairs of legs and then bifurcates into two trunks, one for each side, which supply the mouth-limbs and send a branch to the green gland of each side. The *ventral abdominal artery* (8, fig. 19), in its course through the hinder part of the thorax gives off vessels to the last two legs and then, on arriving at the base of the abdomen, divides into two small branches, which ramify among the abdominal organs. In the possession of these two little vessels, and in the greater regularity of the arrangement of vessels to the limbs, the sternal arterial system of *Coenobita* differs from that of *Eupagurus* described by Bouvier[1].

The *abdominal artery* (9, fig. 19). For a short distance this great vessel runs a straight course backwards, giving off a few small twigs to the muscles of the hinder part of the thorax. But a little behind the junction of thorax and abdomen it divides into two branches. Of these one, the smaller (10, fig. 19), passes on in the middle line above the hind-gut, lessening as it goes by giving off small vessels to the gut and ovary. The larger of the two, however, turns downwards and then backwards again, and continues its course below the liver and above the broad band of muscle which represents, in the Pagurinea, the abdominal muscular system of other Decapods[2]. As it goes, this vessel gives off branches upwards to the liver and testis and downwards to the muscles. In particular one large branch, given off not long after it resumes the backward direction, supplies much of the muscle-band and even sends a branch forward into the thorax. Further back still, the main vessel divides into two. One division passes into the muscles, the other runs on dorsal to the muscle-band, continuing to supply it and the liver. The sub-muscular division reappears at the hind end of the abdomen and curves forward, breaking up and anastomosing with the other vessels of the liver.

Venous system. The arteries, after dividing into finer and finer branches, end by discharging their blood into the great venous sinuses in which all the organs of the body are bathed. The arrangement of these in *Coenobita* seems to be much the same as in other Decapods. In connection with the respiratory organs, however, certain peculiarities must be noticed. Roughly speaking, the blood from a sternal sinus passes to the gills and so to the pericardium, that from a gastric sinus to the branchiostegite and so to the pericardium, and that from an abdominal sinus to a plexus under the skin of the abdomen and thence by two veins on each side to the pericardium. Some further particulars will be found in the next section.

iv. **Respiratory Organs**. Respiration takes place in three distinct regions of the body of a *Coenobita*: (1) in the gills, (2) in the lining of the branchiostegite, (3) in the abdominal skin. It must, of course, be borne in mind that in this case the surrounding medium is not water, as with the great majority of Decapods, but air.

The gills are of the type known as "phyllobranch"; that is to say they consist of an axis bearing on each side a series of thin-walled plates through which the blood flows

[1] Bouvier, "Récherches anatomiques sur le Système Artériel des Crustacés Decapodes." *Ann. Sci. Nat.* (7), v. p. 197 (1891).

[2] See above, p. 69.

freely. The axis is attached at one point to the side of the thorax, and there the blood enters it. The lamellae diminish in size towards each end of the axis, whereby the whole gill becomes spindle-shaped. The gill-formula is as follows[1]:—

	Podobranch	Anterior arthrobranch	Posterior arthrobranch	Pleurobranch	Total
1st maxilliped ...	0	0	0	0	0
2nd „ ...	0	0	0	0	0
3rd „ ...	0	rud.	rud.	0	2 rud.
1st leg...............	0	rud.	rud.	0	2 rud.
2nd „	0	1	1	1	3
3rd „	0	1	1	1	3
4th „	0	1	1	1	3
5th „	0	0	0	1	1
Totals...	0	3+2 rud.	3+2 rud.	4	10+4 rud.

The arrangements for the supply of blood to the gills consist, as usual, of afferent branchial vessels, arising from the sternal sinus, and of efferent vessels leading to the pericardial sinus and so to the heart.

The lining of the branchiostegite is a thin, smooth membrane. There is no spongy tissue such as is found in *Ocypode* or vascular tufts as in *Birgus*. According to Bouvier[2], blood enters the branchiostegite from the large sinus which encloses the stomach, and leaves by the great vein, which may easily be found at the hinder edge of the organ. This starts in front as a small vessel and runs backward round the lower edge of the branchiostegite, enlarging as it goes. Finally it curves inwards with the hinder edge of the branchiostegite and, when this rejoins the body, passes on to the pericardium. I did not find it possible by injecting this vessel to irrigate any definite plexus in the branchiostegite. The coloured fluid passes with great readiness into the space between the strong outer and the delicate inner wall of the organ, but it is here contained in a loose and irregular system of lacunae, or rather in a single cavity divided by strands of tissue.

The gill chamber. Provision for moistening the gills. The third leg in its normal position, pressed up against the soft branchiostegite, indents the latter in such a way as to limit the branchial chamber to a comparatively small region in the hinder and upper parts of the thorax. This chamber is widely open behind, so that the gills can generally be partly seen without lifting the branchiostegite. The animal seems to be able to increase this opening at will, but over the greater part of their surface the branchiostegite lies fairly close above the gills. There is thus no attempt at the formation of anything like a lung. The free edge of the branchiostegite is incurved, and the trough thus formed is lined with hairs and usually very moist. Another hairy surface, possibly of importance in the retention of water, is to be found on the wall of the thorax above the gills, between them and the origin of the branchiostegite.

[1] The gill-formula of *Pagurus* is the same as that of *Coenobita* save that the gills on the third maxilliped and first leg are better developed. *Eupagurus* differs in having only one pleurobranch—that on the fourth leg.

[2] Bouvier, *C. Rend.* cx. pp. 1211 ff. (1890). My observations, which confirm those of Bouvier, were made when I was in ignorance of his researches on the blood supply of the branchiostegite.

The source of the moisture is a problem of some obscurity. It is of the very rarest occurrence for a *Coenobita* to be found in the water except at the breeding period[1]. Ortmann states quite distinctly that, out of many hundreds, he has never seen one in the water. Nor have I myself succeeded any better in this respect. That they do visit the sea, however, I am convinced by two facts. First, that Mr Stanley Gardiner had the good fortune to find a specimen of *C. perlatus* in the water a few feet from the lagoon beach in Minikoi. It is true that this was a female, but there were no eggs or young, nor any traces of them, on her abdominal limbs. Secondly, that the body of a freshly caught specimen is always moist, and in a great many cases (certainly the majority of *C. perlatus* and *C. rugosus*) the shell actually contains a small quantity of salt water[2].

Another possible method of moistening the gills must not be overlooked. In some experiments to test the effect of drying the gill chamber it soon became evident that this was an impossibility. By the careful use of cotton-wool and blotting-paper, a great part of the moisture could be removed, but absolutely dry it was quite impossible to make the chamber. After a time the limpid salt water became replaced by a more sticky fluid, which frothed with the violent efforts of the scaphognathite. Of course it is possible that this was blood, flowing from wounds in the delicate cuticle lining the chamber, made during the process of drying. But I was unable to detect any such wounds, and the same thing happened in each of several experiments. Another explanation of the phenomenon is that the fluid was provided by exudation through the lining of the chamber. No doubt in this case the exudation was abnormal in quantity and quality. But it served to indicate a possible method of keeping the gills moist. In support of this is the fact that specimens made approximately dry[3] with cotton-wool and then placed in a dry wooden box, lived, and remained in good health for weeks. No doubt, if the suggested process of exudation takes place, the different species of the genus are dependent on it to different extents. One would expect, for instance, that it would play a greater part in species such as *C. spinosus*, which often live at some distance from the sea, than in *C. rugosus*, which is generally to be found close to sea-water.

The movements of the scaphognathite. On raising the forepart of the branchiostegite of a *Coenobita* the plate on the second maxilla, to the movements of which the respiratory current in water-living Decapods is due, will nearly always either be found to be in motion or shortly begin to move. When the animal is placed in water, either fresh or salt, it is easy to show, by means of a little carmine or other coloured fluid, that the ordinary current is produced here also. It enters at the hind end of the branchial chamber and between the last two legs, passes over the gills and through the narrow passage which leads downwards and forwards from the upper part of the gill-chamber proper, and finally issues under the antenna. I have not been able to observe a reversal of the current, such as that described by Bohn[4] in many Decapods. The meaning of the movement of the scaphognathite when the animal is on land is not clear. It is possible that its object is, by acting as a fan, to create a draught of air through the gill chamber. In considering this view, however, we are met by the difficulty that there are often long pauses in the movements, and that removal of the scaphognathite has no perceptible effect on the animal.

[1] See below, p. 91.

[2] See below, p. 91.

[3] If the drying process be continued too long, it is apt to kill the animal.

[4] Bohn, *C. Rend.* cxxxv. p. 539.

It may be that the stimulus of lifting the branchiostegite is sufficient to set the appendage in motion, but in this case one would expect the movements either to cease directly or to continue as long as the branchiostegite is raised. This is not what happens, the movements being sometimes steady and sometimes fitful and irregular. A third explanation, and the one which at present seems the most probable, is that we have here an instance of a vestigial habit, retained after it has ceased to be of use to the animal. Lastly, if it could be shown that both sexes are in the habit of going into the water at frequent intervals, yet another solution of the question could be offered. For in that case it would be possible to suppose that the motion of the scaphognathite was retained on account of its being indispensable to the animal under water and at the same time, for some physiological reason, not susceptible to inhibition for long periods and thus perforce continued on land. But this view would require assumptions, which there is no justification for making.

Abdominal respiration. At the time of my sojourn in the Island of Minikoi, I was unaware of Bouvier's[1] researches on this point. My own observations were much less complete than his, but I can confirm his statements with regard to the various channels carrying blood back from the abdominal walls to the pericardium, at least as regards the dorsal pair, the ventral I failed to observe. While he paid considerable attention to the anatomical side of the question, Bouvier does not appear to have made any experiments to test his theories. It is interesting to observe that if the gills of both sides be cut off, leaving small stumps to avoid loss of blood (it would be better to ligature the gills in a future experiment), the animal is still capable of living. Indeed one, on which I performed this experiment, lived several days, and finally escaped from the vessel it was confined in. Taken in conjunction with the fact that the action of the scaphognathite may be suspended without harm to the animal, this fact seems to indicate that abdominal respiration is of considerable importance in *Coenobita*. It is further interesting to note that the soft skin of the abdomen is always damp. Possibly the object of the hairs and fleshy processes on the ventral surface of the abdomen is as much to retain water as to play any part in respiration by movement, as Bouvier suggests. It would certainly appear, from the elaborate precautions taken in various groups of land Decapoda to ensure the presence of moisture on the breathing organs, as though respiration were, in them at least, impossible except through a moist surface.

v. **Kidneys (green glands)** (Pl. III. fig. H).

The kidney of *Coenobita* is a large oval cushion, of a pale greenish colour in the living animal, placed in the head on each side of, and rather behind, the brain, and behind the base of the antennae. The surface of the cushion is not even, but raised into a number of irregular rounded lobes, except in the middle of the upper side, where a space is left smooth, and forms a depression amongst the lobes. The hilum of the gland is in front and on the outside. I am quite unable to distinguish, by injection or otherwise, any vesicle such as is found in nearly all other Decapods and is especially well developed in the Pagurids. The only other instances in which this does not occur are quoted by Marchal

[1] Bouvier, *Bull. Soc. Philomath.*, Paris (8), II. p. 194 (1890). Briefly put the apparatus consists of a tegumentary plexus, fed from the abdominal sinus and communicating with the pericardium on each side by two veins—a long dorsal and a short ventral one. The two veins of each side join before entering the pericardium.

in his work[1] on these organs in the Decapoda. They are afforded by the genera *Porcellana* and *Axius*. A short duct leads from the gland to the opening at the base of the antenna.

vi. **The Nervous System** (fig. 20).

As might be expected, this shows a great general resemblance to that of the Pagurids[2] the chief difference being in the greater concentration of the thoracic ganglia. The *brain* (1, fig. 20) is large, transversely elongated, and swollen at the sides. It gives off nerves to

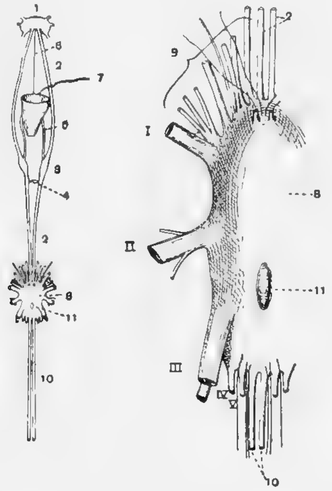


Fig. 20. Central nervous system of *Coenobita clypeatus* from above with abdominal chain removed. To the right an enlarged view of the thoracic ganglion is shewn. 1. Brain. 2. Circumoesophageal commissures. 3. Oesophageal ganglia. 4. Transverse commissure. 5. Oesophageal nerves. 6. Cerebral branch to the visceral nerve. 7. Visceral nerve. 8. Thoracic ganglion. 9. Nerves to the mouth-parts. 10. Longitudinal commissures. 11. Perforation for sternal artery. I—V. Nerves to the legs.

the eyes and antennae. The *circumoesophageal commissures* (2, fig. 20) are very long. For the first part of their course they diverge and again converge in such a manner as to enclose a long oval area, in the middle of which the oesophagus lies. At the hinder end of the oval area a delicate transverse commissure (4, fig. 20) delimits it sharply. Behind this point the circumoesophageal commissures converge much more gradually towards the thoracic ganglion presently to be mentioned, finally running almost parallel for some distance. Just in front of the transverse commissure there is a gentle swelling on each of the longitudinal ones. These are the oesophageal ganglia (3, fig. 20) from which arise the two rather large oesophageal nerves (5, fig. 20). These are joined by a fine nerve (6, fig. 20) which runs backward in the median line from the brain—the three anastomosing in front of the oesophagus. From their point of junction the median visceral nerve (7, fig. 20) runs upwards over the anterior wall of the stomach, to which organ it is distributed as in other Decapods.

The *thoracic ganglion* (8, fig, 20). In the Paguridae the thoracic ganglia are, with the first abdominal, fused into an elongate mass in which, however, certain of the constituents can still be made out, owing to the presence of constrictions in the mass and of perforations to admit the passage of certain small arteries (besides the sternal artery). *Coenobita* shows an advance on this in that the whole of the ganglia are fused into one oval body, through

[1] Marchal, "Récherches...sur l'appareil excréteur des Crustacés Décapodes." *Arch. Zool. Exper.* (2), x. p. 57 (1892). See this work for the excretory organs of the Paguridae (not Coenobitidae), *Porcellana*, and *Axius*.

[2] See Bouvier, *Ann. Sci. Nat.* (7), vii. p. 87 (1839).

which there is but one perforation—that for the sternal artery (11, fig. 20). On each side of the ganglion arise, at wide intervals, three stout nerves for the first three legs. In front and behind, the longitudinal commissures join it as two more slender strands, one close on each side of the middle line but quite distinct. Behind the nerve for the third leg of each side, between it and the longitudinal commissures, the small nerves for the fourth and fifth legs arise. In this region there are also several very fine, thread-like nerves arising from the dorsal surface of the ganglion and running backwards.

In front of the nerve for the first leg, between it and the circumoesophageal commissures, half-a-dozen nerves for the mouth parts arise (9, fig. 20). These come off, not as in the thoracic ganglion of *Pagurus* figured by Bouvier, at one level, along the edge of the ganglion, but at different points scattered over its surface in that region. Two, in fact, arise quite on the dorsal surface. Here again there are several small nerve-threads intermingled with the stouter nerves leaving the ganglion. The nerves of the two sides are not absolutely symmetrical but the asymmetry is not very marked.

The *abdominal chain.* Leaving the thoracic ganglion the longitudinal commissures run backwards as far as the beginning of the sixth abdominal segment. During the whole of their course they remain distinct save where, in each segment, a ganglionic swelling binds them together. Nerves are given off, not only from the ganglia, but also from the intermediate portions of the commissures. The nerves of the two sides are not strictly symmetrical.

The brain and circumoesophageal commissures are easily exposed by removing the stomach from above, when they are found lying respectively against the anterior and ventral body-wall. The hinder part of the circumoesophageal commissures, with the thoracic ganglion and the nerves leaving it, is protected by a stout endosternal skeleton of the macrurous type, joined by the usual rib-like bars with the endopleurae and epimera, which form the rest of the internal skeleton. The abdominal chain lies along the ventral side of the abdomen under the muscle-band.

vii. **The generative organs** (Pl. III. fig. K, *a—c*).

A. *The male organs.* The *testes* lie imbedded in the dorsal part of the liver and more or less completely hidden by the lobes of that organ. They are not symmetrical, the right being placed farther back than the left. It is also rather the larger of the two. Each consists of a much coiled, sacculated tube compacted into a firm, elongate mass, enlarged at the hind end. From this enlarged part arises the *vas deferens,* a somewhat complicated structure, divided into three regions—(1) the conducting tube, (2) the spiral, (3) the glandular tube. The *conducting tube* is a short, irregularly twisted duct arising from the inner, ventral aspect of the testis at its hinder end. In calibre it is smaller than the glandular tube, but rather larger than the spiral. This latter is a fine, semi-transparent pipe arranged in one close coil of about thirty turns. The glandular tube is stout, of an opaque white colour, and thrown into many irregular loops. It runs forward along the inner side of the testis, becoming less convoluted as it goes, traverses the anterior part of the abdomen, and finally passes almost insensibly into the *ductus ejaculatorius*—a simple, uncoiled tube, slightly wider than the vas deferens.

Comparing these structures with the same parts in *Paguristes* and *Eupagurus*[1], the following points appear. The testis is more compact in *Coenobita* than in either of the Pagurid genera. In shape it represents, with its hinder swelling, a more definite form of the type foreshadowed by *Eupagurus*, which is, in this respect, intermediate between *Paguristes* and the land genus. On the other hand, in having one spiral section (instead of two, sundered by a straight tube), as also in the small calibre of this region, *Coenobita* approaches *Paguristes* rather than *Eupagurus*. But in the shortness of the very narrow tube which comes immediately before the spiral, that is which separates the spiral and the conducting tube proper, it again resembles *Eupagurus*. The *male opening* is in the usual position on the coxopodite of the fifth leg of each side. The portion of the joint which bears the opening is always more or less prominent and, in some cases (*C. rugosus*, *C. perlatus*) is, on the right side of the body, prolonged into a penis-like process. In *C. perlatus*, however, in which this feature is very marked, bringing about a complete dissimilarity between the openings of the two sides, there is no sign of degeneration in the left testis, and its duct may contain sperm. The first abdominal segment being, in both sexes, unprovided with appendages, there is here no copulatory organ of the type common in other Decapods.

B. *The female organs.* The *ovaries* are a pair of simple cylindrical structures lying in the abdomen one on each side of the median line close above the hind-gut along the middle portion of its course. In *C. clypeatus* the ovaries are separate. In *C. rugosus* and *C. perlatus* they join for a short distance at their hind ends[2]. The *oviduct* is a simple tube, arising from the anterior end of the ovary and running straight forwards to its small round opening on the ventral face of the coxopodite of the third leg.

C. *The relative numbers of the sexes* seem fairly equal, a collection taken at haphazard giving sometimes a small preponderance of one, sometimes of the other.

viii. **Reproduction**. Whether *Coenobita* have a definite breeding season or not, and, if so, when it occurs are questions that still remain to be settled. Certainly, females with eggs may be taken throughout the summer in Ceylon[3]. The copulation is another point deserving further investigation. Very little is known on this subject as regards most Decapods. *Paguristes* is said to insert a penial process into the vulva of the female[4], and possibly the same use is made of the "penis" of *C. perlatus*. That of *C. rugosus* is too broad for insertion, but is no doubt of use in placing the sperm in some required position. At the same time the reproductive organs of the left side of the body show every sign of being functional in these, as in the other species of the genus, and the problem is thus complicated by the probability that their sperm is deposited in a different way from that of the right side of the body.

The eggs are carried in large masses attached to the long hairs on the well-developed limbs on the right side of the second, third and fourth abdominal segments of the female. They are arranged irregularly along the hairs[5] and fixed, as in other Decapods, by an

[1] Grobben, "Beit. Kennt. Männ. Geschlechtsorg. Dekapoden," *Arb. Zool. Inst. Wien*, I. 2 (1878).

[2] In *Pagurus* they are said to remain separate.

[3] Mr Stanley Gardiner suggests to me that the south-west monsoon is the main breeding season in the Maldives. He was in these islands during the north-east monsoon, and found great difficulty in finding females with eggs at that season. The same is the case in Ceylon.

[4] Ortmann, Bronn's *Thierreich*, v. 2, p. 1075.

[5] In *Birgus* they are in clumps at intervals along the hair. Borradaile, Willey's "Zool. Results," Pt. v. p. 585 (1900), "On the Young of the Robber Crab."

outer shell, prolonged into a stalk which adheres to the hair. The ripe egg is ellipsoidal, and measures, when preserved in spirit, 7·5 mm. by 7 mm. in *C. perlatus*, and in *C. rugosus* rather less. It is thus a little smaller than that of *Birgus*[1]. In two species at least (*C. rugosus* and *C. perlatus*) the young are hatched as zoaea larvae[2] of a type much resembling those of other Pagurinea[3] and washed off into the sea. They are not swept out in the respiratory current in the manner described by Bate[4] for *Eupagurus* nor is it necessary for the female to issue from her shell, though she may do so if kept under water too long in a state of captivity. It is possible, though perhaps not very likely, that the habits of some of the other species, especially those which live at greater distances from the water, may have led to their young being hatched in a later stage[5], as is said to be the case with some land crabs[6]. A zoaea which seemed identical with that of *C. rugosus* was taken at night with the tow-net in the lagoon at Minikoi.

The embryonic skin, which encloses the Decapod zoaea before hatching, and is retained for a varying period in different forms, is here lost very shortly after leaving the egg. It is of simple form and much resembles that found by Sars in other Pagurine zoaeas, though I have not been able to discover any feathering on the processes of the glove-like structure which encloses the telson and its spines. The larva (fig. 21) is rather smaller than that of *Birgus*[7] (the length is, in *C. perlatus*, 3 mm. and in *C. rugosus* 2·5 mm., as against 3·5 mm. in *Birgus*), which it otherwise very closely resembles in all but a few points of detail. The *carapace* has a curved, pointed rostrum of moderate length. The hinder edge is hollowed, and at each side a rounded side-lobe replaces the spine usually found here. The *abdomen* consists of five segments and an end part, which shows indications of its coming division to form the sixth segment and telson[8]. The *telson* (*a*, fig. 21) has the usual fan shape with a rather deep median notch. On each side of the notch are five bristles, increasing in length from the first to the fourth, which is longer than the fifth. These bristles are feathered. The outer angle is provided with a stout tooth. None of the other abdominal segments are armed, save the fifth, which has a single strong spine on each side at the hind end. There are eight pairs of limbs, including a rudimentary pair of third maxillipeds. These limbs are almost exactly like those of the first zoaea stage of *Birgus*[9], except for the mandible (*b*, fig. 21), which has

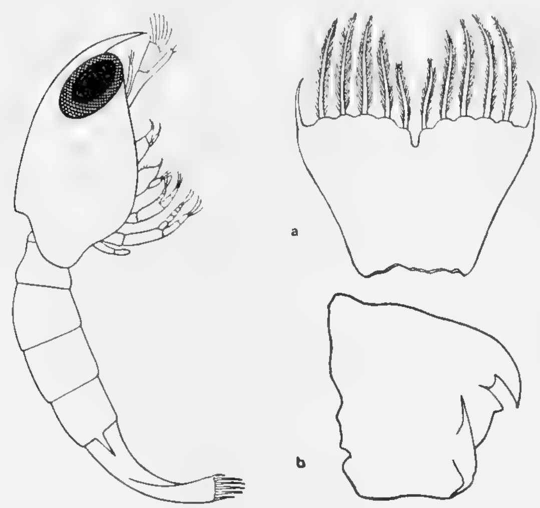


Fig. 21. Zoaea of *Coenobita perlatus*. *a*. Telson enlarged. *b*. Mandible enlarged.

[1] Borradaile, *loc. cit.*

[2] Borradaile, *P. Z. S.*, 1899, p. 937.

[3] G. O. Sars, *Arch. Math. og Naturvid.*, XIII. p. 133 (1839).

[4] Bate, quoted by Stebbing "Crustacea," p. 164, London, 1893.

[5] *C. clypeatus* a few mm. long are found in the jungle in Minikoi in sea shells. For *C. diogenes*, see below, p. 91.

[6] *Gecarcinus* sp. Westwood, *Phil. Trans.*, 1835.

[7] Borradaile, Willey's "Zool. Results," *loc. cit.*

[8] These indications are not altogether wanting in *Birgus*, so far as can be seen in the ill-preserved material from the Pacific at my disposal.

[9] For figures of these see Borradaile, Willey's "Zool. Results," *loc. cit.*

the same main features but is simplified by the absence of its numerous small denticulations. The first antennae are simple, unjointed structures with a few hairs at the free end. The second antennae have a large scale with a tooth at the outer angle and feathered bristles along the inner edge. The endopodite is unjointed. The first maxilla has a jointed palp, two stout feathered spines, and a broad gnathobase. The second maxilla is not much removed from the adult form. The first two maxillipeds are the swimming organs and have long, jointed endopodites and exopodites, bearing hairs.

In every respect the larva has a typical Pagurine organization, but resembles *Birgus* more nearly than the Pagurids. It differs from *Birgus* in: (1) its smaller size; (2) the arrangement of the bristles of the telson, which in *Birgus* are of nearly equal length; (3) the greater length and slenderness of the side spines of the fifth abdominal segment; (4) the greater simplicity of the mandible.

ix. **Notes on the habits**[1].

A circumstance which makes the habits of *Coenobita* somewhat more easy of investigation than those of other hermit-crabs, is that almost the whole of their life is spent on land. It has already been remarked[2] that the animals are rarely to be found in the water, but we must at the same time admit that this question is far from being disposed of. Their organization seems well adapted for a stay under water, and they may be proved experimentally, as we shall see, to have the power of living for some time in that medium, though it eventually proves fatal to them.

According to Hughes[3] *C. diogenes* is "often found cleaving to rocks in the sea" and "sometimes it is caught upon the rocks at a considerable distance from land." Again, in Minikoi, the shells of many examples of *C. rugosus* and *C. perlatus* contained considerable quantities of salt-water, and that in both sexes and irrespective of the carrying of eggs by the females. On the other hand Catesby[4] does not "remember to have seen any of them (*C. diogenes*) go into the sea," Ortmann[5] states that, out of hundreds of examples observed by him in East Africa, not one was found in the water, and, with a single exception[6], the same was the case in Minikoi. Moreover, in the case of species found at a considerable distance from the sea[7], frequent visits to salt water are out of the question. *C. rugosus, C. perlatus* and, according to statements[8], *C. diogenes* undoubtedly go down to the sea, when their young are hatching for the purpose of washing them off. Should they be proved to frequent the water at other times, it will be interesting to discover whether this be in connection with their breathing arrangements[9], or merely for some such purpose as obtaining a favourite food or escaping an enemy, and further whether it take place by night or by day[10].

With regard to the food of *Coenobita*, there is not much that can profitably be said. Their staple is, in Minikoi at least, the fruit of the *Pandanus*, but they are like many

[1] Broderip [*Zool. Journ.*, IV. p. 205] and Ortmann [Bronn's *Thierreich*, v. 2, *passim*] quote passages from various authors on the subject of the habits of *Coenobita*.

[2] See above, p. 85.

[3] Hughes, *Nat. Hist. Barbadoes*, p. 265.

[4] Catesby, *Nat. Hist. Carolinas*, II. p. 33.

[5] Ortmann, Bronn's *Thierreich*, v. 2, p. 1183.

[6] See above, p. 85.

[7] Such as *C. spinosus*, see Borradaile, *P. Z. S.*, 1898, p. 459.

[8] Quoted by Broderip [*Zool. Journ.*, IV. p. 205] from the old "Encyclopédie" [Paris, 1751].

[9] In order to moisten their gills etc. See above, p. 85.

[10] For some remarks on the same problem with regard to *Birgus*, see Borradaile "Willey's Zool. Results," v. p. 585.

other Decapods in being practically omnivorous[1]—belonging, in fact, to the class of scavengers. They pick up various dead sea-animals along the beach, and get other refuse elsewhere. On occasion, even cannibalism is not beyond them, when one of their number is wounded or killed. They are able to find their food in the dark, and there can be little doubt that this is due to a sense of smell, by which, rather than by sight, they are most likely guided in their search. Substances with a strong odour such as roasted coconut or the fruit of the *Pandanus* (which has a distinct and characteristic smell) are particularly attractive to them. It is interesting to watch the way in which a *Coenobita* will pause in its walk, unfold its long antennules[2] (see p. 70) and seem to explore the air with them, waving their flagella gently to and fro over its head. The same limbs are advanced and held over the food during feeding. They find the fruit of the *Pandanus* on the ground, but will also climb the bushes to reach it. On one occasion an individual was found in a *Hernandea peltata* about twenty feet from the ground, but its object in going there is hard to surmise. The curved end-joints of the legs can clasp tightly quite small twigs, and the sharp claws with which they are provided are, no doubt, of use in climbing. The food is often dragged for some distance, and in the case of fruits this is, no doubt, a method of distributing the seeds, which should be taken account of in considering the extension of vegetation over the land surface of a coral island.

In the matter of habitations, the choice is as varied as in that of food. Every available kind of land or sea gastropod shell is used, provided that it be of the right size and not so encumbered with spines as to be awkward in use. Weight seems to be of little account, the heavy *Turbo*-shells being especial favourites with *C. clypeatus*, although only comparatively small individuals can use them. One small specimen of *C. rugosus* in Ceylon was carrying the empty tube of a Serpulid worm. *C. spinosus* is known to use the nutshell of *Calophyllum inophyllum*[3], and *C. clypeatus*, when it has grown too large for gastropod shells, takes the half of a coconut[4]. A case even occurred in which a broken glass tube was made use of[5].

Ortmann[6] has pointed out the existence in *C. rugosus* (traces of the same structure are found in most *C. perlatus*) of an apparatus, which he regarded as adapted for producing a sound. This consists of a row of small ridges on the outside of the great (left) chela and a longitudinal ridge on the underside of the second walking leg of the same side. It is interesting to know that a number of these creatures shut up in a large tin

[1] Ortmann [Bronn's *Thierreich*, I. 2, p. 1234] seems to be of the opinion that *Coenobita* is purely vegetarian in its feeding, and quotes Dahl and Streets in support. But Catesby [*Nat. Hist. Carolinas*, II. p. 33] long ago observed that *C. diogenes* will occasionally take animal food.

[2] These appendages are, of course, those in which a sense resembling that of smell has been found to be located in other crustaceans. Lack of time unfortunately prevented me from making any experiments on this point, which I am sure would repay investigation in *Coenobita*.

[3] Borradaile, *P. Z. S.*, 1898, p. 459. Gastropod shells are probably scarce where this is done.

[4] In such cases as this, the means by which the creature retains its house are of interest. The abdomen is doubled forwards under the thorax, so as to present the roughened surfaces on the 6th abdominal limbs to the inside of the shell, and at the same time the 4th and 5th thoracic limbs make use of the similar patches on their propodites. Even so the hold on the shell is but a feeble one (see p. 72).

[5] A similar case is mentioned by Brock [quoted by Ortmann, Bronn's *Thierreich*, V. 2, p. 1216]. The interest of this observation lies in its bearing on the question of the means by which the animal recognises an object as being suitable for its "house." In this case it seems far more likely that the sense of touch was employed than that of sight. On the other hand, an individual removed from its shell, will make for another shell placed at some distance in a manner which seems to indicate that this is seen.

[6] Ortmann, Bronn's *Thierreich*, V. 2, p. 1249. Hilgendorf is said to have first called attention to the existence of this arrangement.

box, gave out continually a low, chirping sound, though it was not possible to discover how they did this[1]. The object of the sound is not clear, and theories on this subject must wait till the question of the hearing of the creatures is decided. They certainly often seem to be affected by sounds, but whether this may not be due to other vibrations started at the same time in the earth and surrounding objects is still doubtful to me, my information on the point being limited to desultory observations made at Minikoi before I was obliged to leave the island.

While they are not strictly nocturnal animals, the land hermit-crabs are certainly more active by night than by day. They seem to avoid the heat of the sun by preference, and to shelter, during the middle of the day, in nooks and crannies. Their habit of crowding together in any place, where food is to be found, makes them seem gregarious—which, in a strict sense of the word they probably are not. At the same time they may sometimes be found collected in considerable numbers for no apparent cause.

They are not given to fighting to the same extent as the hermit-crabs of the sea. When molested they withdraw quickly into their shells, closing the opening with the big left chela, which is specially adapted for this purpose. In this condition a *Coenobita* in a strong shell, such as that of *Turbo argyrostomus* must be an exceedingly tough nut for most animals to crack, and can also fall from a considerable height without injury. If they are unable to withdraw into their shells they will sometimes endeavour to defend themselves with the same powerful limb that is used to close the shell, but it often requires a considerable amount of teasing to induce them to do this. The grip of the great chela is exceedingly strong and will easily snap a twig which the animal has been made to seize.

If an individual be placed on its back, that is with the mouth of the shell uppermost, it will thrust out its body till the shell overbalances and the animal is able to recover the normal position. In moving, they crawl obliquely forward and to the left. From the accounts of eye-witnesses[2], it would seem that *C. diogenes* is considerably swifter than the Indo-Pacific species.

A series of experiments carried out with the object of investigating the vitality of the animals in fresh and salt water led to the following conclusions:—

(i) Continuous submersion under water is always fatal after a more or less prolonged period. (ii) There is great individual variation in the length of this period, but the sexes do not differ greatly[3]. (iii) The creatures are very sensitive to the effects of overcrowding. (iv) Tinned vessels are more injurious than enamelled ones. (v) There is a difference between the powers of resistance to fresh and salt water in favour of the latter, but the difference is not so great as might have been expected. The greatest length of life in salt water reached by any individual during the experiments was 6 days, but this was exceptional. In fresh water 24 hours was not exceeded. (vi) Of the three species, *C. perlatus* showed the greatest vitality in water and *C. clypeatus* the least, but the number of individuals of the latter experimented with was small. (vii) Before death the animal generally, but not invariably, comes out of

[1] Broderip [*Zool. Journ.*, IV. p. 205] quoting from the old "Encyclopédie" (Paris, 1751) states that *C. diogenes* makes a small sound when it is seized.

[2] Soane, *Nat. Hist. Jamaica*, II. p. 272; Catesby, *Nat. Hist. Carolinas*, II. p. 33.

[3] Females with eggs do not differ from others in this respect, and the hatching larvae died almost as soon in salt as in fresh water. Had it been possible to rig up a "dipper," no doubt some of these might have been reared.

its shell. (viii) An individual, seemingly dead, may often be revived by being placed in the air, just as a marine crab, dying from exposure to the air, will come to life in water[1].

Some 200 specimens, mostly of the species *C. rugosus* and *C. perlatus*, were experimented with. The fresh water used was rain gathered in a "galvanised" iron tank. Owing to the limited number of vessels available and lack of time, the experiments were not as complete as they should have been. Still, they may perhaps serve to induce some more fortunately situated observer to carry on the enquiry. To obtain good results, each individual should be placed by itself in a vessel with a considerable quantity of water, which should be frequently changed. It would be interesting to try and induce the animals to feed under water. The few attempts, which I made at this, were unsuccessful. That death is not due to starvation is, however, certain from a consideration of the fact that they will live for weeks without food, if not placed under water.

3. Some notes on the land crabs of the genus *Ocypode*.

i. *Ocypode ceratophthalma* (Pallas).

This species lives in burrows in the sandy strand of the lagoon. Large warrens of these burrows extend along the shore just below extreme high-water mark. They are thus covered and destroyed at high tide, but during many hours are completely exposed. The mouth of the burrow is not always situated so as to be covered by an average tide, but the lower part always falls in at high water, owing to the loosening of the sand. The crab, which awaits this event at the bottom of its hole, is thus buried for some hours. When the tide falls it works its way out and repairs its burrow, and until the water returns may be seen moving about the shore near the opening[2], and running with extraordinary swiftness when threatened with capture. Under these circumstances the first impulse of the animal is to make for its hole, but, if cut off from this, it will seek safety in the water. The crabs double readily, and a favourite device with them is to remain still till the pursuer approaches and then suddenly dart off. These manœuvres are carried out on the tips of their slender legs and with the eyestalks raised so as to survey as wide a field as possible, and give the impression that the animals possess intelligence of a high order. When finally seized, they make vigorous efforts to defend themselves with their chelae.

As might be supposed from their burrows being submerged at high tide, and from their readiness to take refuge in the sea, the crabs are able to endure immersion in salt water for a number of hours, though they are eventually killed by it. Fresh water, on the other hand, is rapidly fatal, two hours being the longest period that any of them survived an experiment.

The burrows are inhabited each by a single crab, and Major Alcock[3] has shown that the stridulating apparatus, possessed by this species in common with most others of the

[1] In this connection it is interesting to note that the heart of the common hermit-crab [*Eupagurus bernhardus* (Linn.)] and the shore crab [*Carcinides moenas* (Penn.)] may often be found to be beating some time after every outward sign of life is lost from exposure to the air. Even when it has stopped, it may sometimes be induced by mechanical stimulation to give a few beats.

[2] In the hottest part of the day, when the sun shines full upon the beach, they are less active than at other times.

[3] Alcock, *Ann. Mag. N. H.* (6), x. (1892). For *O. ceratophthalma* see Anderson, *Journ. As. Soc. Bengal*, LV. (1894).

genus, is used, in *O. macrocera* at least, to warn out intruders. They differ somewhat in construction with the age of the inhabitant. The full-grown crab, of the sage-green and yellow coloration, makes a hole two or three feet deep with a spiral inclination of about one and a half turns either to the right or to the left indifferently. The burrow grows smaller from above downwards and, in the largest examples, has at the top a sort of vaulted chamber excavated in the sloping beach and leading downwards on one side into the spiral. In this chamber the crab may sometimes be seen sitting. The younger individuals, of a paler, whitish tint and with undeveloped horns on the eyestalks[1], make tubular holes at right angles to the surface of the sand and usually curving to one side or the other at the bottom—the beginning, perhaps, of the spiral of older individuals. There is often a small second opening to these burrows, which thus become roughly U-shaped. When an attempt is made to dig out the crab, it escapes by the smaller opening if one be present. If not, it makes a bolt to get out past the intruder. The larger individuals usually prefer to retire to the bottom of the hole and fight it out.

In digging its burrow, the crab brings up armfuls of sand between the chelae and the body, and throws it away at some little distance from the opening, thus making a low mound, and of course burying any object that may have been there. This process being repeated twice a day by a large number of crabs, a very considerable amount of sand is thus turned over[2], and the burrowing of these creatures must tend in the long run to the same end as that of earthworms—namely to the gradual sinking of any object originally lying on the surface to the level of the bottom of the burrows. That this really happens is shown by the fact that, in digging through the sand, one comes across objects that must have originally lain on the surface, and are now sunk to varying depths. This is the case not only with coral stones but with leaves, sticks, etc., often fresh and of recent burying at a considerable depth. In this connection it must, of course, be borne in mind that the food of the crabs consists largely of leaves and seaweed, which they are in the habit of carrying with them into their burrows[3]. They do not, however, do this with sticks, and a large mass of mammalian dung, found intact at a depth of about a foot in the sand, points to the same conclusion as the sticks. The larger holes reach a layer of coral pebbles interspersed in places with twigs, but in one locality Mr Stanley Gardiner found a mass of decaying vegetable matter containing earthworms. This probably consisted largely of material carried by the crabs to the bottom of their burrows for food.

It is possible that, in addition to their vegetable food, these crabs may be in the habit of catching and eating sandhoppers in the same way as *C. arenaria* (Catesby)[4]. I have not been able to see them do this, but some small individuals, shut up in a bottle with some sandhoppers and a little sand, caused the Amphipods to disappear in the course

[1] These horns, from which the species takes its name, are, of course, well known to be of very variable length in the adult.

[2] I am indebted to Mr Stanley Gardiner for the following figures, which he very kindly obtained for me after my leaving the Island. "Observations in 14 places between Lighthouse and west end of island. Lagoon shore. In areas of 5 sq. yds., greatest number 28 holes; least 2; average 14—15; sand thrown out twice in 25 hrs. Weight of sand from 12 large holes 19 lbs. 3 ozs.; average weight 9—10 ozs. Positions selected quite at random, at too great a distance to allow me to see whether they contained any holes or not."

[3] One or two leaves or pieces of seaweed may often be found in the burrows, but I have never come across anything like a lining of these materials. The destruction of the burrows by the tide would probably prevent this.

[4] S. I. Smith, cited by Stebbing, "Crustacea," p. 86, London, 1893.

of a few hours. The Ocypodes appear to find their food by sight, rather than by smell like *Coenobita*.

ii. *Ocypode cordimana*, Desm.

While it is alive, this crab is easily distinguished from *O. ceratophthalma* by its darker and more brownish colour, but when preserved in spirit it takes on much the same dull greyish-green hue as the other species. The two are, however, always quite easily separated by the absence, from *O. cordimana*, of the stridulating apparatus found in *O. ceratophthalma* as in all the rest of the genus. Their habits are also considerably different. Unlike the strand-haunting *ceratophthalma*, *cordimana* lives inland, digging its burrows in the light sandy soil along the paths and open spaces of the island. Instead of being directed downwards, these burrows usually take the form of more or less horizontal galleries with two, or sometimes three, openings. I have not found leaves, seaweed or food of any sort in those that I have opened, but they run among the roots of the vegetation and these may perhaps serve for food.

Two points of interest are raised by the facts just mentioned. In the first place it is worth remarking that the darker colour of *O. cordimana* harmonises better with that of its earthy environment than would the sandy hues of *O. ceratophthalma*. In the second, the existence of a species whose burrows are situated on land, well above the tide-mark, invalidates the conclusions, as to the raising of the land in Diego Garcia, drawn by Bourne[1] from the presence of Ocypod-holes in certain situations there. The form of these holes would have to be carefully investigated before any such conclusions could be drawn from them.

III. A list of land and fresh water Crustaceans collected in the Maldive Islands.

I am indebted to Mr Stanley Gardiner for the notes incorporated in the following list.

BRACHYURA, CATOMETOPA.

Family **Ocypodidae**. Genus *Ocypode*, Fabr., 1798.

1. *Ocypode ceratophthalma* (Pallas), 1772.

For references, see above, p. 67.

Generally distributed throughout the group.

2. *Ocypode cordimana* Desm., 1825.

For references see above, p. 67.

All the larger islands of the group except in Suvadiva and Addu atolls.

Genus *Uca*, Leach, 1815.

3. *Uca annulipes* (H. M.-Edw.), 1837.

Gelasimus annulipes, H. M.-Edwards. Crust. II. p. 55, pl. XVIII. figs. 10—13 (1837); Alcock, As. Soc. Bengal LXIX. ii. 3, p. 353 (1900) [references].

Uca annulipes, Ortmann, Zool. Jahrb. Syst. X. p. 355 (1897).

Mangrove Swamp, Furnardu, Miladumadulu atoll.

[1] Bourne, *P. R. S.*, vol. 43, p. 445 (1888).

Family **Grapsidae.** Genus *Geograpsus,* Stimps., 1858.

4. *Geograpsus grayi* (H. M.-Edw.), 1853.

For references see above, p. 67.
In every inhabited island of the group.

Genus *Metasesarma,* H. M.-Edw., 1853.

5. *Metasesarma rousseauxi* H. M.-Edw., 1853.

For references see above, p. 68.
General distribution throughout the group in damp land, especially at dry edges of mangrove swamps. Not found in Addu atoll.

Family **Geocarcinidae.** Genus *Cardiosoma,* Latr., 1825.

6. *Cardiosoma carnifex* (Hbst) 1794.

Cancer carnifex, Herbst, "Krabben" II. v. p. 263, Pl. XLI. figs. 1, 2 (1794).
Cardiosoma carnifex, Alcock, As. Soc. Bengal, LXIX. ii. 3, p. 445 (1900) [references].

Of general distribution throughout the northern atolls. Especially common in Miladumadulu and Mahlos. Generally makes its burrows under coconut trees at the edges of *kuli* or swamps, the openings being often covered at high tide. Not found in Addu atoll.

ANOMALA, PAGURINEA.

Family **Coenobitidae.** Genus *Coenobita,* Latr., 1826.

The distribution of this genus in the Maldives is somewhat peculiar. In nearly every island one species at least is found, but it is rare to find three. Two are frequently met with in the same island, and *C. rugosus* is the most common. In Goidu all four are met with, and Hulule, Male, has *perlatus, rugosus* aud *clypeatus.*

7. *Coenobita perlatus* H. M.-Edw., 1837.

For references see above, p. 68.
Of general distribution throughout the group.

8. *Coenobita rugosus* H. M.-Edw., 1837.

For references see above, p. 68.
Of general distribution throughout the group.

9. *Coenobita compressus.* Guérin, 1830.

Coenobita compressa Guérin, Voy. "Coquille," II. 2, p. 29 (1830).
Coenobita compressus, Ortmann, Zool. Jahrb. Syst. VI. p. 318 (1892) [references].
Goidu, and probably elsewhere.

10. *Coenobita clypeatus* Latr., 1826.

For references see above, p. 68.
Of general distribution throughout the group.

CARIDEA.

Family **Palaemonidae**. Genus *Leander*, Desm.

11. *Leander debilis* (Dana), 1852.

Palaeman debilis, Dana, U.S. Expl. Expd., Crust. I. p. 585, Pl. XXXVIII. figs. 6, 7 (1852).
Leander debilis, Ortmann, Zool. Jahrb. V. Syst. p. 515 (1890) in part.

Ortmann (*loc. cit.*) included under this species, as varieties, several other Leanders described by various authors. Among these was *L. longicarpus*, Stimps, 1860, which has since been identified by de Man and Coutière with *L. concinnus* Dana, 1852. The present collection contains examples of a form allied both to *L. debilis* and to *L. concinnus*, though more closely to the former than to the latter. In fact the points of difference between the preserved specimens would certainly be sufficiently small to justify their inclusion in a single species were it not that they exhibit considerable differences in colour and habitat. For notes on these I am indebted to Mr Gardiner.

The present species has 6—9 teeth on the underside of the rostrum and 4—6 above, and the carpopodite of the second leg just reaches the end of the antennal scale. Its size is rather greater than that of *L. gardineri*. When alive it is colourless, but has eggs of a brilliant dark green.

The only locality in which it was found in the Maldives was a kuli surrounded by a mangrove swamp in Landu, Miladumadulu atoll. It was here few in numbers and solitary in its habits.

12. *Leander gardineri*, n. sp.

Under the rostrum of this species are 4—6 teeth, and above it 5—6. The second leg of full grown individuals is longer than in *L. debilis* and its carpopodite exceeds the antennal scale. The size is less than that of *L. debilis*, the largest specimen being 33 mm. in length. The third flagellum of the antennule resembles that of *L. debilis*, and not *L. concinnus*, in being free for less than half its length. The colour is intermediate between straw and brown, the eggs being of a darker shade of the same; the branchiostegites a silvery-white.

This prawn was found in enormous numbers at the edges of a large fresh-water kuli in Ekasdu, Miladumadulu atoll. Both it and the former species are thus of interest in that, contrary to the usual habits of the genus, they live in fresh water. The allied *L. concinnus* lives indifferently in fresh, brackish or salt water.

ISOPODA, ONISCOIDEA.

Family **Ligiidae**. Genus *Ligia*, Fabr., 1798.

13. *Ligia exotica* Roux, 1828.

Ligia exotica, Roux, Crust. Médit. III. Pl. XIII. fig. 3 (1828).

Fairly common throughout the group on boats, ships, wharves, etc. At Mahugudu, Miladumadulu atoll, extremely common all round the shores of the island on the rocks. The specimens from the latter locality are somewhat smaller than those from other places in the group or than those met with in Ceylon or Minikoi, and their colour is different, consisting of a white ground covered with microscopic dark spots, giving a greyish appearance unlike the uniform dark green of typical specimens. Possibly this is due to a state of contraction of the chromatophores at the time of capture. It may be, however, that we have here a local variety of the species.

Family **Oniscidae**. Genus *Porcellio*, Latr., 1802.

14. *Porcellio maldivensis*, n. sp. (fig. 22).

Definition:—A *Porcellio* with the body oblong-oval, rather more than twice as long as broad, not very convex, covered with large granules; lateral lobes of front moderate, rounded, anterior border of the same not much produced in the middle; hinder edge of first free thoracic segment curved forwards at the sides, that of the second less so, that of the third transverse; on the fourth a backward trend appears and grows increasingly strong till the seventh is reached; hinder angles of first three segments rounded, of fourth rectangular, of fifth to seventh acute; antennae rather more than half the length of the body, the two joints of the flagella equal; epimera of third, fourth and fifth abdominal segments of moderate size, very acute; somewhat adpressed; anal ring long, narrow, very acute, projecting well beyond the epimera of the fifth abdominal segment.

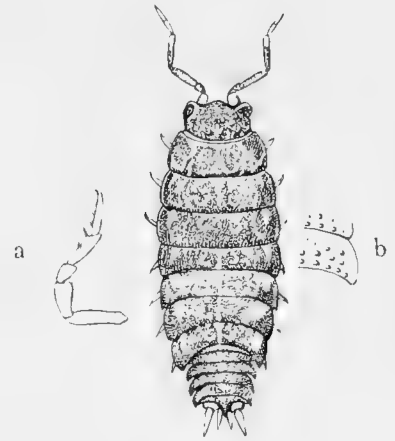


FIG. 22. *Porcellio maldivensis* (×8). *a.* Leg enlarged. *b.* Portion of segment enlarged to show sculpture.

Colour in spirit: brown mottled with yellowish; legs yellowish.

Length of longest specimen 6 mm.

This species seems somewhat transitional to *Metoponorthus*.

Mafaro, Miladumadulu atoll, under damp leaves.

Genus *Alloniscus*, Dana, 1854.

15. *Alloniscus maldivensis*, n. sp. (fig. 23).

Diagnosis:—An *Alloniscus* with the body oval and convex; the antennae not quite half the length of the body, the first two joints of the flagellum subequal, the third somewhat longer; the hinder margin of the first trunk segment curved forwards, those of the second and third transverse, that of the fourth slightly recurved at the sides, that of the fifth more strongly so, those of the sixth and seventh bent backwards sharply at an obtuse angle; the epimera of the third, fourth and fifth abdominal segments moderately large, acute and subequal; the end segment nearly twice as broad as long, triangular, acute, its sides slightly concave.

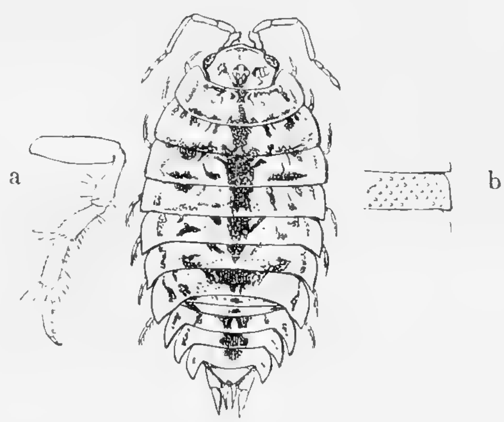


FIG. 23. *Alloniscus maldivensis* (× 6). *a.* Leg enlarged. *b.* Portion of segment enlarged to show sculpture.

Colour in spirit: yellow marbled with black. Legs yellow with a few black spots.

Length of longest specimen: 3·5 mm.

Hedufuri, Mahlos atoll, under stones at edge of well.

Genus *Philoscia,* Latr. 1803.

16. ? *Philoscia gracilis,* Budde-Lund, 1879, var.

The collection contains specimens of a *Philoscia* taken in several different localities, but unfortunately all more or less damaged. They are at all events allied to *P. gracilis* (Budde-Lund Prosp. 2, 1879, and Isop. Terrest, p. 220, 1885), but differ from the description given by the author of that species in the following points:

1. The inner ramus of the uropod, though well-developed, is shorter than the outer.
2. The fifth trunk segment is no darker in colour than the rest.

Common in damp vegetable matter throughout the group, from Mahlos to Addu atoll.

17. *Philoscia,* sp.

Damaged specimens of a *Philoscia* from Hedufuri, Mahlos atoll.

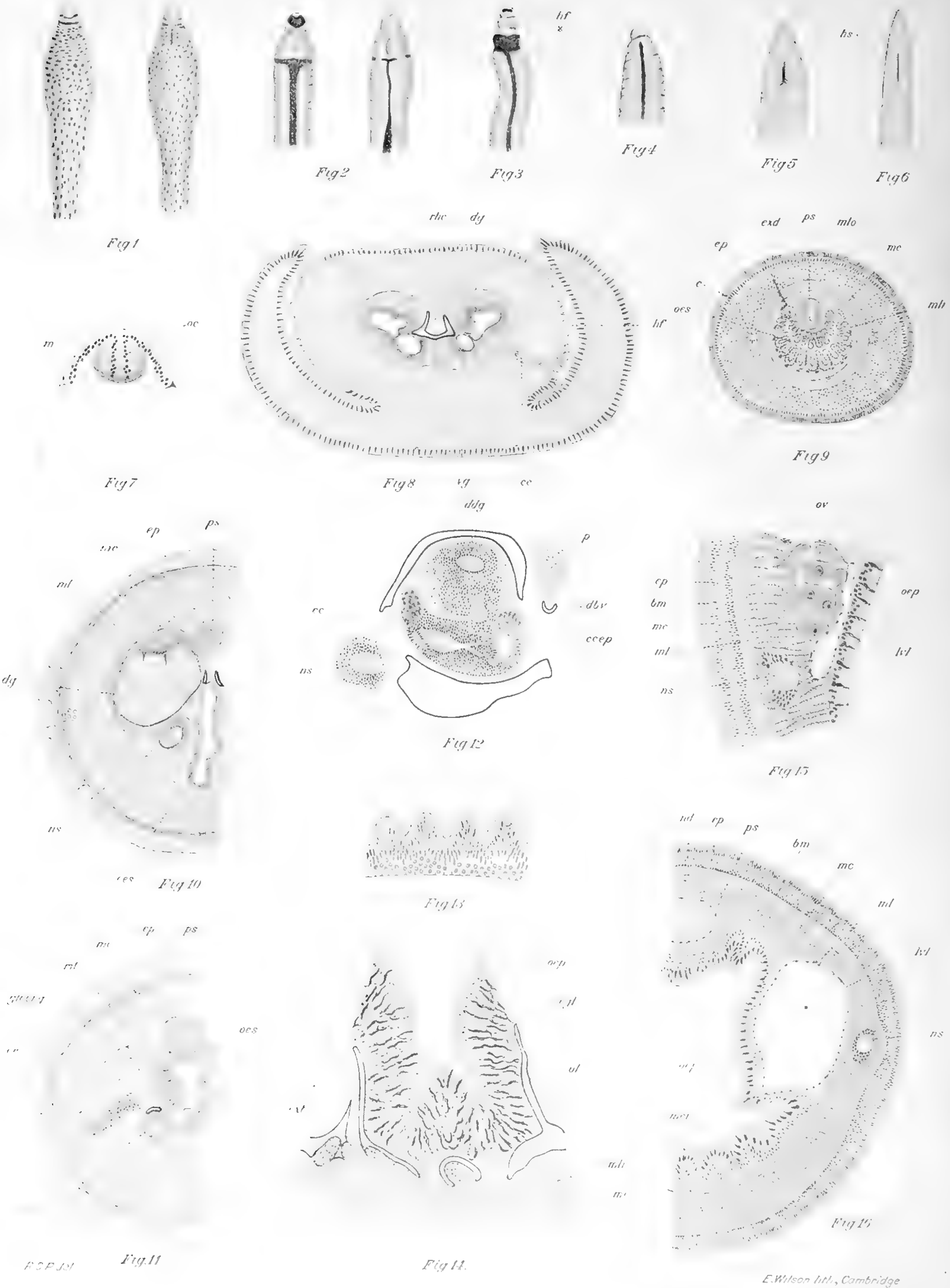
Family **Armadillidiidae**. Genus *Cubaris,* Brandt, 1833.

18. *Cubaris murinus,* Brandt, 1833.

For references see above, p. 68.

Addu and probably also other atolls.

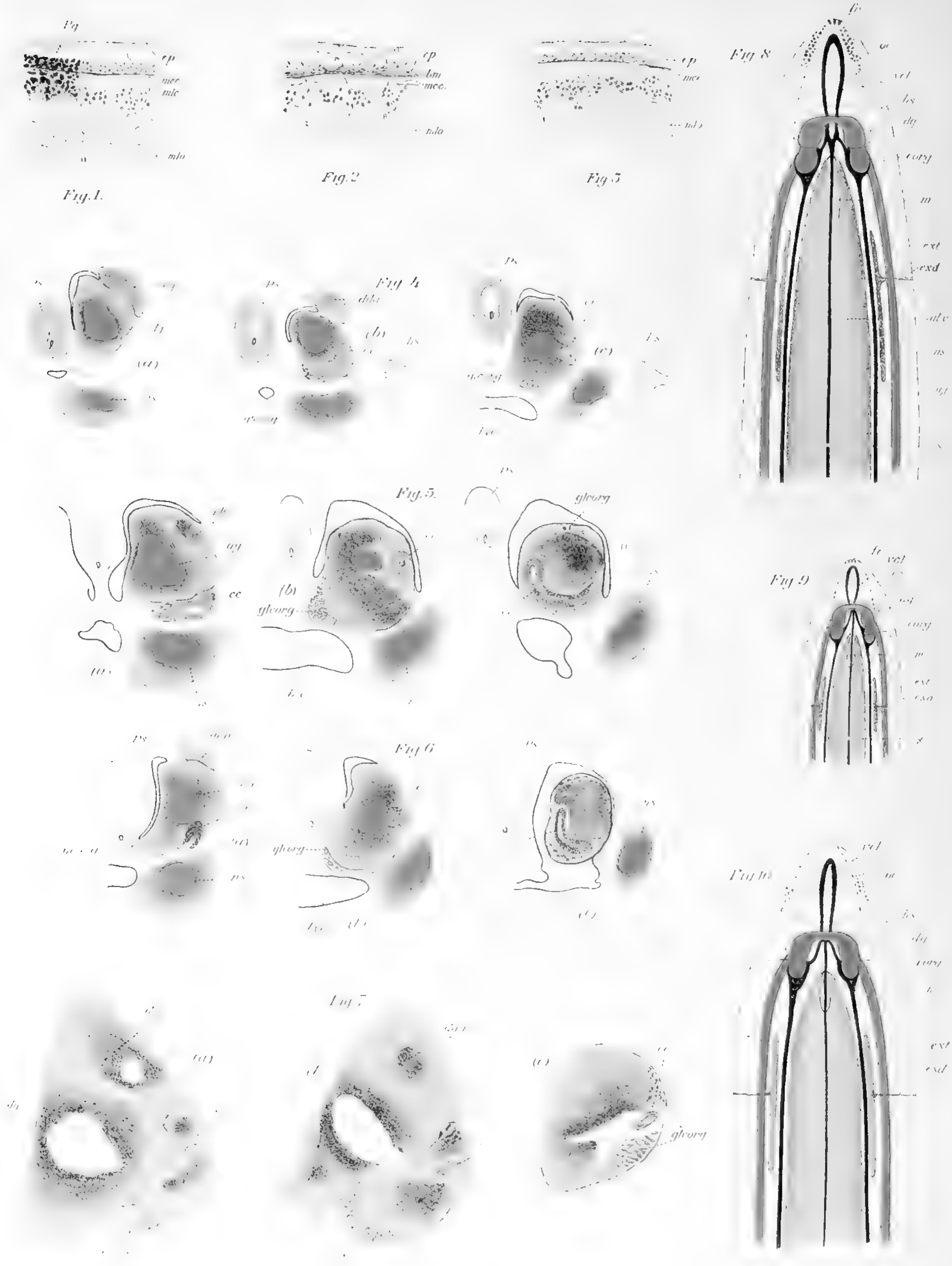
With the exception of the new species, all the above crustaceans are Indo-Pacific in distribution. The only feature of interest in this respect exhibited by the collection is the absence from Addu of several species found in the more northern atolls.



R.C.P. del.

E. Wilson lith., Cambridge

Punnett - Nemertea



R.C.P. del.

E.Wilson, Cambridge.

Punnett – Nemertea

NEMERTEANS.

By R. C. PUNNETT, B.A. (Cantab.).

With Plates IV. and V.

To judge from our previous knowledge of the Nemerteans of the Indian and Eastern Pacific Oceans, the collection of these worms made by Mr Stanley Gardiner is, on the whole, much what one would have been led to expect. The genera *Eupolia* and *Drepanophorus* are well represented, as also is the family of the Lineidae. The curious genus *Prosadenoporus*, first met with at Amboina, is recorded for the second time only. The collection also includes examples of two of the most widely distributed Nemerteans in this part of the world, *i.e. Eupolia hemprichi*, and *Lineus albovittatus*. The collection is however noteworthy in that it adds to the fauna of these seas the first Mesonemertean recorded. *Cephalothrix aliena* belongs to a genus, which has hitherto been recorded from the North Atlantic and from the North-west Pacific[1] only. It is however not unlikely that, as the Nemertean fauna of the various regions of the globe becomes better known, this genus may turn out to be almost cosmopolitan. Almost all the species are excellently preserved, and I would take this opportunity of thanking Mr Gardiner for the energy and trouble expended in forming this collection. In the following pages a brief diagnosis of each new form is given, and this is followed by a more complete description. At the end of the paper I have appended a brief synopsis of the genus *Drepanophorus*.

SYSTEMATIC LIST.

I. Protonemertini[2]. (None.)

II. Mesonemertini.

Fam. **Cephalothricidae.**

1. *Cephalothrix aliena*, n. sp. Comparatively short, stout form with thick epithelium and basement membrane. Mouth beneath brain. No eyes. . . . p. 102

[1] Coe, W. R., *Proc. Wash. Acad. Sc.*, 1901, p. 19.

[2] The classification is that given by Bürger, *Naples Monograph*, 1895.

ACCOUNT OF THE SPECIES.

1. *Cephalothrix aliena*, n. sp. (Pl. IV. figs. 15, 16.)

Represented by 5 cc. of fragments about 1·5 mm. in breadth. Colour dirty white. Ant. end rounded and much contracted. No external markings to be distinguished. Posterior portion missing.

Locality. Felidu atoll, Maldive Is. Dredged from 20 fathoms.

The epithelium is, for this genus, very high (Pl. IV. fig. 15) and is marked by two rows of nuclei—one near the base of the epithelium and one about the middle. In the outer portion of the epithelium occur a few rhabdite-like structures which take a bright yellow hue with picric acid. This epithelium rests upon a thick basement membrane which is more than half the thickness of the epithelium itself.

A delicate circular muscle layer lies just beneath the basement membrane and is less than half the thickness of this latter structure. A thicker longitudinal muscle layer lies beneath the circular layer. Beneath this layer again there is in the oesophageal region an inner very delicate layer of circular muscles (Pl. IV. fig. 16 *mci*), which is well marked on the ventral surface of the oesophagus, and which is continued laterally to enclose the two lateral blood vessels. On the dorsal surface of these the fibres end. Between the proboscis sheath and the alimentary canal there is a delicate layer of longitudinal muscles both in the oesophageal and the intestinal regions.

The vascular system is extremely simple as in the other members of the genus. There are two longitudinal lateral vessels which unite together over the rhynchodaeum anteriorly. In the oesophageal region these vessels are exceedingly spacious. They are lined by a delicate flattened endothelium. They do not extend to the proboscis sheath.

The mouth is situated on the ventral surface directly beneath the brain. Its hinder termination is at a level slightly in front of the hind end of the brain. The oesophagus is short and passes directly into the intestine, which can be readily distinguished by the absence of gland cells in its epithelium. It possesses small lateral diverticula.

The proboscis is exceedingly fine, not exceeding ·16 mm. in diameter. It possesses a longitudinal muscle layer and an exceedingly delicate circular muscle layer just beneath the proboscis epithelium. The proboscis sheath possesses an extremely fine inner longitudinal and a somewhat thicker outer circular muscle layer. The rhynchocoelom is small.

There is no trace of nephridia.

The nervous system is poorly developed. The brain is small and the ventral ganglion is as large as the dorsal. The ventral commissure is fairly stout—the dorsal commissure is weak. Through the nervous ring thus formed pass proboscis sheath and blood vessels. The oesophageal nerves are well marked. A well marked median dorsal nerve is present between the basement membrane and circular muscle layer. There is also between these two layers of the body wall what appears to be an exceedingly delicate layer of nerve fibrils, and minute twigs may be observed piercing the basement membrane to reach the epithelium above.

There are no special sense organs, frontal organ, eyes, and cerebral organ being all absent. Moreover there are no traces of cephalic slits. There are no head glands.

The single individual procured is a female and the ovaries extend into the hinder oesophageal region. They lie rather dorsal to the level of the nervous side stems (Pl. IV. fig. 16), and to the outer side of the blood vessels into which they project. The cavity of the ovary is only separated from that of the vascular system by the delicate endothelium of the latter. No gonidial ducts are developed. The ova are apparently not yet mature.

The most marked point of difference between *C. aliena* and the rest of the genus lies in the relative positions of mouth and brain. In all the other species whose anatomy has been described the mouth lies behind the brain, and usually some distance behind. The structure of the epithelium with its double layer of nuclei is more complex than in the rest of the genus. In the presence of an inner circular muscle layer *C. aliena* resembles *C. signata* and differs from the other species of *Cephalothrix*. The great thickness of the basement membrane also is unusual. Moreover to judge by the figures in Bürger's Monograph (Taf. II.) the rhynchocoelom is less spacious and the blood vessels considerably more so than is usually the case.

2. *Eupolia hemprichi* (Ehrenberg, 1831). (Pl. IV. figs. 2, 3.)

Syn. *Nemertes hemprichi*, Ehrenberg, Symbolae Physicae, 1831.
Eupolia brocki, Bürger, Zeit. f. wiss. Zool., 1890.
Eupolia hemprichi, Bürger, Naples Monograph, 1895.
Eupolia hemprichi, Punnett, Willey's Zool. Results, Pt. v., 1900.

Locality. Found sparsely on every reef.

Several specimens of this common and widely-distributed species were obtained from the reefs both in the Maldive and the Laccadive Islands.

The size after preservation varied from 6·5 cm. to 104 cm. in length. The last-mentioned specimen is larger than any other yet recorded. The following note was made on the living worm by Mr Stanley Gardiner: "Length when obtained out of a hole in the rock of the reef-flat 5 ft. 6 in. (= 167·6 cm.). Black streak down centre of back and same transverse behind head." These markings become brown after preservation. There was in this specimen also a pigment fleck on the tip of the head and further a ventral line of about the same width as the dorsal extending along the whole length to the collar just behind the mouth. Here, however, it is much thinned (Pl. IV. fig. 2), and the collar is also incomplete ventrally. In markings as well as in size this specimen is intermediate between the figures which Bürger gives of *E. brocki* (*loc. cit.* 1890, Taf. I. fig. 10) and of *E. mediolineata* (Zool. Jahr. Bd. 7, Abt. f. Syst. Taf. VIII. fig. 1). The thickness of the dorsal and ventral lines and also of the transverse one is exceedingly variable. In one case the line may be at least one-third of the body-width, whilst in another it is exceedingly fine. Sometimes again the dorsal stripe is the broader of the two, whilst in others the ventral exceeds the dorsal in width. Such considerations render it not unlikely that the species described by Bürger as *E. mediolineata* may be merely a local variety of *E. hemprichi*. The species has a wide range, extending from New Britain in the East Pacific, across the Indian Ocean to the Red Sea.

In a previous paper I mentioned that the excretory system in a specimen of this species (Punnett, 1900, *loc. cit.*) was not provided with ducts. This led me to make sections right through this region in a specimen from the Maldives. The result was a confirmation of the previous statement that the excretory system is here unprovided with ducts opening to the exterior.

3. *Eupolia indica*, n. sp. (Pl. IV. figs. 8, 12, 13, 14.)

Locality. Hulule, Male atoll, Maldive Is. From reef.

A single complete specimen was obtained measuring 22 cm. in length, and with an average breadth of 35 mm. In external appearance much wrinkled and somewhat flattened. There is a well-marked circular head furrow. On the dorsal surface there is a very pale brown stripe about $\frac{1}{4}$ of the body-width. A similar stripe occurs also on the ventral surface.

The skin is fashioned in the style characteristic for the genus. The closely packed layer of cutis glands is about three times the thickness of the epithelium. The connective tissue layer of the cutis is rather thicker than the glandular layer.

The circular muscle layer in the oesophageal region is rather thicker than the inner longitudinal layer. The outer longitudinal layer is stouter than the other two together.

The vascular system in the snout region forms a distinct cephalic loop, though the vessels are very wide and separated only by a thin partition. This loop lies dorsal to the rhynchodaeum, *i.e.* in the same position as the anastomosing lacunae of other species of *Eupolia*. In other respects the vascular system shews no peculiarities marking it off from the usual arrangement such as that found in *E. curta*.

The alimentary canal shews no marked peculiarities.

The proboscis is peculiar in possessing only one layer of muscle fibres, *i.e.* a longitudinal layer. The epithelium is comparatively low.

The excretory system starts about 4 mm. from the tip of the snout. It lies entirely at or below the level of the line joining the nervous side stems. It extends over about 5 mm. It possesses no ducts to the exterior nor any traces of such structures. Fine cords of cells however, which have almost the appearance of delicate ducts compressed to obscure the lumen, pierce the glandular layer of the oesophagus (Pl. IV. fig. 14) and may be traced to the oesophageal epithelium. Such an arrangement recalls the peculiar condition found in *Eupolia melanogramma*[1], though the communications differ probably from this latter species in not being functional.

The brain is much flattened in shape (Pl. IV. fig. 8), its breadth being about three times as great as its depth. The dorsal commissure is thick, straight, and short. The dorsal ganglion lies more lateral than dorsal to the ventral ganglion.

The cerebral organ is not large and is considerably flattened. The ciliated canal passes straight to the inner border of the organ where it dilates into a large spherical vesicle with high epithelium containing a few gland cells (Pl. IV. fig. 12). A small quantity of glandular secretion also occurs within this expansion of the ciliated canal. The dorsal lobe of the dorsal ganglion reaches some way over the cerebral organ. The opening of the cerebral organ is lateral and slightly ventral (Pl. IV. fig. 8). The ciliated canal in this position opens into the circular head furrow, and the circular head furrow in this species is peculiar in being marked by a number of small longitudinal furrows which extend entirely round it (Pl. IV. fig. 8). The epithelium of these small head furrows is characterised by an absence of epithelial glands and by the numerous closely packed oval nuclei (Pl. IV. fig. 13). Along the summits of these small ridges occur small refractive bodies which do not stain. Such head furrows are peculiar to this species of *Eupolia* so far as is known, and recall the small head furrows found in a similar position in the genus *Drepanophorus* ("Kopfgrübchen").

[1] Punnett, *Quart. Journ. Mic. Sc.*, vol. 44, p. 116.

Numerous small eyes occur on the dorsal surface of the snout. They lie for the most part in the cutis, though some are found in the outer longitudinal muscle layer.

The head glands are well developed and are of the typical *Eupolia* type. They reach backwards as far as the level where the excretory tubules start. Anteriorly they open into the well-marked frontal organ.

4. *Eupolia unistriata*, n. sp. (Pl. IV. fig. 4.)

Locality. Hulule, Male atoll, Maldive Is. From reef.

Two specimens were obtained. The larger measures 55 cm. in length, whilst the average breadth is 6 mm., and depth 4 mm. The smaller specimen measures 26 cm. in length and 5 mm. in breadth. In life the worms were white with a black stripe down the back. The width of the stripe is less than 1 mm. In the larger specimen the stripe stops short at the head furrow (Pl. IV. fig. 4), whilst in the smaller one it is continued on to the snout. No markings on the ventral surface.

In external form this species bears a great resemblance to *E. melanogramma* (Punnett, Quart. Journ. Mic. Sc., vol. 44, p. 113). This resemblance is found also in the internal structure. It will be sufficient here to indicate the main points of difference.

The connective tissue layer of the cutis is not so thick as the glandular layer. In *E. melanogramma* these proportions are reversed.

The excretory system possesses numerous openings to the exterior, but it lacks the peculiar ducts opening into the oesophagus which characterise *E. melanogramma.*

The arrangement of the vascular system in the cerebral region is that characteristic of the genus. In *E. melanogramma* the arrangement is slightly different (*loc. cit.* p. 115).

With these exceptions the anatomy of the two species is practically identical. As in *E. melanogramma* there is present also in this species a well-marked sub-anal nervous commissure.

5. *Cerebratulus maldivensis*, n. sp. (Pl. IV. fig. 5, and Pl. V. figs. 3, 6, 9.)

Locality. Miladumadulu atoll, Maldive Is. Dredged in 22 fathoms.

This species is represented by about 30 mm. of fragments. The average breadth is about 1·7 mm. The more posterior portion is much flattened, not measuring more than ·3 mm. in depth. The anterior end is more rounded. The hind end is missing. The proboscis pore is terminal, and the mouth is situated about 2 mm. behind the tip of the snout, which is somewhat pointed. Colour whitish after preservation. No markings present.

The epithelium is thin and contains a few unicellular glands which stain deeply with picric acid. The basement membrane is exceedingly thin (Pl. V. fig. 3). Just below it there is a well-marked layer of circular muscle fibrils and just beneath these again a few longitudinal fibrils which are separated from the outer longitudinal muscle layer by a very thin layer of cutis glands. The whole cutis is but feebly developed.

The outer longitudinal muscle layer in the oesophageal region is about double the thickness of the circular layer. The inner longitudinal layer in this region is of approximately the same thickness as the circular layer. All these three layers are somewhat massive compared with the size of the worm. Between the dorsal surface of the oesophagus and the proboscis sheath a few longitudinal muscle fibres are present. There is no diagonal muscle layer. A few horizontal muscles occur over the mouth.

The opening of the mouth is situated just before the level where the cerebral organs terminate. The oesophagus is comparatively small and becomes exceedingly constricted posteriorly.

The vascular system shews a well-marked cephalic loop (Pl. V. fig. 9). The buccal commissure is very large. The oesophageal lacunae unite, directly behind the nephridia, to form a single small lateral lacuna on either side, which eventually passes into the lateral vessel. The last named is distinguished from the lacuna by the fact that it has an outer lining of parenchyma cells and gives off small dorsal vascular commissures to the median dorsal vessel at regular intervals. The median dorsal vessel leaves the proboscis sheath just after the termination of the excretory system.

The proboscis is unfortunately lacking. Judging by the small size of the rhynchocoelom it could not have been very large. It was attached very far forwards to the dorsal wall of the sheath just behind the excretory region.

The excretory system is small and confined to the anterior region of the oesophagus. The tubules extend both dorsally and ventrally to the level of the nervous stems. About the centre of the system there is a single excretory duct (Pl. V. fig. 9) on either side which makes an angle of about 45° with the level of the nervous stems.

No gonads are to be distinguished.

The brain is well developed and the dorsal ganglion is double the size of the ventral. Both in the brain and in the nervous side stems the internal fibrous core is more strongly developed than usual. For this reason the nervous side stems are larger and more conspicuous in transverse section than is usually the case, and their large size may possibly be connected with the unusually thick body musculature. A large neurochord cell is present on the ventral and inner surface of each ventral ganglion soon after its separation from the dorsal ganglion. The median dorsal nerve is not well marked. The dorsal brain commissure is short and rather stout. The cerebral organ (Pl. V. fig. 6) is large and ovoid in shape. The glands developed in connection with it are somewhat scanty. It lies at first directly above and then to the inner side of the nervous stem. The head slits reach nearly to the brain. They continue deep a little way after the ciliated canal has been given off.

A frontal organ is present. Eyes are absent. The head glands are very scanty.

6. *Cerebratulus maculatus*, n. sp. (Pl. IV. fig. 1, and Pl. V. figs. 1, 5, 10.)

Locality. Suvadiva atoll, Maldive Is. Dredged from 45 fathoms on mud bottom.

Represented by fragments of a single specimen amounting to 62 mm. Average breadth about 3 mm. Anterior end somewhat rounded, posterior portion much flattened. Hind end lacking. The colour of the preserved specimen is a pale brownish-yellow marked with black spots. These markings are short broken transverse lines in the anterior oesophageal region. A short distance further back they become round, whilst still further back in the posterior oesophageal and intestinal regions they become short longitudinal markings. They are present both on the dorsal and on the ventral surface. (Pl. IV. fig. 1.)

The epithelium is somewhat low, and the nuclei form a well-marked layer at the bases of the cells. In the outer clear portion of the cells are a few unicellular glands, which take a vivid yellow stain with picric acid. A very thin basement membrane separates the epithelium from an exceedingly delicate layer of circular muscle fibrils. Below these again come a few longitudinal muscle fibrils, which are separated from the outer longitudinal muscle layer by a layer of nuclei, apparently representing the cutis glands. The pigment, which gives rise to the black markings of the worm, is situated partly in the cutis (Pl. V. fig. 1) and partly in the nuclear layer of the epithelium. The outer portion of the outer layer of longitudinal muscles is more or less divided into bundles by strands of connective tissue.

Of the muscle layers of the body wall the circular muscle layer is rather thicker than the inner longitudinal but less than half the thickness of the outer longitudinal layer. There are well-marked horizontal fibres over the mouth. The precerebral region is more closely packed with muscle fibres than is usually the case. There is no diagonal muscle layer.

The mouth commences shortly before the level where the cerebral organ terminates. There is no ventral gutter to the intestine.

The vascular system shews a well-marked cephalic head loop. The buccal commissure is well developed. Shortly after the termination of the excretory tubules the oesophageal lacunae are gathered together into a single small lateral lacuna which extends to the intestinal region. Here it acquires a coat of parenchyma cells, and gives off dorsal commissural branches, becoming the lateral blood vessel.

The proboscis is fairly well developed, and shews the three muscle layers characteristic of the Lineid proboscis. Muscle crosses are present.

The excretory system commences soon after the hinder termination of the mouth. There is a median longitudinal tubule running along at the level of the nervous stem. Into it smaller tubules open at intervals, extending a little way above and below the level of the side stems. They are however both small and few in number, the whole excretory system being much attenuated. There is a single duct (Pl. V. fig. 10) on either side about the middle. The lumen of these ducts is also reduced, and it is probable that they were not functional in the living animal.

No gonads are developed.

The brain is not very large. The dorsal ganglia lie directly over the ventral which are closely apposed. Both dorsal and ventral commissures are extremely short. The median dorsal nerve is well marked. Neurochord cells are present in the ventral ganglia though they are not so large as usual. The cerebral organ is fairly well developed though the gland cells in connection with it are somewhat scanty. It lies for the most part dorsal to and just inside the nervous side stems. The head slits reach nearly to the brain and extend backwards to the level where the cerebral organ terminates.

Numerous small eyes are present on the tip of the head just dorsal and ventral to the head slits. Frontal organ and head glands are both absent.

7. *Cerebratulus gardineri*, n. sp. (Pl. IV. figs. 6, 9, and Pl. V. 2, 4, 8.)

Locality. Minikoi, Laccadive Is. From lagoon sand.

Fragments of two specimens preserved, *i.e.* about 73 mm. of one worm and 98 mm. of a somewhat smaller specimen. The latter specimen is almost complete. The breadth is fairly uniform, being about 2·5 mm. in the larger and 2 mm. in the smaller specimen. The intestinal region is somewhat flattened, though not greatly so. The head is sharply pointed, the head slits are long, and the mouth is long and slit-like. Colour when alive white or whitish flesh.

The epithelium is somewhat low and contains a large number of unicellular oral glands. It rests on a thick basement membrane (Pl. V. fig. 2) beneath which is a well-marked layer of circular muscle fibrils. Between this layer and the outer longitudinal muscle layer is the cutis, which contains a few small bundles of longitudinal muscle fibres, traces of cutis glands and a little connective tissue.

The muscles of the body wall are fairly well developed. The outer longitudinal layer is about double the thickness of the circular layer (Pl. IV. fig. 9) in the oesophageal region, and this again is twice as thick as the inner longitudinal layer. The oesophagus is provided with a separate and very delicate coat of longitudinal muscles. There is a strong layer of horizontal muscles over the mouth.

The mouth commences at the level where the cerebral organ terminates, or slightly in front of that level. The intestine possesses a well-marked ventral gutter. The hinder part of the oesophagus is much constricted.

In the vascular system there is present a cephalic loop. Shortly behind the termination of the excretory tubules the oesophageal lacunae are gathered into a single lacuna, which later becomes the lateral blood vessel of the intestinal region as in *C. maldivensis* (p. 107), *C. maculatus* (p. 108). The dorsal blood vessel leaves the proboscis sheath at the level where the oesophageal lacunae are gathered into a single lacuna, *i.e.* rather more than 1 mm. behind the termination of the excretory tubules. The arrangement of the blood lacunae in the cerebral region conforms to the typical Lineid type.

The proboscis is long and fairly stout, being about 1 mm. in diameter. It presents the usual three muscle layers and possesses two muscle crosses.

The excretory tubules first appear in section just before the posterior limit of the mouth. They extend a little way dorsally and ventrally to the level of the nervous stems. In one specimen there was a single duct on either side, making an angle of about 45° (Pl. IV. fig. 9, *exd.*) with the nervous side stems. In the other specimen there was a single duct placed rather in front of the middle of the system on the right side, whilst on the left side there were four ducts, the most anterior of which had almost disappeared.

No gonads were found in either specimen.

The brain is large and the dorsal ganglion is more than double the size of the ventral. The median dorsal nerve is not well marked. Neurochord cells occur on the inner side of each ventral ganglion shortly before its separation from the dorsal ganglion. The median dorsal nerve is not well marked. The cerebral organ is large (Pl. V. fig. 4 *c*), and the gland cells in connection with it are somewhat scanty. The head slits are deep, reaching almost to the brain. At the same time they are exceedingly wide. They continue deep after the ciliated canal has been given off, and terminate at a level slightly behind the posterior end of the cerebral organ.

A frontal organ is present. Numerous small eyes occur, chiefly on the dorsal surface and just beneath the basement membrane. Head glands not well marked.

8. *Cerebratulus ischurus*, n. sp. (Pl. V. fig. 7.)

Locality. Hulule, Male atoll, Maldive Is. From reef.

Fragments of a single specimen amounting to 21 cm. in all. The oesophageal region is rounded in shape, and the breadth here is about 7 mm. The intestinal region is somewhat flattened, and shews a well-marked median ventral longitudinal groove. It measures about 14 mm. in width and about 5 mm. in depth. No record has been preserved of the colour in life. After preservation it is a uniform pale dirty brown.

The epithelium is thin, and contains a few unicellular gland cells. The basement membrane is very thin, and beneath it is a fine layer of circular muscle fibrils and then some longitudinal fibrils separating the last named from the cutis glands. The last are not well developed. The structure of the body wall bears a great resemblance to that of *C. haddoni* (Punnett, Proc. Zool. Soc. 1900, Pl. LV. fig. 8), from which it differs in the somewhat greater development of the cutis glands.

The muscles of the body wall are strongly developed. The outer longitudinal layer is about half as thick again as the circular layer. This in its turn is about double the thickness of the inner longitudinal layer. There is a thick layer of longitudinal muscles between the proboscis sheath and oesophagus. It is continued round the oesophagus as a delicate investment of longitudinal muscle fibrils.

The mouth commences at the hind level of the dorsal ganglion and lies below the cerebral organ.

The vascular system in the snout shews a system of lacunar anastomosing spaces in lieu of a well-marked head loop. The hinder part of the cerebral organ is surrounded by a blood lacuna. The oesophageal lacunae are spacious.

The proboscis is slender. It is two layer as regards musculature, and shews two muscle crosses. The wall of the proboscis sheath is remarkably muscular. Its circular muscle layer is just over half the thickness of the circular muscle layer of the body wall. There is also a delicate outer investment of longitudinal muscle fibrils continuous with the layers separating the proboscis sheath from the oesophagus and circular musculature of the body wall respectively.

The excretory system commences some way behind the mouth. The tubules extend ventral to the nervous side stems and also dorsally to the proboscis sheath. In the anterior fragment cut there was but one excretory duct. Judging from other forms, it is exceedingly probable that had more excretory ducts been present some would have occurred in the comparatively large number of sections through the excretory region. Consequently it is probable that *C. ischurus* is a form with but one pair of excretory ducts.

The brain is small compared with the bulk of the animal. The fibrous core of the dorsal ganglion is about twice the size of that of the ventral ganglion. The dorsal nervous commissure gives off a median dorsal, which for a very short distance behind the brain lies in the outer longitudinal muscle layer, and not between it and the circular layer as is usually the case, whilst here it gives off a strong proboscis sheath nerve ("untere Rückennerv"). Shortly afterwards it dips down to lie in the normal position between the outer longitudinal and circular muscles. A similar arrangement, though much more marked, occurs in *Oxypolia beaumontiana*[1].

The cerebral organ is small and for the most part much compressed (Pl. V. fig. 7). It possesses a very scanty supply of glands. The head slits are deep, reaching nearly to the brain. They end abruptly where the ciliated canal comes off.

The head glands are fairly well marked. The frontal organ is very small. Eyes absent.

9. *Lineus albovittatus* (Stimpson, 1857), Bürger, 1890.

Locality. Hulule, Male atoll, Maldive Is. From reef.

One specimen measuring 155 mm. in length and 8 mm. in breadth. Its wide distribution has already been noted[2].

10. *Prosadenoporus buergeri*, n. sp.

Locality. Minikoi, Laccadive Is. From beneath a stone in the boulder zone of reef.

A single specimen was obtained. Length after preservation, 70 mm.; breadth, 2·5 mm. The breadth is uniform throughout, and the body is rounded in external appearance. The proboscis was extruded, and measured 35 mm. in length and 1·5 mm. in breadth. Colour in life pink-white.

The epithelium rests on a well-marked basement membrane. The circular muscle layer is considerably thicker than the basement membrane, and is well developed for a metanemertean. The longitudinal muscle layer is several times as thick as the circular layer.

The oesophagus and rhynchodaeum are fused together a little way behind the common opening which is situated nearly terminally on the ventral surface. There is no well-marked ventral blind gut, but where the oesophagus passes into the intestine a single lateral diverticulum is given off from the latter on either side. These two diverticula are spacious and, lying on either side of the oesophagus, extend forwards nearly to the region of the brain. The intestinal diverticula are wide and shallow.

The vascular system presents the usual metanemertean arrangement.

The proboscis sheath extends to the hind end. It possesses an inner layer of longitudinal muscles surrounded by a layer of circular ones. The proboscis is formed on the usual metanemertean plan. It contains 19 nerves.

The excretory system is absent.

The gonads are comparatively undeveloped. They are small sacs containing minute ova. The genus is stated by Bürger to be hermaphrodite, but no traces of testes were to be distinguished in this specimen, though in the other species of the genus this author found ova and spermatozoa both ripe at the same time.

The brain is not large and I have been unable to distinguish neurochord cells. The small cerebral organs lie ventral to and entirely in front of the brain. They open on the ventral surface.

[1] R. C. Punnett, *Quart. Journ. Mic. Sc.* Vol. 44 (in the press).

[2] R. C. Punnett, *Proc. Zool. Soc.* 1900, p. 826.

Two very large eyes are present on either side.

As in the other species of the genus the head glands are exceedingly well developed and reach back a little way past the brain. They open into a deep pit lined by modified ectoderm resembling that figured by Bürger (Naples Monograph, Taf. 18, fig. 12).

The only account of the genus *Prosadenoporus* is that given by Bürger in founding the genus on several species from Amboina (Zeit. f. Wiss. Zool. 1890, p. 30). I have therefore thought it fitting to name this new species in honour of the zoologist to whom our entire previous knowledge of the genus is due. From the account given in this publication it will be seen that the present species differs from the forms there described chiefly in the absence of external markings, the number of proboscis nerves, and in the ventral position of the opening of the canal of the cerebral organ.

11. *Drepanophorus roseus*, n. sp. (Pl. IV. fig. 7.)

Localities. Hulule, Maldive Is. From boulder zone. Naifaro, Fadiffolu atoll, Maldive Is.

Several specimens, most of which were somewhat fragmentary. In three complete specimens the length varied from 50—64 mm. and the breadth from 5—5·5 mm. after preservation. The posterior and middle portions of the body were exceedingly flattened. Colour in life pink to red.

The epithelium is high, and contains numbers of elongated unicellular glands with small granules inside ("Stäbchenzellen"). It is separated from the circular muscle layer by a thick basement membrane. The relative thickness of the three layers, epithelium, basement membrane, and circular muscle layer, is as 4 : 3 : 2. The longitudinal muscular layer is well marked, being of about the same thickness as the preceding three layers together. A thin diagonal layer occurs between the circular and longitudinal.

Mouth and proboscis pore open separately into a common depression on the ventral surface near the anterior extremity. The latter opening is the more anteriorly placed. At first without glands the oesophagus begins to shew large deeply staining unicellular glands in the cerebral region. There is a well-marked ventral blind gut passing forward from the junction of oesophagus and intestine. It does not however reach forwards quite two-thirds of the distance between its point of origin and the brain. The intestine is a small round tube whose area in cross-section is not much more than double that of one of the nervous stems at the same level.

The vascular system conforms to the usual metanemertean arrangement. It contains numbers of large oval corpuscles which render it exceedingly conspicuous in section. The lateral vessels lie just dorsal to the nervous stems, and the commissural vessels which they give off pass directly up between the intestinal diverticula to the median dorsal vessel. Others, however, pass right round the ends of the intestinal diverticula before reaching the median dorsal vessel.

The proboscis sheath presents the usual basket-like arrangement of its muscle fibres which characterises the genus. The diverticula are long and slender, and pass round the intestinal pouches to reach as far as the nervous stem. The proboscis shews the usual metanemertean structure, and contains twenty-two nerves. The length of the proboscis is about half that of the body.

The excretory tubules are first found in section just after the hinder end of the cerebral organ. When first seen in section the tubules lie laterally and dorsally in the gelatinous connective tissue just beneath the longitudinal muscle layer. As it issues from the nervous ring the lateral blood vessel on either side makes a short bend to the lateral edge of the body before taking up its position just dorsal to the nervous stem. The portion of the vessel forming this bend is somewhat dilated, and the excretory tubules enter into close relation with it. The excretory pore is situated about ·5 mm. behind the termination of the brain on either side. The duct in each case passes round the outer side of the nervous stem and opens on the ventral surface directly beneath it. The excretory tubules extend backwards nearly to the intestinal region, being all the way closely apposed to the lateral blood vessel.

Gonads undeveloped in all the specimens.

The brain is large and round, and the dorsal ganglia have about 4—5 times the area of the ventral in section. The dorsal commissure is very long and slender. The distance between the nervous stems in the intestinal region is about half the width of the body. A small median dorsal nerve occurs between the circular muscles and the basement membrane. Just behind the dorsal commissure a small but well-defined nerve leaves the dorsal ganglion on either side to run along the side of the proboscis sheath just above the diverticula of that structure. It passes into the longitudinal muscles of this region. It is not to be distinguished behind the oesophageal region. Whether this nerve supplies the muscle fibres or whether it passes through the muscles and basement membrane to pass to the skin is doubtful. The fact that it comes off the dorsal ganglion probably indicates a sensory nerve. The nervous stems posteriorly form a well-marked supra-anal commissure. One pair of neurochord cells is present in the brain.

The cerebral organ is large, being in cross section about $\frac{2}{3}$ of the area of the dorsal ganglion at its largest. It lies exactly lateral to the dorsal ganglion and terminates posteriorly at the same level. It possesses a cap of gland cells over its hinder portion, which extends rather further forwards dorsally than ventrally. The opening of the cerebral organ is situated rather in front of the organ and exactly on the lateral edge of the body. There are well-marked little longitudinal head furrows ("Kopfgrübchen") extending some way dorsally and ventrally. The cerebral organ is supplied by one large nerve which comes off the hind end of the dorsal ganglion.

Numerous large eyes are present arranged in four longitudinal rows (cf. Pl. IV. fig. 7.) There are well-marked head glands, but these are short, not extending more than one-third of the distance from the tip of the snout to the brain.

12. *Drepanophorus cerinus.* (Bürger. 1890.) (Pl. IV. figs. 10, 11.)

Literature. Bürger, O. Zeit. für Wiss. Zool., 50 Bd. 1890.

Locality. Suvadiva atoll, Maldive Is. From 38 fathoms.

The account given by Bürger is exceedingly short. The small size and the peculiar structure of the cerebral organ, however, render the species fairly easy to identify. I have added below a somewhat fuller account than that given by this author.

Two specimens were obtained measuring about 25 mm. in length and 5 mm. in breadth. The specimens were not quite so flattened dorso-ventrally as most members of this genus, owing to the fact that their bodies were bulged out by ripe gonads. The proboscis is stout and measures about 10 mm. in length. The colour is a very pale pinkish-brown after preservation, and no external markings are distinguishable.

The epithelium is thick and rests upon a very thin basement membrane, which is not nearly so strong as the circular muscle layer just beneath it. The longitudinal muscle layer is strong.

The vascular system presents the usual metanemertean arrangement.

The mouth opens just behind the proboscis pore, but the separation between the two openings is complete. There is not even a depression into which both open as in most species of the genus. In the cerebral region the greater part of the oesophagus (Pl. IV. fig. 10) lies squeezed between the brain lobes. The blind gut extends about half-way from its point of origin towards the brain.

The proboscis sheath shews the usual basket-like arrangement of the muscle fibres. The first few rhynchocoelomic diverticula are exceedingly small, and even in the posterior oesophageal region they reach barely as far as the nervous stems. The proboscis shews the usual structure. It contains but 14 nerves.

The excretory tubules reach forward nearly as far as the opening of the cerebral organ. The excretory pore (which is paired) is about the same distance behind the brain as the front end of the brain is from the tip of the snout. It is ventral in position, and in the specimen cut the duct is much reduced and was probably not functional.

The gonidial sacs of the specimen cut contained large ripe ova. The sacs start in the posterior oesophageal region, and then open just dorsal to the nervous stems on either side. In the intestinal region the openings are ventral near the lateral edge of the body.

The brain is very large, the dorsal ganglion being about 6—7 times the size of the ventral (cf. Pl. IV. fig. 10). The two lobes of the brain are closely apposed, both dorsal and ventral commissures being comparatively short. There is a small median dorsal nerve between the basement membrane and circular muscle layer. The distance between the two lateral stems in the intestinal and in the oesophageal regions is more than half the total breadth of the body of the worm. There is a well-marked supra-anal nerve commissure.

The cerebral organ is very large. It is situated entirely behind the brain. Its opening is rather behind the level where it first appears in section[1]. It is lateral and slightly ventral (cf. Pl. IV. fig. 11). The structure of the organ has already been described by Bürger in the paper referred to above. The essential peculiarity of the organ is the greatly elongated glandular tube which stretches backwards above the nervous stems for a distance which is rather more than double that of the organ itself. The head furrows are well marked and extend round nearly two-thirds of the circumference of the head region.

Large eyes are found, though the number of these is rather smaller than in most species of the genus. About 26 in all are present.

[1] Bürger gives a reconstruction of the organ (*Zeit. für wiss. Zool.* 1890, p. 240) from which it would appear that the organ is not placed entirely behind the brain. This relation may be a local variation and does not appear sufficient to separate the present form as a distinct species.

Synopsis of the genus Drepanophorus.

Since the publication of Bürger's Monograph in 1895 several new species of *Drepanophorus* have been described. With the idea partly of assisting future workers and partly of drawing attention to the gaps in our knowledge I have prepared the small table below by selecting such features as seem likely to prove of use in classification. Since, as can be seen from this table, the gaps in our knowledge are considerable, it is not yet possible to arrange the existing species in any order expressing their relationships. Roughly it may be said that the majority of the genus conform to a certain type of which *D. crassus* may be taken as the example. More or less closely resembling this species are the European *D. igneus* and *D. albolineatus*, together with the exotic forms *D. latus*, *D. lifuensis*, and *D. roseus*. The remaining species are, so far as can be seen, more widely separated from one another. The enormous development of the glandular portion of the cerebral organ characterises *D. cerinus* and, to a lesser degree, *D. willeyanus*. *D. lankesteri* is conspicuous by the ventral position of the gonidial pores, the fusion of the anterior rhynchocoelomic pockets, and the regularity of its ventral nerve commissures. Perhaps the form, which differs most from the rest, is *D. borealis*, the only Arctic species known. In its broad, stumpy body, the ventral openings of the cerebral organ, the dorsal position of the gonidial pores, the small number of eyes, and the peculiar expansions of the rhynchocoelom over the brain it stands apart from the remaining species.

In order to include the more recent species the diagnosis of the genus below shews a few points of difference from that given by Bürger, though these are by no means numerous or very important.

Genus *Drepanophorus.*

Flattened forms exhibiting a relatively great breadth in comparison to their length.

The mouth and rhynchodaeum open separately. The proboscis is large and contains 14—32 nerves. Its armature is characteristic for the genus.

The proboscis sheath gives off lateral diverticula alternating regularly with the gut pockets.

The nervous stems are ventral in position and the distance between them is seldom more than half the diameter of the body laterally. They unite posteriorly above the anus.

The cerebral organ is large and never lies in front of the brand.

Small longitudinal head furrows ("Kopfgrübchen") are developed in connection with the circular head furrow.

Neurochord cells occur in the ventral ganglia.

The eyes may be few or numerous but are always of large size.

Head glands but slightly developed.

The sexes are separate. The gonads exhibit great divergence in the number and position of their ducts.

	*Literature (see below)	Position of opening of cerebral organ	Position of cerebral organ	Eyes	Proboscis nerves	Gonidial pores	Peculiar features
D. crassus (=serraticollis)	(1), (2), (3), (4), (5), (6)	Lateral		>30	19—20	1 lateral to each intestinal diverticulum	
D. spectabilis (=rubrostriatus)	(1), (2), (3), (4), (5), (6)	Lateral	Beside and rather beyond brain	>30	24		
D. lankesteri	(2)		Behind brain			2 ventral to each intestinal diverticulum	Anterior rhynchocoelomic diverticula fuse. Nephridial pore at post. end of nephridium
D. latus	(4), (6), (7)	Lateral, rather dorsal		>30	>30		
D. cerinus	(4), (6), and this paper	Lateral and rather ventral	Behind brain	<30	14	1 ventro-lateral to each intestinal diverticulum	Very long posterior glandular process to cerebral organ
D. massiliensis	(5)						
D. igneus	(6)				14		
D. albolineatus	(6)	Lateral and slightly ventral		>30			
D. lifuensis	(8)	Lateral	Beside and not behind brain	>30	>30		
D. willeyanus	(8)	Lateral	Chiefly behind brain	<20	16	1 lateral to each intestinal diverticulum	Long posterior glandular process to cerebral organ
D. borealis	(9)	Ventral	Beside and not behind brain	<20	14	3 dorsal to each intestinal diverticulum	Anterior rhynchocoelomic diverticula fuse and form expansions over brain
D. roseus	This paper	Lateral	Beside and not behind brain	>30	22		

* List of more important or more recent papers referring to the genus :—

(1) Hubrecht, A. A. W. The genera of European Nemerteans critically revised. Notes. *Leyden Mus.* 1879.
(2) Hubrecht, A. A. W. The Nemerteans, *Challenger Reports*, Vol. 19. 1887.
(3) Joubin, L. *Archiv de Zool. Exp. et Gen.* 1890.
(4) Bürger, O. *Zeit. für wiss. Zool.* 1890.
(5) Joubin, L. *Faune française.* 1894.
(6) Bürger, O. Die Nemertinen. *Fauna und Flora des Golfes von Neapel.* 1895.
(7) Staub, J. Semon's *Zoologische Forschungsreisen.* 1900.
(8) Punnett, R. C. Willey's *Zoological Results*, Pt. V. 1900.
(9) Punnett, R. C. *Proc. Zool. Soc.* 1901.

EXPLANATION OF PLATES.

bm	= basement membrane.	*mci*	= internal circular muscle layer.
c	= cutis.	*ml*	= longitudinal muscle layer.
cc	= ciliated canal.	*mlc*	= longitudinal muscle layer of cutis.
ccep	= expanded end of ciliated canal.	*mli*	= internal longitudinal muscle layer.
corg	= cerebral organ.	*mlo*	= outer longitudinal muscle layer.
dbv	= dorsal blood vessel.	*nd*	= median dorsal nerve.
ddg	= dorsal lobe of dorsal ganglion.	*ns*	= lateral nervous stem.
dg	= dorsal ganglion.	*oc*	= eyes.
ep	= epithelium.	*oep*	= oesophageal epithelium.
exd	= excretory duct.	*oes*	= oesophagus.
ext	= excretory tubule.	*ogl*	= oesophageal glandular layer.
fr	= frontal organ.	*ol*	= oesophageal vascular lacunae.
glcorg	= glands of cerebral organ.	*p*	= proboscis.
hf	= head furrow.	*pg*	= pigment.
hs	= head slit.	*ps*	= proboscis sheath.
lvl	= lateral vascular lacuna.	*rhc*	= rhynchocoelom.
m	= mouth.	*vcl*	= vascular cephalic lacuna.
mc	= circular muscle layer.	*vg*	= ventral ganglion.
mcc	= circular muscle layer of cutis.		

PLATE IV.

Fig. 1. *Cerebratulus maculatus.* Dorsal and ventral view of anterior end. × 2.

Fig. 2. *Eupolia hemprichi.* Dorsal and ventral view of anterior end. × 1.

Fig. 3. *E. hemprichi.* Anterior end of another specimen from dorsal surface. × 2.

Fig. 4. *E. unistriata.* Anterior end from dorsal surface. × 1.

Fig. 5. *Cerebratulus maldivensis.* Ventral view of anterior end. × 4.

Fig. 6. *C. gardineri.* Ventral view of anterior end. × 2.

Fig. 7. *Drepanophorus roseus.* Ventral view of anterior extremity. From specimen cleared in cedar oil. × 5.

Fig. 8. *Eupolia indica.* Section through region of head furrow, shewing outline of brain. × 22.

Fig. 9. *Cerebratulus gardineri.* Section through oesophageal region, shewing relative thickness of muscle layers and position of excretory duct. × 15.

Fig. 10. *Drepanophorus cerinus.* Section through brain region immediately after the separation of the dorsal and ventral ganglia. × 45.

Fig. 11. *D. cerinus.* Section just anterior to the opening of the cerebral organ. × 45.

Fig. 12. *Eupolia indica.* Section through cerebral organ and hinder part of dorsal ganglion. × 45.

Fig. 13. *E. indica.* Grooved epithelium of circular head furrow as seen when more highly magnified than in Fig. 8.

Fig. 14. *E. indica.* Section through portion of oesophagus in excretory region, shewing a cord of cells from an excretory tubule* piercing the oesophageal glandular layer and reaching to the inner surface of the alimentary canal. × 80.

* The asterisk marks the level where the dorsal vessel emerges from the proboscis sheath.

FIG. 15. *Cephalothrix aliena.* Section through body wall in hinder part of oesophageal region. The greater portion of the section is somewhat dorsal to the level of the nervous stem. × 80.

FIG. 16. *Cephalothrix aliena.* Section through anterior part of oesophageal region. × 45.

PLATE V.

FIG. 1. *Cerebratulus maculatus.* Section through skin of oesophageal region. × 160.

FIG. 2. *Cerebratulus gardineri.* Section through skin in oesophageal region. × 110.

FIG. 3. *Cerebratulus maldivensis.* Section through skin of oesophageal region. × 110.

FIGS. 4—7. Sections taken at intervals through the hind brain and cerebral organ of the following species:

FIG. 4 (*a*—*c*). *C. gardineri.* At intervals of 80 μ.

FIG. 5 (*a*—*c*). *C. maculatus.* At intervals of 100 μ.

FIG. 6 (*a*—*c*). *C. maldivensis.* At intervals of 80 μ.

FIG. 7 (*a*—*c*). *C. ischurus.* 50 μ between *a* and *b*; 150 μ between *b* and *c*.

FIGS. 8—10. Schematic reconstructions through the anterior end of several Lineidae. The buccal vascular vessels, the oesophageal nerves, the proboscis and its sheath, have, for the sake of simplicity, been omitted. The oesophageal vascular lacunae have also been represented as simple vessels.

FIG. 8. *C. gardineri.* × 10.

FIG. 9. *C. maldivensis.* × 10.

FIG. 10. *C. maculatus.* × 10.