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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 late Balfour Student of the University of Cambridge.

VOLUME I. PART III.

With Plates XIV—XVII and Text-Illustrations 41—75

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THE ACTINOGONIDIATE ECHINODERMS OF THE MALDIVE AND LACCADIVE ISLANDS.

By F. Jeffrey Bell, M.A., *Emeritus Professor and Fellow of King's College, London.*

By the kindness of Mr Stanley Gardiner I have had the opportunity of examining the Echinoderms collected by him in the Maldive and Laccadive Islands. The collection is of the ordinary coral-reef type, and consists, as did that from the Macclesfield Bank (see *Proc. Zool. Soc. London*, 1894, p. 392), very largely of young forms; these are, of course, of very great value and interest, more, I think, than any number of "new species," but they make no show in a systematic report. When a study is made of the changes that occur during post-larval growth these specimens will be seen at their full value. There are a large number of *Ophiuroids*, and some would probably, if determined, require describing as "new species"; since 1888, however, we have known of 132 (or 120) species of *Ophiuroids* from the Indo-Pacific area (see Brock, *Zeitschr. f. wiss. Zool.* xlvii. p. 538); since then I and others have helped to swell the list, but, so far as I know, no one has done anything to codify or set in order the numerous so-called species, based, many of them, on one or a few specimens, and often so described as to be quite misleading. I have not thought it my duty on this occasion to swell the list. On the other hand, just as in the Bassett Smith collection, I was able to detect the rare and interesting *Ophiopteron elegans*, so in the Stanley Gardiner collection I have found the very rare *Ophiaethiops unicolor* described by Brock in the journal just cited. As I have also found *O. elegans* in some quantity I am able to point out that Brock's statement as to the poverty of the western forms of the Indo-Pacific, as compared with the eastern, requires some modification.

Lastly, there is a point which is of far wider interest than the discovery of new species in these variable forms; again and again on working through the *Ophiuroids* I have observed that the upper surface of the disc has disappeared. I can only again urge on those who are for a time staying near a reef to investigate the problem which I raised in 1888, and which, to his regret (see *Tijds. Nederl. Dierk. Ver.* v. (1898), p. 306) was not known to Dr Sluiter till ten years later. It is clear that, if the gonads of an *Ophiuroid* be set free by the separation of the disc, and if a new disc be formed and new gonads developed, the question of germ-plasm may be considered settled.

I have endeavoured as on some previous occasions (see especially *P.Z.S.* 1887, p. 523) to avoid the treatment at inordinate length which appears to be a real joy to many naturalists;

I have given a systematic list of the species with references sufficient to make clear what is meant, and aid in any further research that it may be desirable to make; the nature of the bottom is stated, and in many cases the frequency or rarity of the species is mentioned.

CRINOIDEA.

I. Genus **Antedon.**

Immature forms—not identifiable—were dredged on 10 occasions, sometimes in considerable numbers, between 19 and 37 *f.* (fathoms), and a few were also secured by diving off the west reef of Hulule. They seem to especially frequent the inner ends of the passages, where they embouch into the lagoons; in all cases the bottom is recorded as having rubble or coral, with perhaps sand or weed.

1. *Antedon laevissima.*

Comatula laevissima Grube, *J.B. Schles. Ges.* LIII. (1875), p. 74.

Antedon laevissima, P. H. Carpenter, *Chall. Rep. Comat.* (1888), p. 197.

I still hope to be able to obtain the late Dr P. H. Carpenter's notes on Grube's 'type.'

Dredged eight times in seven atolls between 20 and 37 *f.*, usually from a hard sand or shell bottom with some weed. In one dredging, 37 *f.*, in the middle but just within the N. passage of Suvadiva, some adults and thousands of the immature forms of this species of Crinoid—and no other—were obtained.

2. *Antedon milberti.*

Comatula (*Alecto*) *milberti,* Müller, *MB. Akad. Berl.* 1846, p. 178.

Antedon milberti, P. H. Carp. *Chall. Rep. Comat.* (1888), p. 194.

Suvadiva, 43 *f.*, sand, strewn with dead oyster shells.

3. *Antedon palmata.*

Comatula (*Alecto*) *palmata,* Müller, *Physik. Abhandl. Akad. Berlin,* 1847 (1849), p. 261.

Antedon palmata, P. H. Carp. *Chall. Rep.* (1888), p. 226.

Kolumadulu, 38 *f.*, mud and weed, and Mulaku, 40 *f.*, weed, fine sand and rubble.

4. *Antedon indica.*

Comatula indica, E. A. Smith, *Ann. Mag.* XVII. (1876), p. 406; *Phil. Trans.* 168 (1879), p. 564.

Antedon indica, P. H. Carp. *Chall. Rep.* (1888), p. 225.

From the west reef of Hulule, Male Atoll, among corals.

5. *Antedon variipinna.*

Antedon variipinna, P. H. Carp. *J. Linn. Soc. Lond.* XVI. (1882), p. 506; *id. Chall. Rep.* (1888), p. 256, *ibique citata.*

S. Nilandu, 19 *f.*, at the seaward end of a passage, living corals.

II. Genus **Actinometra.**

Young forms were obtained off the coral masses of the west reef of Hulule. It is noticeable that neither this genus nor Antedon was found in the lagoon nor on the reefs of Minikoi.

6. *Actinometra typica.*

Phanogenia typica, Lovén, *Öfv. Vet. Akad. Förh.* 1866, p. 231.

Actinometra typica, P. H. Carp. *op. cit.* p. 296.

Suvadiva, 42 *f.*, hard sand.

7. *Actinometra fimbriata.*

Comatula fimbriata, Lamk. *Anim. s. Vert.* II. (1816), p. 534.

Actinometra fimbriata, P. H. Carp. *op. cit.* p. 317; Hartlaub, *Nova Acta Leop. Carol. Akad.* LVIII. (1891), p. 102.

Dr Hartlaub has already called attention to a specimen which he referred to this species, part of which was, in the terminology of Carpenter, bi-, and the other part tri-distichate. Several specimens in the present collection exhibit the same striking peculiarity; in 1894 (*P.Z.S.* p. 398) I adduced evidence against the value of the syzygy as a specific character; now doubt is thrown on the safety of the number of the distichals.

From the western reef-edge, Hulule, and dredged six times in five atolls, 24—35 *f.*, rubble or sand, mud or weed.

8. *Actinometra multiradiata.*

Asterias multiradiata, Linn. *Syst. Nat.* (1758), p. 663.

Comatula multiradiata, Lamk. *Anim. s. Vert.* II. (1816), p. 533.

Actinometra multiradiata, Duj. and Hupé, *Echinodermes* (1862), p. 210; P. H. Carp. *Chall. Rep.* (1888), p. 322.

Hulule, 15—20 *f.*, from slope of western reef, hard bottom.

9. *Actinometra sentosa.*

Actinometra sentosa, P. H. Carp. *op. cit.* p. 325.

N. Male, 25 and 27 *f.*, coral masses and coarse sand.

10. *Actinometra maculata.*

Actinometra maculata, P. H. Carp. *op. cit.* p. 307.

From the west reef of Hulule, and very commonly seen at shallow depths on lagoon reefs in all the more open atolls of the Maldives.

ASTEROIDEA.

III. Genus **Acanthaster.**

11. *Acanthaster echinites.*

See the synonyms given by Prof. Perrier in *Arch. Zool. expér.* IV. (1875), p. 361, and the observations of M. de Loriol, in *Mém. Soc. Phys. et d'hist. nat. de Genève,* XXIX. no. 4 (1885), pp. 6 *et seq.*

From the sand flat to the north-west of Hulule.

IV. Genus **Linckia.**

A number of young forms collected one night in the swabs, when at anchor in N. Male, 25 *f.*, rubble, *Polytrema* and sponges.

12. *Linckia laevigata.*

Asterias laevigata, Gmelin, *Syst. Nat.* (1788), p. 3169.

Linchia laevigata, Lütken, *Videnskab. Meddel.* 1871, p. 47.

From the boulder zone of the reef at Minikoi only.

13. *Linckia multiforis.*

Asterias multiforis, Lamk. *Anim. s. Vert.* III. (1816), p. 254.

Ophidiaster multiforis, M. Tr. *Syst. Aster.* (1842), p. 31.

Linckia multiforis, von Martens, *Arch. f. Naturg.* XXXII. (1866), p. 65.

Common on every reef of the Maldives, especially frequenting the shaded under-surfaces of stones of the boulder zone. Large numbers were attracted at Minikoi to a baited basket placed under a stone, after 24 hours no less than 37 specimens being collected.

V. Genus **Scytaster.**

14. *Scytaster variolatus.*

Asterias variolata, Retzius, *Diss. spec. Aster.* (1805), p. 19.

Scytaster variolatus, M. Tr. *Syst. Aster.* (1842), p. 34.

S. Nilandu, 25 *f.*, with corals, sponges and Alcyonarians, and Mulaku, 25, 30 and 35 *f.*, all mud and a little weed.

15. *Scytaster novae-caledoniae.*

Scytaster novae-caledoniae, Perrier, *Arch. Zool. expér.* IV. (1875), p. 426.

Found on all the sand-flats in the Maldives and Minikoi. In colour it is generally brown or blue; most forms at Minikoi were blue, while five specimens from Hulule were all brown.

VI. Genus **Ophidiaster.**

16. *Ophidiaster cylindricus.*

Asterias cylindrica, Lamk. *Anim. s. Vert.* III. (1816), p. 255.

Ophidiaster cylindricus, M. Tr. *Syst. Aster.* (1842), p. 29.

A regular denizen of the boulder zone of every reef visited in the Maldives, also at Minikoi. See Dr Mac Munn's Note on the pigment of this species, pp. 189—90, Vol. I. Part II. of this publication.

VII. Genus **Retaster.**

The genus was represented by a few immature forms from Mahlos, 23 *f.*, and Mulaku, 30 *f.*, sand and rubble.

VIII. Genus **Mithrodia.**

17. *Mithrodia clavigera.*

Asterias clavigera, Lamk. *Anim. s. Vert.* II. (1816), p. 562.

Mithrodia clavigera, Perr. *Arch. Zool. expér.* IV. (1875), p. 378.

Suvadiva, 30 *f.*, across the inner end of a passage, hard bottom.

IX. Genus **Fromia.**

18. *Fromia milleporella.*

Asterias milleporella, Lamk. *Anim. s. Vert.* II. (1816), p. 564.

Fromia milleporella, Perr. *Arch. Zool. expér.* IV. (1875), p. 437.

A single specimen found under the overhanging side of a growing coral near the edge of the east reef of Naifaro, Fadifolu.

X. Genus **Asterina.**

19. *Asterina cepheus*[1].

Asteriscus cepheus, M. Tr. *Syst. Aster.* (1842), p. 41.

Asterina cephea, Perr. *Arch. Zool. expér.* V. (1876), p. 235.

Fadifolu, 15 *f.*, from a passage covered with coral growth, and from the outer reef off Maradu, Addu. Immature forms are common on the Maldive reefs, but only the single above-mentioned adult was obtained. The young cling to the rock of the reef-flat or boulder zone, and do not seek cover in the daytime as do most species.

XI. Genus **Pentagonaster.**

Two immature forms were dredged from 35 *f.*, Kolumadulu, dead, and broken shells.

XII. Genus **Stellaster.**

Young specimens from 30 *f.*, S. Nilandu, hard sand, corals and sponges, and 40 *f.*, Mulaku, weed, sand and rubble.

20. *Stellaster incei.*

Stellaster incei, Gray, *Proc. Zool. Soc. Lond.* 1847, p. 76.

Pentagonaster (*Stellaster*) *incei*, Perr. *op. cit.* V. p. 43.

Dredged three times in different atolls, 23—30 *f.*, sand and rock.

[1] Some writers say cephea, but, as any astronomer will tell them, cepheus is a star, and was the name of a Greek king.

XIII. Genus **Astropecten.**

Immature forms from 40 *f.*, Suvadiva, broken corals and nullipores, and Halimeda, and 34 *f.*, Felidu, sand covered with weed.

21. *Astropecten polyacanthus.*

Astropecten polyacanthus, M. Tr. *Syst. Aster.* (1842), p. 69.

Dredged five times in four atolls, 19—38 *f.*, hard bottom with corals, or mud with weed and sponges (Mulaku).

22. *Astropecten indicus.*

Astropecten indicus, Döderlein, *Zool. JB. Syst.* III. (1888), p. 828.

Suvadiva, 40 *f.*, fine mud.

XIV. Genus **Luidia.**

23. *Luidia maculata.*

Luidia maculata, M. Tr. *Syst. Ast.* (1842), p. 77.

S. Nilandu, 19 *f.*, seaward end of a passage.

OPHIUROIDEA.

XV. Genus **Ophiocoma.**

Large numbers of immature specimens are obtained on breaking up decaying corals and under beach sandstone masses between tide marks. They are sometimes also found in sponges.

24. *Ophiocoma erinaceus.*

25. *Ophiocoma scolopendrina.*

In 1887, I wrote (*Scient. Trans. Roy. Dublin Soc.* III. (1887), p. 648), "It is almost certain that in a short time systematists will be agreed as to the necessity of uniting these two species of *Ophiocoma.*" In 1888 the late Dr Brock (*Zeitschr. f. wiss. Zool.* XLVII. (1888), p. 495), said, "Es ist wohl jetzt kein Zweifel mehr, dass beide Arten vereinigt werden müssen." Fifteen years' further experience only confirms me in this view.

The form called *O. erinaceus* is characteristic of the reefs of Minikoi and all parts of the Maldives wherever there is decaying coral rock. It was dredged also with dead coral rubble off a shoal in Suvadiva, 25 *f.* The second form, *O. scolopendrina,* was only found at Minikoi, where it is numerous under stones on the reef to the east of the island.

26. *Ophiocoma valenciae.*

Ophiocoma valenciae, M. Tr. *Syst. Ast.* (1842), p. 102.

A regular species of the boulder zone in Minikoi and all parts of the Maldives.

27. *Ophiocoma brevipes.*

Ophiocoma brevipes, Peters, *Arch. f. Nat.* 1852, p. 85.

On every part of the reefs of Minikoi and the Maldives, but especially numerous under beach sandstone masses.

XVI. Genus **Ophiomastix.**

28. *Ophiomastix annulosa.*

Ophiomastix annulosa, M. Tr. *Syst. Ast.* (1842), p. 107.

Minikoi only, common in the boulder zone.

29. *Ophiomastix venosa.*

Ophiomastix venosa, Peters, *Arch. f. Naturg.* 1852, p. 83.

Common in the Maldives, at Hulule a regular form in and under coral masses on the sand-flat.

XVII. Genus **Ophionereis.**

An immature specimen from Kolumadulu, 22 f., sand and rubble.

30. *Ophionereis porrecta.*

Ophionereis porrecta, Lyman, *Proc. Boston Soc. N. H.* VII. (1860), p. 260.

Dredged three times in different atolls, 24—35 *f.*, coral, rubble or hard bottom.

XVIII. Genus **Ophiothrix.**

Immature forms—often very numerous—in 11 dredgings, 22—46 f., usually sand with some rubble, but in the deepest fine, hard mud.

31. *Ophiothrix aspidota.*

Ophiothrix aspidota, M. Tr. *Syst. Ast.* (1842), p. 115.

Suvadiva, 20 *f.*, across the inner end of a passage, hard bottom.

32. *Ophiothrix nereidina.*

Ophiura nereidina, Lamk. *Anim. S. Vert.* II. (1816), p. 544.

Ophiothrix nereidina, M. Tr. *Syst. Ast.* (1842), p. 115.

Minikoi and Maldives, under corals of reef-flat.

XIX. Genus **Ophiopteron.**

33. *Ophiopteron elegans.*

Ophiopteron elegans, Ludwig, *Zeitschr. f. wiss. Zool.* XLVII. (1888), p. 459.

Dredged five times in 3 atolls, 22—35 f., in every case near passages, hard bottom, perhaps rubble and weed.

XX. Genus **Ophioaethiops.**

34. *Ophioaethiops unicolor.*

Ophioaethiops, Brock, *Zeitschr. f. wiss. Zool.* XLVII. (1888), p. 524.

This is the most interesting of Mr Gardiner's finds, as, with the exception of the three specimens found at Amboina by Brock, the species is unknown. I had little doubt as to the identity of the creature, but to make sure I submitted it to Prof. Ehlers of Göttingen,

who compared it with the originals. As Brock remarked that *Ophioaethiops* was closely allied to Dr Marktanner-Turneretscher's *Ophiolophus* I was glad of the opportunity afforded me by Dr von Marenzeller of comparing the two. I confess I was struck by the differences between them.

In a hole of a coral mass from the reef of Naifaro, Fadifolu.

XXI. Genus **Astrophyton.**

35. *Astrophyton clavatum.*

Astrophyton clavatum, Lyman, *Proc. Boston Soc. N. H.* VIII. (1861), p. 85.

Mahlos, 24 f., dead and living corals, and Suvadiva, 38 *f.*, coarse shell and coral fragments.

ECHINOIDEA.

XXII. Genus **Cidaris.**

36. *Cidaris metularia.*

Cidarites metularia, Lamk. *Anim. S. Vert.* III. (1816), p. 56.

Cidaris metularia, A. Ag. *Rev. Ech.* (1872), p. 98.

Found constantly on every part of all the reefs visited, wedged in between the branches of growing corals. Dredged five times with corals, 20—25 *f.*

XXIII. Genus **Diadema.**

37. *Diadema saxatile.*

Echinus saxatilis, Linn. *Syst. Nat.* (1758), p. 664.

Diadema setosum, auct. plurim.

Diadema saxatile, Lovén, *Bih. Sven. Vet. Akad. Hdlgr.* 13, IV., no. 5 (1887), p. 135.

Found on every reef under stones or in hollows of the boulder zone, or between growing corals.

XXIV. Genus **Echinothrix.**

38. *Echinothrix diadema.*

Echinus diadema, Linn. *Syst. Nat.* ed. X. (1858), p. 664.

Echinothrix calamaris, A. Ag. *Rev. Ech.* (1872), p. 119.

Echinothrix diadema, Lovén, *Bih. Sven. Vet. Akad. Hdlgr.* 13, IV. no. 5 (1887), p. 137.

Both this and the next species were common in Minikoi and in the Maldives in the same position as *Diadema saxatile.*

39. *Echinothrix desori.*

Astropyga desori, Ag. *Ann. Sci. nat.* VI. (1846), p. 345.

Echinothrix desori, A. Ag. *Rev. Ech.* (1872), p. 120.

XXV. Genus **Astropyga.**

Immature forms, N. Male, 25 *f.*, coral masses, Polytrema, etc., and Mulaku, 30 *f.*, green and dead weed, also from Minikoi lagoon, 6 *f.*

XXVI. Genus **Asthenosoma.**

40. *Asthenosoma urens.*

Cyanosoma urens, Sarasins, *Zool. Anzeig.* IX. (1886), p. 80.

Asthenosoma urens, iid. *Ergeb. Forschungen auf Ceylon*, I. (1888), p. 86.

A large number of specimens, Mulaku, 27 *f.*, mud and sponges, also Haddumati, 40 *f.*, mud and weed, and Suvadiva, 43 *f.*, soft mud.

XXVII. Genus **Temnopleurus.**

Immature forms in 5 dredgings, 22—25 *f.*, sand, weed and generally rubble.

41. *Temnopleurus toreumaticus.*

Cidaris toreumatica, Leske, *Addit. ad hist.* p. 155.

Temnopleurus toreumaticus, Agass. *in Valentin's Anat. du genre Echinus* (1841), p. viii; Bell, *P.Z.S.* 1880, p. 428.

Mulaku, 28 *f.*, and Haddumati, 40 *f.*, mud and weed.

XXVIII. Genus **Salmacis.**

42. *Salmacis bicolor.*

Salmacis bicolor, Agass. *op. cit.* p. viii.; Al. Ag. *Rev. Ech.* (1872), p. 156.

Suvadiva, 30 *f.*, hard sand (?), and Haddumati, 32 and 40 *f.*, dead coral masses, mud and weed. The Suvadiva specimen had associated with it a similarly coloured Gastropod, which was resting in an especial clearing among its spines.

XXIX. Genus **Tripneustes.**

43. *Tripneustes angulosa.*

Cidaris angulosa, Leske, *Addit.* (1788), p. 92.

Tripneustes angulosa, Bell, *P.Z.S.* (1879), p. 657.

Occasionally found at Minikoi and the Maldives on the sand-flats, not uncommonly cast up on the lagoon beaches.

XXX. Genus **Echinometra.**

44. *Echinometra lucunter.*

Echinus lucunter, Linn. *Syst. Nat.* ed. X. (1758), p. 665.

Echinometra lucunter, De Blainv. *Actin.* (1834), p. 225; Lovén, *Bih. Sv. Vet. Akad. Hdlgr.* 13, IV. no. 5 (1887), p. 153.

Wedged into hollows in the extreme seaward edges of all reefs, almost where the rollers break. The animal varies rather in colour, the lighter forms occurring further out.

XXXI. Genus **Fibularia.**

A large number of immature specimens from a velu or lagoon of one of the smaller rim atolls (faro) of N. Male, 5 *f.*, coarse sand.

45. *Fibularia volva.*

Fibularia volva, Ag. *Ann. Sci. Nat.* VII. (1847), p. 142; Al. Ag. *Rev. Ech.* (1872), p. 130.

Mahlos, 24 *f.*, living and dead coral.

XXXII. Genus **Echinoneus.**

46. *Echinoneus cyclostomus.*

Echinoneus cyclostomus, Leske, *Addit.* (1778), p. 173; Al. Ag. *Rev. Ech.* (1872), p. 117.

From sand under stones or coral masses on the sand-flats at Minikoi and throughout the Maldives. A large number of young specimens were dredged in the lagoons of Minikoi and Hulule, 6—8 *f.*, these appearing to be their nurseries. The young shells were never found alive on any surface reef, but they are a regular constituent of sandy beaches.

XXXIII. Genus **Laganum.**

Immature forms dredged 6 times, 30—36 *f.*, hard bottom with rubble, corals, sponges and weed.

47. *Laganum depressum.*

Laganum depressum, Ag. *Mon. Scutel.* (1841), p. 110.

Dredged 9 times in 6 atolls, 18—38 *f.*, rubble bottom with sand, or mud and perhaps weed.

XXXIV. Genus **Clypeaster.**

An immature specimen from a passage into S. Nilandu, 25 *f.*, corals and sponges.

XXXV. Genus **Brissopsis.**

Immature forms only, from Mulaku, 30 *f.*, sand and weed.

XXXVI. Genus **Brissus.**

A few immature specimens from Hulule.

XXXVII. Genus **Lovenia.**

48. *Lovenia elongata.*

Spatangus elongatus, Gray, in Eyre, *Discov. Central Austral.* I. (1845), p. 436; Al. Ag. *Rev. Ech.* I. (1872), p. 139.

Lovenia elongata, Gray, *Ann. and Mag. N.H.* VII. (1851), p. 131.

Only from the sand-flat to the north of Hulule, under corals.

XXXVIII. Genus **Maretia.**

49. *Maretia alta.*

Maretia alta, A. Ag. (1863), see *Rev. Ech.* 1872, p. 139.

Felidu, 34 *f.*, sand covered with weed.

50. *Maretia planulata.*

Spatangus planulatus, Lamk. *An. s. Vert.* III. (1816), p. 31.

Small forms found occasionally at low tide level on lagoon flats everywhere. Dredged 7 times in Kolumadulu and Felidu, 20—35 *f.*, rubble or shells and sand, also Haddumati, 40 *f.*, weed and mud.

ORTHOPTERA.

By Malcolm Burr, F.Z.S., F.E.S., F.L.S.

The collection includes twenty-four species, of which one adult, a *Liphoplus*, cannot be identified with any known form. Almost all the others are cosmopolitan or widely distributed Oriental species, probably all occurring also in India or Ceylon. A few field notes have been added by Mr Stanley Gardiner.

FORFICULARIA.

1. *Anisolabis annulipes* Luc. Minikoi, 1 ♂.

BLATTODEA.

2. *Periplaneta americana* L. Minikoi. Common throughout the Maldives, infesting the larger boats, but seldom found on shore.

3. *Leucophaea surinamensis* L. Minikoi, I ♂, 1 ♀.

4. *Phyllodromia vitrea* Br. Minikoi, 2; Hulule, 1; Mahlosmadulu, 1. Rare in the Maldives, only being found in the northern atolls of the group.

5. *Epilampra* sp. Minikoi, 3 larvae, obtained at the lighthouse.

6. *Panesthia* sp. Mahlosmadulu, 1 larva.

MANTODEA.

7. *Hierodula simulacrum* Serv. Minikoi.

This form is fairly common near the village and in the dense jungle to the south of the main island of Minikoi, principally affecting the shrubby *Hibiscus* trees. Occasionally it is caught against the lantern of the lighthouse. The larvae, while rare elsewhere, are common round the freshwater, coir-making pools near the village. The species is not found in any part of the Maldives.

ACRIDIODEA.

Fam. **Truxalidae.**

8. *Epacromia tamulus* Fabr. Minikoi, Hulule, Goidu, Mahlosmadulu and Miladumadulu; a large number of specimens.

This species is abundant and widely distributed throughout the Oriental region. It is the commonest grasshopper in the Maldives and Laccadives, any number being caught in open, dry spots by means of the sweep-net.

Fam. **Pyrgomorphidae.**

9. *Atractomorpha gerstaeckeri* Bol. Minikoi, 1 ♂.

10. *Atractomorpha similis* Bol. Hulule, 1 ♂.

11. *Atractomorpha crenulata* Fabr. Minikoi.

Very common in the above island, frequenting the paths in the densest jungle. Much more numerous towards sunset.

Fam. **Acridiidae.**

12. *Oxya intricata* Stal., var. *tibiis posticis ferrugineis.* A large number of specimens from Minikoi, Mahlosmadulu, Miladumadulu, Goidu and Hulule.

This form is only found in the northern part of the Maldive Group, and does not extend to Suvadiva and Addu. It is in no island so abundant as at Minikoi. The species frequents open spaces, especially the dry grain lands of Miladumadulu atoll.

13. *Acridium septemfasciatum* Serv. Minikoi, 1 ♂, 1 ♀, not found in the Maldives.

Fam. **Tettigidae.**

14. *Hedotettix gracilis* Haan. Minikoi, 1 ♂.

LOCUSTODEA.

Fam. **Phaneropteridae.**

15. *Phaneroptera indica* Br. A number of specimens from Minikoi, Mahlosmadulu and Hulule. The commonest locust in the Maldives, found throughout the whole group from Miladumadulu to Addu.

All the specimens appear to be referable to the above species, but are somewhat smaller than the dimensions given by Brunner.

Fam. **Conocephalidae.**

16. *Conocephalus breviceps* Redt. Minikoi, 1 ♀; Mahlosmadulu, 2 ♂, 1 ♀.

17. *Conocephalus* sp. Hulule, 1 ♀ larva.

18. *Xiphidium maculatum* Le Gou. A number of specimens from Minikoi and the Maldives.

A widely distributed Oriental species. It is very common in Minikoi, but, although seen in nearly every atoll of the Maldives, rare everywhere.

GRYLLODEA.

Fam. **Myrmecophelidae.**

19. *Liphoplus* n. sp. Minikoi, 1 ♀.

This appears to be a new species, but I refrain from describing it as the collection contains but a single female, not in perfect condition. It differs from *Liphoplus fasciatus* Br., in its paler colour and larger size; from *L. novarae* in its larger size and black-bordered elytrae; and from *L. guerinianus* in its paler colour.

20. *Ectatoderus longicaudus* Sauss. Minikoi, 2 ♂, 6 ♀ and 4 larvae. Common in the roots of the grass near the lighthouse.

I am not quite positive as to the correct identification of this species, but the genus is little known, and the species are not very clearly defined. The specimens from Minikoi approach nearer to this than any other described form.

Fam. **Trigonididae.**

21. *Trigonidium cicindeloides* Serv. Minikoi, 4 ♂, 3 ♀ and 3 larvae.

This species is common on the shores of the Mediterranean, and occurs also in Ceylon and Burmah.

22. *Homoexiphus histrio* Sauss. Minikoi, 2 ♀.

Fam. **Gryllidae.**

23. *Landreva picta* Sauss. Hulule, 1 ♀.

I refer the single female with some hesitation to this species.

24. *Gryllus mitratus* Burm. Minikoi, 1 ♀; Mahlosmadulu, 1 ♀; and Hulule, 1 ♂. A common Oriental species.

MARINE CRUSTACEANS.

III. THE XANTHIDAE AND SOME OTHER CRABS.

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

(With Text-figures 41—60.)

The instalment of the Marine Crustaceans of the Expedition described in this paper includes, besides the Xanthidae, two new genera, possibly allied to them, and a couple of small families—the Atelecyclidae and the Hapalocarcinidae—which are taken here for reasons of convenience. Some remarks on the natural history of the crabs will be found under the headings of the families, genera, etc. to which they belong.

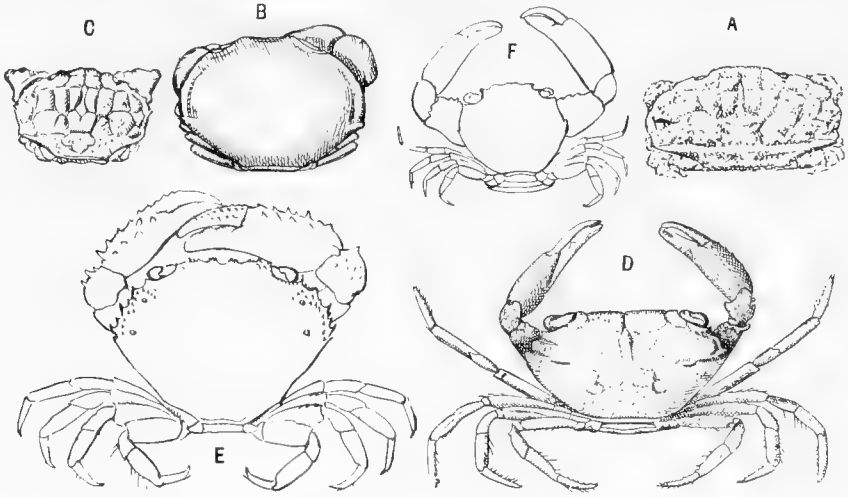

Fig. 41. Types of the Xanthid Crabs. *A. Actaea fossulata*, resembling water-worn coral pebbles and found in the lower parts of a coral stock or other situations into which pebbles could be washed. *B. Carpilius exsculptus*, adapted for passively withstanding surf and currents. *C. Euxanthus exsculptus* var. *rugosus*, found amongst stones, etc. on the reef. *D. Chlorodius barbatus*. *E. Domoecia hispida*, a coral crab. *F. Trapezia ferruginea*, also a coral crab. The drawings are not made to scale. *B* is a large crab, *C* and *F* of moderate size, and the others small.

Family **Xanthidae.**

Of all the families of crabs the Xanthidae are the most numerous in genera and species, and the most varied in form, though this preeminence is seen chiefly in the Tropics, and there best in the littoral belt, where they are to be found in every possible position.

Morphologically, the Xanthids are characterised, among the other round-fronted crabs (Cyclometopa), by the absence of a rostrum, the sloping or transverse first antennae and short second antennae, the sharp fore edge to the mouth, and the legs of the last pair not adapted for swimming, nor the branchial regions swollen. Bionomically they are harder to characterise, but, speaking broadly, we may say that they are not sand crabs, nor swimming crabs, nor land crabs, but essentially crabs of the reef surface and the coral stocks, though some of them may be found in other positions. Their division into subfamilies and genera depends on such characters as the shape of the orbits and antennae, and the relationships of these to one another, the ridges on the palate (endostome) which mark out the channels by which water leaves the gill-chamber, and the shape of the body[1]. The species are separated by details such as the shape of the front and the hands, the sculpture and areolation of the carapace, and the presence or absence of spines on the limbs or the sides of the body.

The body of a typical Xanthid—a *Xantho*, for instance (Fig. 50), or an *Actaea* (Figs. 41 *A*, 53, 54), or *Carpilius* (Fig. 41 *B*), is of a transversely oval shape, heavy and compact, with a hard cuticle and short legs, which can be folded up close under the body[2]. The chelae are usually large and powerful, and the habits sluggish. Such crabs live almost anywhere on the reef, sometimes showing a preference for some particular kind of shelter, such as holes or cracks in the rocks, but more often, I think, adapting themselves to any that can be found. Specimens are thus often taken in coral stocks, though the crabs cannot be said to be characteristically coral crabs, being equally, if not more often, found under stones, which afford the most favourite hiding-place of all; some of the larger species are restricted to the reef, but many of the smaller ones are also to be found in the lagoon wherever coral

[1] In the following key the sub-families of the Xanthidae are defined by means of these features:

I. Endostome ridges wanting. Shape of the body transversely oval or rounded.

A. Flagellum of antenna not shut out of orbital gap.

1. Second joint of antennal stalk cylindrical, reaching the front but not entering the orbital gap.
Xanthinae.

2. Second joint of antennal stalk as in Xanthinae but entering the orbital gap.
Carpilinae.

B. Flagellum of antenna shut out of orbital gap by part of the second joint of the stalk.
Etisinae.

II. Endostome ridges present. Shape of the body often square or squarish.

A. Front less than half, and fronto-orbital edge (front and orbits together) not more than two-thirds the greatest breadth of the carapace. Front usually makes an arch with the anterolateral edge. Flagellum of antenna usually not shut out of orbital gap.

1. Second joint of antennal stalk cylindrical, and may or may not reach the front, with which it is not broadly in contact. Endostome ridges vary in shape and size.
Menippinae.

2. Second joint of antennal stalk somewhat irregular in shape and broadly in contact with the front. Endostome ridges strong, and project on the fore edge of the mouth.
Oziinae.

B. Front at least half, and fronto-orbital edge more than two-thirds the greatest breadth of the carapace. Front makes an angle with the anterolateral edge. Flagellum of antenna always shut out of orbital gap.

1. Endostome ridges strong, and project on the fore edge of the mouth.
Eriphiinae.

2. Endostome ridges moderate, and make no projection on the fore edge of the mouth.
Trapeziinae.

The genera will be found ranged under these sub-families below.

[2] The figure (41 c) of *Euxanthus exsculptus* gives an excellent example of the way in which the limbs are often folded up so as to form with the body a compact mass. Fig. 47 shows how the legs are sometimes specially shaped for folding into a small compass.

grows. The massive, compact form of body and the strong cuticle are, no doubt, adaptations to a life spent in positions where they are surrounded with hard, stony objects, and exposed at times to surf and strong currents, and at others to enemies which they are unable to escape by swimming like the Portunidae.

From this typical body-form there are, of course, deviations in various directions, of which a few only can be mentioned here. Such genera as *Chlorodius* (Fig. 41 *D*) and *Pseudozius* (Fig. 45) are flatter and lighter built, with longer legs, though the cuticle is still strong, and they are more often to be found in situations like the interstices of coral stocks, where they must maintain their position by the use of their limbs, rather than by their weight or by wedging themselves fast, like the heavier genera. Yet even these[1] are far from being true coral crabs, restricted to the living parts of the stock, like *Melia* (Fig. 49), *Domecia* (Fig. 41 *E*), or the Trapeziinae (Figs. 41 *F*, 58), on which some remarks will be found below[2]. Another very characteristic *habitus* is that of *Pilumnus* (Figs. 46—48), slightly built, very hairy, and often with squarish, rather than oval, bodies, falling very steeply in front.

As to the meaning of the numerous, and often very beautiful, features by which the Xanthids are distinguished in detail, it is as yet impossible, in most cases, to say anything. Why, for instance, are the species of *Actaea* bejewelled with the most beautiful pearly granules (Figs. 53, 54)? And why do these granules become sharp thorns in some species (Fig. 56), and flatten themselves into leaflets in others (Fig. 55)? Why should the back of *Euxanthus* (Fig. 41 *C*) be rough and uneven, or that of *Carpilius* (Fig. 41 *B*) glassy smooth? Why is *Liomera* barrel-shaped (Fig. 52) and *Pseudozius* often as flat as a board (Figs. 43, 44)? Before these questions can be answered, much more must be known about the habits of the crabs. We may, however, indicate some directions in which it will be well to look for the answer. The texture of the back and legs, and their nakedness or hairiness, will perhaps be found to depend on the necessity of friction with the surrounding objects when the animal wedges itself firmly into its hiding-place, or of presenting a smooth surface to waves and currents, so that they may pass over the animal without sweeping it away; or again to the need of disguise, either by a covering of fine silt, held by hairs or bristles (often a very effectual device) or by adherent organisms which will not grow on a smooth surface, or even [*Actaea cavipes* and *fossulata* (Fig. 41 *A*)] by a likeness to water-worn pebbles of coral. The shape of the hands may be adapted to the food, or to defence against some special enemy, or—in correspondence with that of the front—to breathing among foreign particles of various grades of coarseness[2], or in some cases seems to be a sexual character. The remarkable hoof-like ends to the fingers (Fig. 57 *C*), which turn up again and again in different genera[3], may serve to give their owner a foothold among the rough coral branches, or may gather food in some special way, like the tufted, spoon-like fingers of the prawn *Atya*. The shape of the front depends on the way in which the antennae are used, and on the need of keeping open a way for the breathing stream, a function which it shares with the chelipeds[4]. And lastly the shape of the end-joints of the walking legs, which shows a

[1] Except, probably, *P. coralliophilus* and *P. triunguiculatus* (p. 241 ff.).

[2] pp. 249, 263.

[3] Garstang, *Q. J. M. S.* XL. p. 211.

[4] This phenomenon of the occurrence of the same feature in groups which cannot be related to one another is not uncommon among Decapods, and is worthy of more attention than it has yet received. Another instance of it, mentioned below (p. 242), is the pulley arrangement at the end of the walking legs. Of course the closure of the orbital gap has happened over and over again in various groups of Crabs, and the loss of the mandibular palp and the epipodites among Prawns is a similar case.

very great diversity, will be found, I believe, to be connected with the nature of the ground on which the animal's life is passed, whether it live among stones or in sandy places or in coral stocks, and to its habits, whether it crouch with folded limbs under shelter or hold fast with its legs.

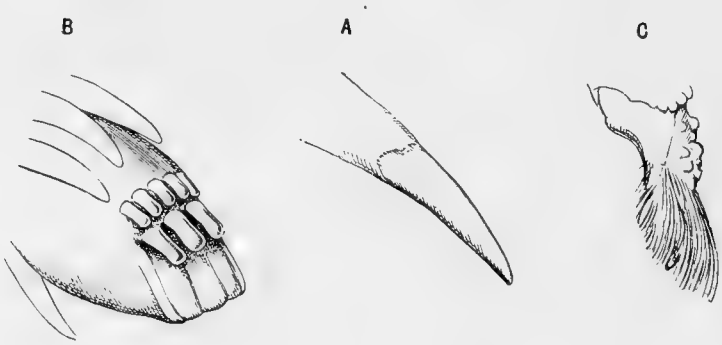

Fig. 42. Ends of the walking legs of Xanthid Crabs. *A*. Tip of the end-joint in *Carpilius convexus* (Fig. 41 *A*). *B*. Same part in *Trapezia ferruginea* (Fig. 41 *F*). *C*. Whole end-joint in *Actaea speciosa*. The drawings are not made to scale, *A* being much less enlarged than *B* or *C*.

A number of examples of this feature may be found in the illustrations scattered through the present paper, but in the accompanying figure (Fig. 42) three of the most unlike of them are shown enlarged. *Carpilius convexus* is a heavy-bodied, spindle-shanked crab, too big and clumsy to climb among the branches of coral stocks, which leads a sluggish and uneventful life among objects on the bottom, and has even been found enclosed as in a cage by the growth of coral[1]. Its legs (*A*) accordingly end in a very simple claw. *Trapezia ferruginea* is a typical crab of the living coral, and we may suppose that the remarkable ending of its legs (*B*) is in some way connected with this fact. But what can be the meaning of the curious brush of hairs at the end of the first walking leg of *Actaea speciosa* (*C*), and why this structure is not found on the other legs, cannot as yet be even guessed. Some remarks on the different ways in which the last joint may be hinged on to that before it will be found below on p. 242.

According to Henderson [*Tr. Linn. Soc. Zool.* (2) v. p. 332] the colour markings of shore Decapoda are generally protective in their nature, but this is certainly not always the case, as, for instance, in *Trapezia* and *Carpilodes*.

In another respect, besides those of structure and habits, the Xanthids offer a contrast to the swimming crabs, described in the last number of this publication, which, next to them, are the most conspicuous family of crabs in the Tropics. They are, with some striking exceptions, not very variable, and are not varietal, save in a few cases. In the Trapeziinae, however, varieties appear, and the genus *Pilumnus* shows a remarkable plasticity of constitution, which leads to the formation of numerous local species and will be alluded to again below[2].

[1] Coutière, *Bull. Mus. hist. nat.*, 1898, 5, p. 238.

[2] p. 244.

Subfamily **Menippinae.**

Genus *Pseudozius* Dana, 1851.

1. *Pseudozius dispar* Dana, 1852.

Pseudozius dispar, Calman, *Tr. Linn. Soc.* (2) VIII. p. 14 (1900)[1].

The granular field on the larger hand of the male of this species grows relatively smaller with age.

Taken on the reef in Male, Goifurfehendu and Fadifolu Atolls, and in Funadu Velu, Miladumadulu Atoll.

2. *Pseudozius caystrus* (Ad. and Wh.), 1848. Alcock, III. p. 181.

This very common species, which is recorded by Alcock from the Laccadives, almost certainly occurs at Minikoi, though unfortunately no specimens of it have reached England[2].

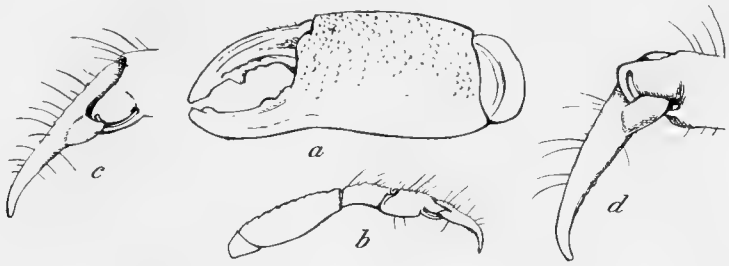

FIG. 43. Limbs of *Pseudozius coralliophilus*; *a*. outside of greater hand, *b*. walking leg, *c*, *d*. end of the same enlarged.

3. *Pseudozius coralliophilus*, n. sp. (Fig. 43).

Diagnosis: "A *Pseudozius* with the carapace finely granular, bearing a few scattered hairs, the regions faintly marked out; the front sloping gradually downwards, cleft into two low, rounded lobes, the furrow between the front and the orbit ending on a small lobe; the antero-lateral edge with three very low humps, from the last of which a fine ridge runs inwards on the back; the chelipeds unequal, finely granular, their fingers widely gaping, especially on the large hand, furrowed and subcylindrical, with a few isolated blunt teeth, the arm and wrist (meropodite and carpopodite of the cheliped) without spines, the fore edge of the arm finely toothed; and the walking legs fairly stout, with a long end-claw."

Length: 3 mm. Breadth: 4 mm. Colour in spirit: cream, with pale brown, cream-tipped fingers.

A single male specimen was taken from a block of the brain-coral *Leptoria tenuis* growing in the lagoon at Minikoi. It was sheltering at the bottom of one of the holes in the coral made by another little crab—*Cryptochirus coralliodytes*[3]. Whether the first owner of the hole had died, or left willingly, or had been ousted by the *Pseudozius* there was nothing to show, nor can we tell as yet whether the latter lives always in *Cryptochirus*-holes or had merely retreated into one in this case as the water drained off the surface of the coral. In another of these holes there was found a female *Pseudozius*, sheltering in the same way, and it was

[1] Where synonyms will be found. For the principle on which references are given in this paper see p. 192 of Part II. of the present publication.

[2] See footnote to p. 191 of Part II. of this publication.

[3] See below, p. 271.

natural to suppose at first that this was the female of the crab whose male we have just described. Further examination, however, showed differences between the two so great that they must belong to different species. The second specimen is described below under the name of *P. triunguiculatus.*

I am much obliged to Mr Edwin Wilson, F.E.S., for calling my attention to a very interesting structure which he discovered on the legs of this crab (Fig. 43 *b—d*). As usual, the last joint (dactylopodite, end-joint) is held in a deep notch at the end of the one before it (propodite). But in the present case it bears on the hinder side a flange, and on the flange a knob, which works in a groove on the propodite. At the inner end of this groove is a small pit, into which the knob slips when the joint is fully flexed, so that the end-joint is held firm in this position, thus providing the crab with a hook, by which, no doubt, it keeps its position on the coral. *P. triunguiculatus* has a less perfect form of the same apparatus (Fig. 44 *c*). In it, the flange on the last joint works against a special process of the one before

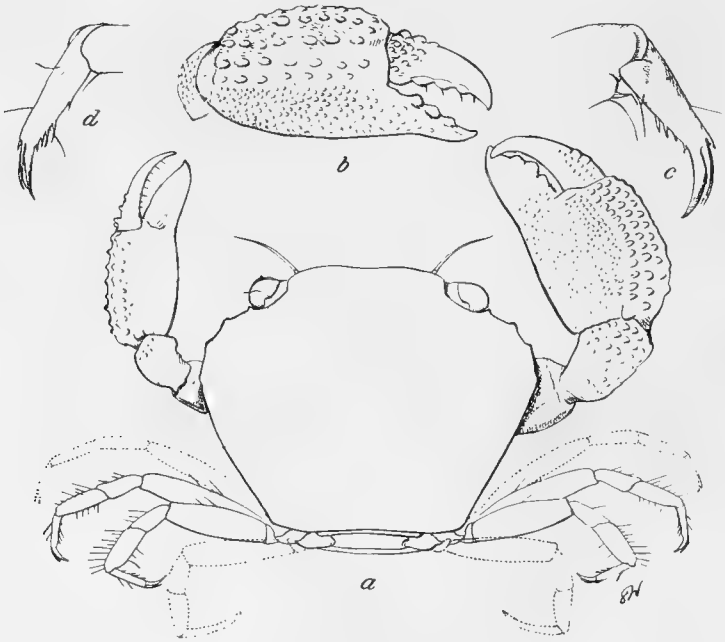

Fig. 44. *Pseudozius triunguiculatus*, symbiotic with a coral; *a*. whole animal, *b*. outside of greater hand, *c*. hinder side of end of walking leg, *d*. fore side of the same.

it, but this process has only a smooth surface and no groove. A small spine under the propodite seems placed in this position to prevent the end-joint from being unduly flexed, and no doubt the other spines give a foothold to the animal. On the whole, these structures, as well as the general appearance of the body and limbs, give the impression that the crabs are indeed symbiotic with the coral, living always on its surface, but take refuge in the *Cryptochirus* holes at times only.

Interestingly enough, the same structure, in its simpler form of a flange on the end-joint working along a smooth path on the joint before it, turns up again in the coral crabs of the Trapeziinae and in *Domecia*, though not in *Melia*, which crooks the whole leg and not the last joints only, and is also present in *Chlorodopsis* (Fig. 57 *c*) and *Phymodius*, which, without

being true coral crabs, are often found in coral stocks, and in the *Actaeas* of the *flosculata*-group, of whose habits as yet nothing is known, since they have only been taken with the dredge. *Actaea speciosa* (Fig. 42 *C*) is an example of a species in which the flange is not found. The object of the apparatus is, no doubt, to enable the end-joint to be moved more evenly and accurately and held fast in any position; and it is only an elaboration of structures found in most crabs, which have usually a small facet on the hinder side of the last joint for the end of the propodite. Its absence is, nevertheless, particularly interesting in the case of *Eriphia*, which is allied to *Domecia*, and of *Pseudozius* other than the two species mentioned above. A single glance at the orbits of these latter species is enough to show that they have no place among the Trapeziinae, Eriphiinae, or Etisinae, so that the formation of the legs in question must have arisen, like so many other characters of the crabs, independently in two or more cases[1]. It is probably an adaptation to clambering.

4. *Pseudozius triunguiculatus*, n. sp. (Fig. 44).

Diagnosis: "A *Pseudozius* with the carapace flat, smooth (microscopically roughened) and hairless, the regions not marked out; the front sloping slightly downwards, standing well forward beyond the eyes, with a wide shallow bight instead of the usual notch in the middle, no side lobes, and a shallow median furrow; the anterolateral edge with three low, blunt teeth, the hindermost of which is hardly distinguishable; the chelipeds, large, unequal, covered with granules of some size, which are largest on the upper part of the outside of the hand, no spines on the arm or wrist, the fingers flattened, not gaping, sharply pointed at the tips, in the large hand the fingers set, on their opposed edges, with a row each of conical teeth, in the small hand these edges blade-like, making up a remarkable pair of shears, which are no doubt adapted to some peculiarity in the habits; and the walking legs rather slender, each bearing on its last joint a set of three slender, brown end-claws, of which two are somewhat smaller than the third."

Length: 3 mm. Breadth: 4 mm. Colour in spirit: pale brown, the walking legs white, the back covered with small dark-brown spots, the fingers white.

One female specimen taken on *Leptoria tenuis* in Minikoi lagoon.

Subgenus *Platyozius*, n.

A specimen dredged in Suvadiva cannot be referred to any known species, and is also difficult to place in a genus. It differs from *Pseudozius*, as hitherto defined, in more than one point, but none of these is of importance enough to warrant the setting up of a new genus, and it is therefore taken here as the type of a new subgenus *Platyozius*. Other groups of species akin to *Pseudozius* will probably have to be reduced to this rank before long.

Platyozius differs from *Pseudozius* s. str. in the following points: (1) Relatively greater fronto-orbital breadth. (2) Absence of small outer lobes from the front. (3) Equality of the chelipeds. (4) Slenderness of the legs. (5) A flatter and shallower body. (6) Less marked endostome ridges.

5. *Pseudozius* (*Platyozius*) *laevis*, n. sp. (Fig. 45).

Diagnosis: "A *Platyozius* with the carapace smooth, hairless, without regions; the front broad, bent slightly downward, almost straight, with a broad shallow bight in the middle and

[1] See above, footnote to p. 239.

notches separating it from the orbits, but no outer lobes; the anterolateral edges short, with two big blunt triangular teeth behind the orbital angle, and a small notch, rather than a projecting tooth, at the junction with the posterolateral edge; the hinder edge slightly hollowed; the chelipeds equal, smooth, without spines but with a blunt tooth at the inner angle of the

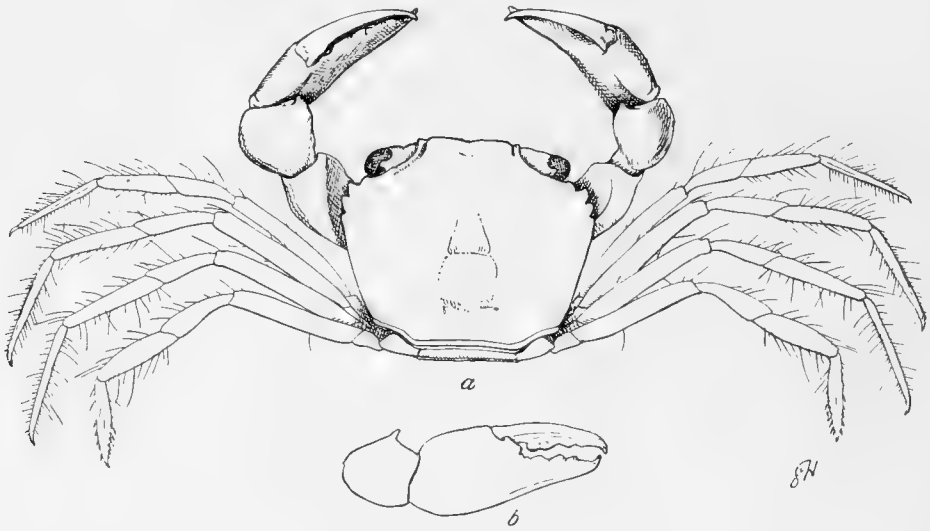

Fig. 45. *Pseudozius laevis*; *a*. whole animal, *b*. outside of hand.

wrist, the fingers compressed, grooved, not gaping, each with a row of triangular teeth interlocking with those of the other; and the walking legs long, slender, sparsely hairy, and without spines, except on the dactylopodite of the last leg, which is rather broad, while those of the other walking legs are very long and narrow."

Length: 5 mm. Breadth: 6 mm. Colour in spirit: white.

One male specimen dredged in 20 fathoms in Suvadiva Atoll.

Genus *Pilumnus*, Leach, 1815.

As a general rule the species of crabs are not local in distribution, but are spread over wide areas and are probably correlated with habitative[1] rather than geographical differences in environment. There are, of course, exceptions to this rule, as for instance the land and freshwater crabs of the genera *Sesarma* and *Potamon*. *Pilumnus* is another of these exceptions, as may be seen at once on looking down a list of the known species, when it will be evident that many of them have been only recorded from one locality. This impression is strengthened on reading the remarks of various authors in recording a species from a new locality. In many cases the identification is doubtful, or the description does not tally with that of the original specimens. The present collection affords an excellent example of this, not one of the 11 species being represented by specimens which exactly obey former diagnoses. Under the circumstances I shall describe as new species the forms which do not agree closely with specific descriptions already published, and rank as subspecies[2] those which in-

[1] For the meaning of this word, see p. 195 of Part II. of this publication.

[2] See footnote to p. 195 of Part II. of this publication.

fringe such descriptions in small points only. The phenomenon of local variation in *Pilumnus* deserves, and would repay, careful investigation, especially with regard to the existence of intermediates, their number relative to those of the described forms, and their distribution, whether they be found in intermediate localities or no. In short, information is needed as to whether the subspecies of *Pilumnus* be "discontinuous," like true varieties, or no.

The members of the genus live under stones, in coral blocks, etc.

6. *Pilumnus vespertilio* (Fabr.) 1793. Alcock, III.[1] p. 192.

The fur of the Maldive specimens is not dark, as in the type, but of a golden-yellow colour, like that of Alcock's Karachi and Tavoy race. At the same time the usual smooth patch is to be found near the base of the finger of the large hand. Perhaps these characters are distinctive of local races or subspecies of *P. vespertilio.*

The species, which is sluggish in its habits, lives under stones, etc., and was taken on the reef at Hulule, Male Atoll, and in Funadu Velu, Miladumadulu.

7. *Pilumnus andersoni* de Man, 1887. subsp.[2] See Alcock, III. p. 194.

The Maldive specimens differ from the race defined by Alcock in the following points: (1) There are no granules on the carapace, which is everywhere smooth and finely pitted. (2) The spines on the fore edge of the meropodites of the walking legs are vestigial, and there is no spine at the end of the joint. (3) The arrangement of the spines on the fore edge of the arm does not agree with that described by de Man. Alcock does not mention these spines, but, as he cites de Man's paper, it is presumable that all his specimens presented the same arrangement as the type. In the Maldive example there is a row of strong, blunt teeth, growing smaller from without inwards. In de Man's specimens there were two, large, arched, sharp spines at the outer end, with a small spine at the base of the distal of the two. The more proximal was larger than the distal one, and behind it were four or five acute granules.

Dredged in 5—39 fathoms in Minikoi, South Nilandu, and Haddumati Atolls.

8. *Pilumnus hirsutus* Stimps, 1858. subsp. See Alcock, III. p. 197.

The Maldive specimens differ from those on which Alcock's description was founded in the following points: (1) A small subhepatic tooth is present. (2) The gaps on the orbital edge are fairly distinct.

According to Haswell (*Cat. Austral. Crust.* p. 69), the meropodites of the walking legs of this species should bear three or four spines. Alcock does not mention these spines, and they are wanting in the Maldive specimens, in which the fore edge of the meropodite is roughened by a row of low, blunt teeth. Alcock is doubtful about the identity of the species he is describing as *P. hirsutus,* and it seems likely that the three forms[3] are distinct.

A single specimen from South Nilandu, which bears a *Sacculina,* differs from the others in the following points: (1) The antennal flagella are long and hairy. (2) The large hand is rather less "full." (3) The body is rather flatter. (4) The legs are a little longer.

[1] *Journ. As. Soc. Beng.* LXVII. ii. pp. 67—233 (1898). For the principle on which references are given in this paper see Vol. I. Part II. p. 192 of the present publication.

[2] See footnote to p. 195 of Part II. of this publication.

[3] I am using the word "form" in its broadest sense to include species, subspecies, and varieties. In this sense it is a useful counterpart of "group," used to include all divisions of the animal kingdom from genera upwards. For definition of "variety" and "subspecies" see the article on Varieties in Part II. of this publication.

It is impossible to say whether any or all of these features be due to the presence of the parasite.

The figure of a specimen referred to this species in the *P.Z.S.* for 1900 [pl. XLII., fig. 9] was drawn with the hair on the body and in consequence the side-teeth and frontal notch have not been shown by the artist.

Dredged in 22—45 fathoms in Haddumati, Felidu, Addu, Mulaku, North Male, South Nilandu, Suvadiva, and Kolumadulu Atolls.

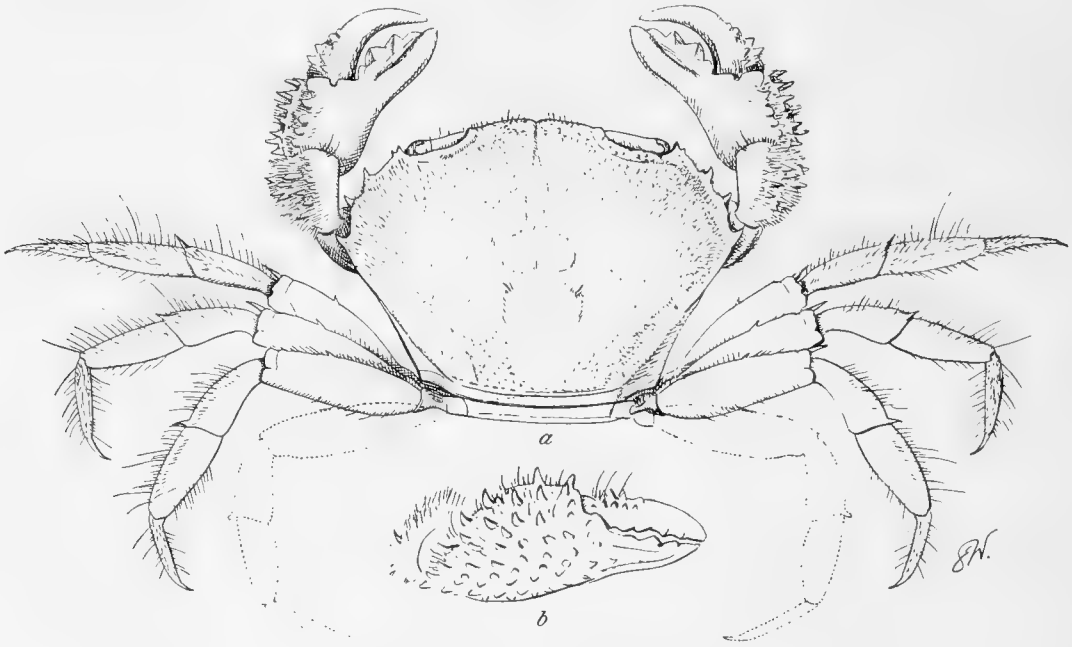

FIG. 46. *Pilumnus rotundus*; *a*. whole animal, *b*. outside of hand.

9. *Pilumnus rotundus*, n. sp. (Fig. 46).

Diagnosis: "A *Pilumnus* with the carapace very convex, subglobular, covered with short hairs, the regions faintly marked; the lobes of the front only moderately prominent, with faintly granular edge; the lower rim of the orbit denticulate, the upper rim granular, with two distinct but shallow notches; the anterolateral edge bearing four spiniform teeth, of which the first is the orbital angle, the teeth being short and set wide apart and having smaller teeth at their bases; the chelipeds rather unequal, covered outside with stout thorns, which are arranged in somewhat irregular rows and are largest on the upper side, the fingers bent at an angle with the hand, the moveable finger bearing a strong ridge above; and the walking legs moderately long, covered with long hairs, and with a thorn on the upper edge of the meropodite and one at the end of both the meropodite and the carpopodite."

Length: 8 mm. Breadth: 12 mm. Colour in spirit: yellowish-white, with white fingers.

Dredged in 35 fathoms in Kolumadulu Atoll.

10. *Pilumnus dorsipes* Stimps, 1858. Alcock, III. p. 197.

The specimens agree very closely with Alcock's definition, but I am quite unable to detect

any granulation of the carapace, which, when laid bare, is absolutely smooth, save for the stumps of the hairs. The larger hand is very stout and the fingers short.

The species was taken in South Nilandu, Haddumati, North Male, Mulaku, Suvadiva, Felidu, Kolumadulu, and Fadifolu Atolls, in 12—70 fathoms of water.

11. *Pilumnus maldivensis*, n. sp. (Fig. 47).

Diagnosis: "A *Pilumnus* with the carapace convex both fore and aft and from side to side, smooth, pubescent and hairy, the regions faintly marked; the middle lobes of the front prominent, the outer lobes very small; the lower rim of the orbit finely toothed, the upper rim smooth, with traces of two notches; the anterolateral edge short, with three spiniform teeth and a spine on the orbital angle; the chelipeds unequal, granular and hairy outside, a small bare patch at the base of the fingers and along the lower edge of the greater hand, fingers moderately long, smooth; and the walking legs of moderate length and stoutness, hairy and pubescent, and without thorns on the meropodites."

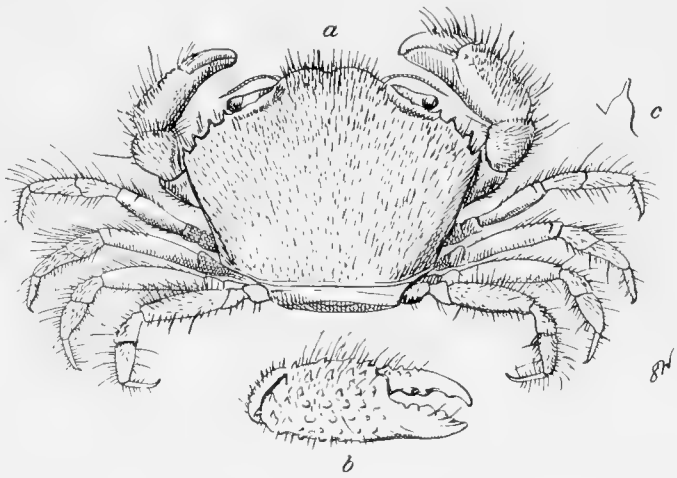

Fig. 47. *Pilumnus maldivensis*; *a*. whole animal, *b*. outside of hand, *c*. one of the teeth of the anterolateral edge.

Length: 4 mm. Breadth: 5 mm. (Largest specimen.) Colour in spirit: yellowish-white, fingers white.

This species seems to be akin to *P. caerulescens* A. M.-Edw. 1873, which is included in Major Alcock's list of Indian Crabs, but the colour and the spiniform orbital angle serve to distinguish it. It was dredged in Suvadiva, North Male, Miladumadulu, and South Nilandu Atolls, in 25—43 fathoms.

12. *Pilumnus rotumanus* Borradaile, 1900. ? subsp.

Pilumnus rotumanus Borradaile, *Proc. Zool. Soc.* 1900, p. 581, pl. XLI. fig. 6 (1900).

A single female of this crab was taken on the shore at Hulule, Male Atoll. It differs from the type specimen in two points: (1) The moveable finger, which in *P. rotumanus* has a slightly uneven cutting-edge, has in the Maldive example a row of well-marked teeth. (2) The carapace of the Maldive specimen is narrower relatively to its breadth.

Both specimens are females, but it is possible that these differences may be due to age, since the Rotuman individual is much larger than that from Hulule (length 15 mm. as against 8 mm.). Or, again, a series from each locality might show that the features in question are not characteristic.

13. *Pilumnus elegans* de Man, 1887. subsp.

See *Pilumnus elegans* de Man, *Arch. Naturges.* 53 I. p. 310, pl. XII. fig. 3 (1887).

The specimens agree with de Man's description in all points but the two following:

(1) The fore edge of the meropodites of all the walking legs bears three spines besides that at the end of the joint. In de Man's race there is only one, and that is wanting from the last leg. (2) The red colour mentioned by de Man is wholly wanting, though of course this may be due to the state of preservation.

Taken in South Nilandu Atoll, in 19—25 fathoms.

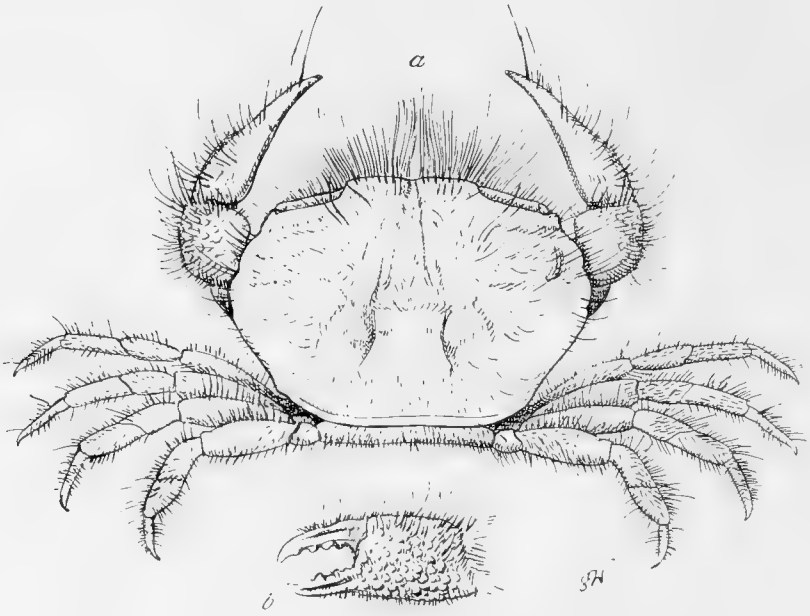

Fig. 48. *Pilumnus alcocki*; *a*. whole animal, *b*. outside of hand.

14. *Pilumnus alcocki*, n. sp. (Fig. 48).

Diagnosis: "A *Pilumnus* with the carapace of moderate breadth only, covered rather sparsely with long hairs but without pubescence, the regions well marked; the front almost straight, slightly arched, not deeply notched in the middle, bearing a fringe of very long hairs; the anterolateral edge raised into three low mounds, the hindermost of which is very inconspicuous; the outer orbital notch shallow, the inner wanting, the lower orbital rim granular, the orbital angle not at all prominent; the chelipeds subequal, granular and covered with long hairs, the fingers gaping, somewhat furrowed and toothed; and the walking legs short, stout, hairy and pubescent, and without thorns on the meropodites."

Length: 4·8 mm. Breadth: 6·2 mm. Colour in spirit: white.

Dredged in 20 fathoms in Suvadiva Atoll.

I have called this species after Major A. Alcock, F.R.S., to whose excellent work on the Indian Crabs it has so often been necessary to refer in the present paper.

Genus *Actumnus* Dana, 1851.

15. *Actumnus globosus* (Dana), 1852.

Pilumnus globosus, Dana, *U.S. Expl. Expd. Crust.* I. p. 236, pl. XII. fig. 10 (1852).

By the shape of its body this species seems to belong to *Actumnus*, rather than to

Pilumnus, though, in any case, with *A. obesus* Dana, 1852, and *A. elegans* de Man, 1887, it holds an intermediate position.

Taken on the reef at Minikoi.

16. *Actumnus setifer* (de Haan), 1835. Alcock, III. p. 202.

The carapace is very sparsely granular in the larger specimens.

Dredged in 23—30 fathoms in Mahlos and South Nilandu Atolls.

17. *Actumnus tomentosus* Dana, 1852. Alcock, III. p. 202.

Dredged in 25 fathoms in South Nilandu Atoll.

Genus *Melia* Latr., 1825.

I have followed Ortmann in placing this genus provisionally in the Menippinae chiefly because the orbital gap forbids its being included in the Trapeziinae, to which its body-shape, coral haunting habits, and coloration seem at first to show a relationship. For the rest, the shape of the body may be reached without much difficulty from that of *Pilumnus*, and none

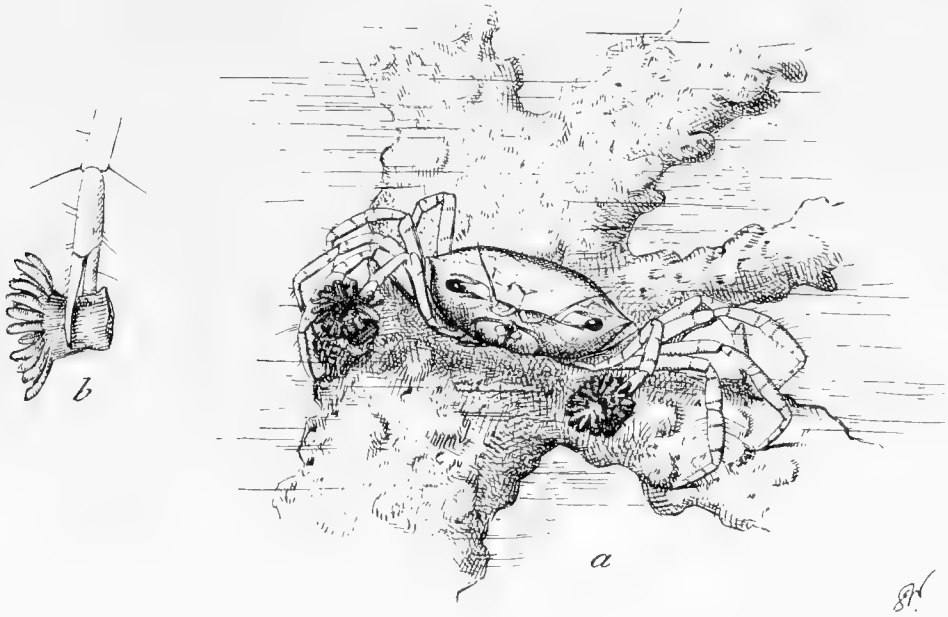

Fig. 49. *Melia tessellata*, bearing in its claws two sea anemones. The colour of this crab in life is very beautiful Its translucent legs are ringed, as in the figure, with dark purple, and lines of the same colour mark out the body into polygonal fields which are coloured pale pink or brown and lemon yellow. The anemones when alive are olive-green, and the coral pink or green. The whole figure is considerably enlarged, and *b*, which shows the "hand" holding an anemone, is very much so.

of the other characters offers any great obstacle to our classifying it with the present subfamily. It has obviously undergone considerable modifications in structure in connection with its peculiar and interesting habits.

18. *Melia tessellata* (Latr.) (Fig. 49.)

Melia tessellata, Borradaile, *Proc. Zool. Soc.* 1900, p. 580.

This crab, which lives, like *Trapezia*, among the living branches of coral stocks, holding on by its long slender legs, has for some time[1] been known to be in the habit of carrying in each chela a small sea anemone. The object of this habit is not known, but it is certainly a voluntary act on the part of the crab, for the actinian is not attached, but held between the fingers of the *Melia*, and, if it be taken away, will be again seized. Usually there is an anemone in each hand, but sometimes one or both hands are empty. The actinians, which are grasped firmly round the middle below the tentacles, may be useful, by means of their stinging-cells, either for defence or to "fish" for food with, or perhaps for both purposes. The chelipeds are slender and feeble—ill-suited for defence, but at the same time mobile and well adapted to wield the anemones they carry, and, if the crab be threatened, it will stretch out its arms towards the aggressor, as though it would ward him off with the disagreeable obstacles it thus presents to his attack. Certainly the fingers cannot be used to take food unless the anemone be first dropped, but, on the other hand, the tentacles of the latter are directed outwards, away from the mouth of the crab. The third maxillipeds are mobile, with the proximal joints rather slender and the last three stout, and are fringed with long hairs. Possibly they are used to catch small organisms for food in much the same way as those of the China Crabs (Porcellanidae), which part with their chelipeds so readily when they are attacked, since they do not use them for taking food.

In any case we seem to have here an interesting example of the use of an implement by an animal which, however intelligent, has at least a very differently organised nervous system from the Vertebrata. It should be noted that the case is different from that of a spider crab, which sticks pieces of seaweed on its back and enjoys passively the concealment gotten thereby. For the *Melia* carries the anemone in its cheliped—the chief grasping organ of the animal, corresponding to the hand of a primate or the trunk of an elephant—and, whatever its use, it cannot be a means of passive concealment, to which its size is wholly inadequate[2].

Melia tessellata is not recorded from the Indian region by Alcock, who finds the genus represented there by two quite distinct new species (*M. caestifer* and *M. pugil*). It would be interesting to know the precise distribution, geographical and habitative, of these three species. The "hairs" mentioned by Alcock as found on the fingers of his new species may possibly be the remains of actinians, rotten from bad preservation, and in that case it would be needful to determine whether each species of crab has its own species of anemone. Of course we must also know whether the latter be full grown or only young individuals. The species was taken on the reef in Male, Addu, Minikoi and Goifurfehendu Atoll.

Subfamily **Xanthinae.**

Genus *Cymo* de Haan, 1833.

The members of this genus live under stones, in coral blocks, etc.

[1] The fact was noted in 1880 by Richter (Möbius' *Meeresfauna Mauritius*), but since then its interest, and indeed its very existence, have been generally overlooked.

[2] The ant *Oecophylla smaragdina* uses its own larvae (which have glands for making a cocoon) as spinning implements to fasten together the edges of the leaves which form its home, holding them, the while, in its jaws. There is also said to be a wasp which uses a stone to beat down the earth over its burrow.

19. *Cymo andreossyi* (And.) 1826, var. *melanodactylus* (de Haan) 1833. Alcock, III. p. 174.

Taken on the shore in Minikoi and Goifurfehendu Atolls, and dredged from 12 fathoms in Fadifolu Atoll.

20. *Cymo quadrilobatus*, Miers, 1884. Alcock, III. p. 175. This species is probably identical with *C. tuberculatus* Ortmann (*Zool. Jahrb.* VII. Syst., p. 443).

Taken on the shore in Male, Goifurfehendu and Fadifolu Atolls.

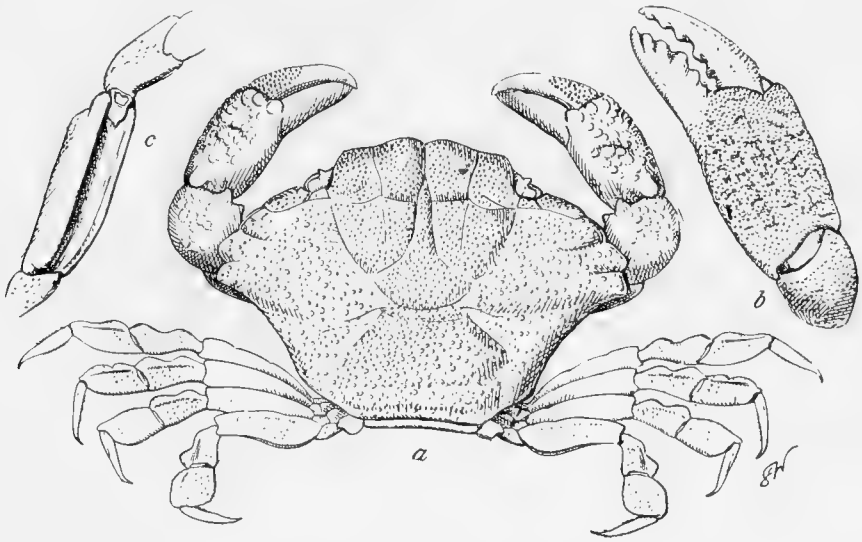

FIG. 50. *Xantho frontalis*; *a*. whole animal, *b*. outside of hand, *c*. underside of meropodite of walking leg, to show the groove into which the last three joints can be folded.

Genus *Xantho* Leach, 1815.

21. *Xantho frontalis*, n. sp. (Fig. 50).

Diagnosis: "A *Xantho* with the whole body finely and evenly granulated, the regions marked out by fine sharp lines; the front prominent, its outline like that of a cupid's bow; the anterolateral edge divided into four lobes, of which the first two are low and rounded and the last two prominent and conical; the chelipeds subequal, their outer surface rough and uneven, the hands with four indistinct longitudinal ridges, the fingers furrowed and bearing interlocking teeth, the upper side of the hand with an irregular-rounded lobe, the inside of the wrist with a conical tooth; and the walking legs short, with long end-joints, two knobs on the upper side of the carpopodite, and a hollow under the meropodite into which the outer joints can be folded."

Length: 5 mm. Breadth: 8 mm. Colour in spirit: white with pale-brown fingers.

Genus *Xanthias* Rathbun, 1897.

22. *Xanthias lamarcki* (H. M. Edw.), 1834. Alcock, III. p. 157.

Taken on the shore in Male, Goifurfehendu, Miladumadulu, Fadifolu, S. Mahlos, and Minikoi Atolls.

23. *Xanthias notatus* (Dana), 1852. Alcock, III. p. 158.

Taken on the reef and in the lagoon at Minikoi.

Genus *Leptodius*, A. M.-Edw., 1863.

The numbers of this genus may be taken under stones and in coral stocks.

24. *Leptodius nudipes* (Dana), 1852. Alcock, III. p. 121.

Taken on the shore in Male, Goifurfehendu and Minikoi Atolls; in the latter locality from a coral mass on the outer reef.

25. *Leptodius sanguineus* (H. M.-Edw.), 1834. Alcock, III. p. 119.

Taken on the shore in Goifurfehendu Atoll.

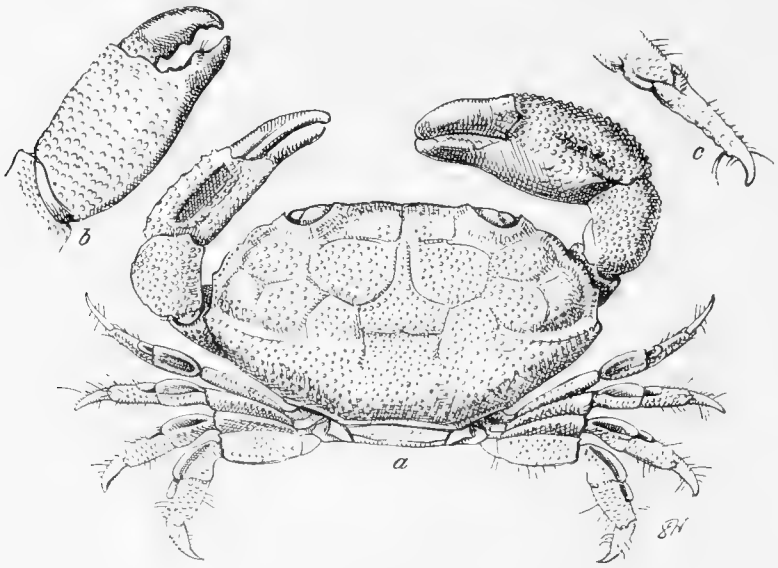

FIG. 51. *Leptodius cristatus*; *a*. whole animal, *b*. outside of hand, *c*. end of walking leg.

26. *Leptodius* (*Xanthodius*) *cristatus*, n. sp. (Fig. 51).

Diagnosis: "A *Xanthodius* with the carapace flat behind, falling steeply in front, somewhat sparsely granular all over, the granules being smaller and closer set in the hinder part, and naked, the forepart of the carapace divided up by wide, smooth grooves; the front bent strongly downwards, with an almost straight, thickened, granular edge and a rather shallow notch in the middle; the notches in the orbital rim indistinct; four low side-teeth with thickened, granular edges; the hind edge of the carapace slightly hollowed; a feeble ridge on the endostome reaching the fore edge of the mouth; the basal joint of the antenna short; the chelipeds unequal, granular all over except on the facet against the body, the hands with a crest and a smooth furrow above, the fingers deeply hoofed at the tip, a little granular at the base, furrowed on the smaller hand only, with a few blunt teeth on the larger hand; and the walking legs finely granular, their last two joints hairy; the carpopodite and propodite with a crest and a broad smooth groove above."

Length: 5 mm. Breadth: 7 mm. Colour in spirit: mottled purple and orange-brown, fingers dark-brown with paler tips.

Four female specimens were found under stones on the inner part of the reef-flat at Minikoi.

Genus *Lioxantho* Alc., 1898.

27. *Lioxantho asperatus* Alc., 1898. Alcock, III. p. 92.

The specimens agree exactly with Alcock's definition, except in not having hair on the dactylopodites.

Taken on the shore at Hulule, Male Atoll.

28. *Lioxantho tumidus*, Alc., 1898. Alcock, III. p. 91.

Taken on the shore in Male and Goifurfehendu Atolls.

29. *Lioxantho punctatus* (H. M. Edw.), 1834. Alcock, III. p. 91.

Taken on the shore at Hulule, Male Atoll.

Genus *Liomera* Dana, 1851.

30. *Liomera cinctimana* (White), 1847. Alcock, III. p. 88.

Taken on the shore at Goidu, Goifurfehendu Atoll.

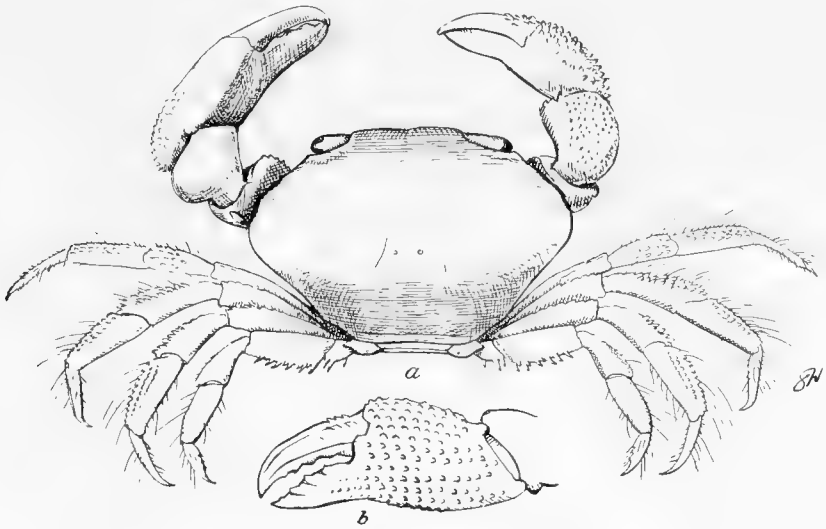

FIG. 52. *Liomera spinipes*; *a*. whole animal, *b*. outside of hand.

31. *Liomera spinipes*, n. sp. (Fig. 52).

Diagnosis: "A *Liomera* with the carapace smooth and polished, without a trace of regions, rather more than half as long as broad; the front divided into two well-marked rounded lobes of simple outline; the anterolateral edge sharp, almost crest-like in its hinder half, with traces of the last two lobes only, not marked off by a tubercle from the posterolateral edge; the orbital rim without notches; the antennal flagellum rather longer than the breadth of the orbit; the fore edge

of the third maxilliped almost straight; the chelipeds stout; the arm short and broad, with a large tooth near the end of the upper edge and the lower edge roughened; the outside of the wrist roughened in parts; the outside of the hand covered with small, sharp thorns, and some of the same thorns on the base of the moveable finger; the fingers compressed, toothed on their opposite edges, and furrowed outside; and the walking legs having the upper edge of the meropodites much compressed and finely toothed, but not crested; the lower edge of the last meropodite with long thorns, those of the other meropodites with much smaller thorns, and the carpopodites and propodites of all the legs rather sparsely hairy, with broad upper sides covered with prickles."

Length: 5 mm. Breadth: 8 mm. Colour in spirit: white.

Dredged in 30 fathoms in Mulaku Atoll.

Genus *Actaea* de Haan, 1833.

32. *Actaea tomentosa* (H. M.-Edw.), 1834. Alcock, III. p. 140.

Taken on the reef in Male, Goifurfehendu, Addu, and Minikoi Atolls.

33. *Actaea affinis* (Dana), 1852.

Actaea affinis, Borradaile, *Proc. Zool. Soc.*, 1900, p. 583.

Taken on the reef in Male, Goifurfehendu, Fadifolu, and Minikoi Atolls.

34. *Actaea rufopunctata* (H. M.-Edw.), 1834. Alcock, III. p. 142.

One very small female dredged in N. Male was without the fine felt between the lobules of the back.

Taken on the shore in Goifurfehendu Atoll, and dredged in Minikoi, North Male, and Miladumadulu Atolls.

35. *Actaea speciosa* (Dana), 1852. Alcock, III. p. 143. (Fig. 42 *C*.)

The first walking leg of this crab bears an organ which seems not to have been noticed hitherto. A brush of stiff yellow bristles surrounds and hides the end-claw on the last joint of the limb. What can be the use of this structure it is hard to see, but so definite and constant an organ must correspond to some feature in the habits of the crab.

Taken on the reef in Male, Goifurfehendu, and Fadifolu Atolls.

36. *Actaea ruppelli* (Krauss), 1843. Alcock, III. p. 144.

The specimens are not so hairy as Alcock's definition indicates. A. Milne-Edwards says that the species is "légèrement poilue." Probably the amount of hair depends greatly on the state of preservation of the specimens, in this as in other Xanthids.

Taken on the reef in Goifurfehendu Atoll.

37. *Actaea lata*, n. sp. (Fig. 53).

Diagnosis: "An *Actaea* with the carapace broad (length : breadth = about 7 : 10) and strongly lobulated all over, though the lobules are not very convex, the grooves between the lobules smooth and lined with fine dark pile, the lobules covered with pearly granules, which are smaller on the hinder lobules than on those before them, long golden-brown hairs and

shorter black bristles arising among the granules, the front bent strongly downwards, not much arched or very strongly notched in the middle line; the anterolateral edge with four low lobes, the first being confluent with the orbital angle; the orbit with two notches in its upper rim and one in the lower; the under side of the body furred, and grooves running from between the lobes of the edge over the finely granular pterygostome; the posterolateral edge not marked by a row of granules; the chelipeds subequal, the wrist and hand lobulated above, the hands swollen, rounded and covered with granules outside and inside, the fingers short, much arched, not compressed or hollowed at the tip, with a few blunt teeth on the opposed edges and some granules at the base of the moveable one, which is furrowed, though not to the tip; and the walking legs covered with granules, hairs and bristles like those of the carapace and with a furrow on the hinder side of the carpopodite."

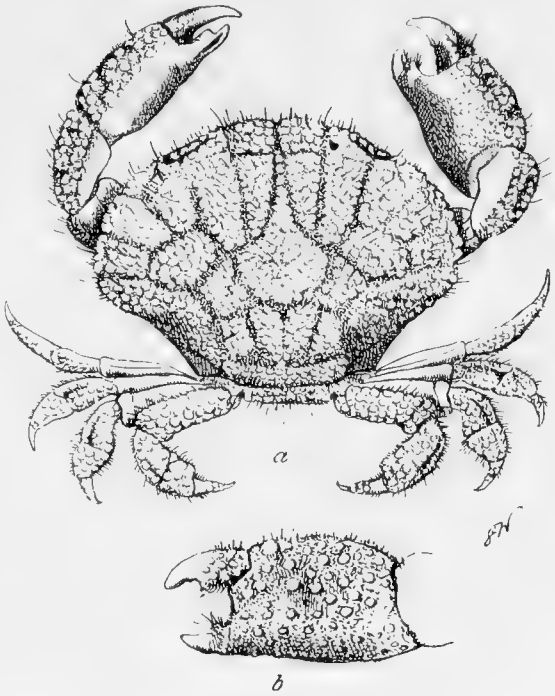

Fig. 53. *Actaea lata*; *a*. whole animal, *b*. outside of hand.

Length: 7 mm. Breadth: 10 mm. Colour in spirit: white with red spots; the fingers black with white tips, the black spreading over a great part of the inner and outer sides of the palm.

The species is allied to *A. hirsutissima* (Rüppell), 1830, and *A. kraussi* Keller, 1861, but may be distinguished from both by the shape of the hands.

Dredged in 15 fathoms in Fadifolu Atoll.

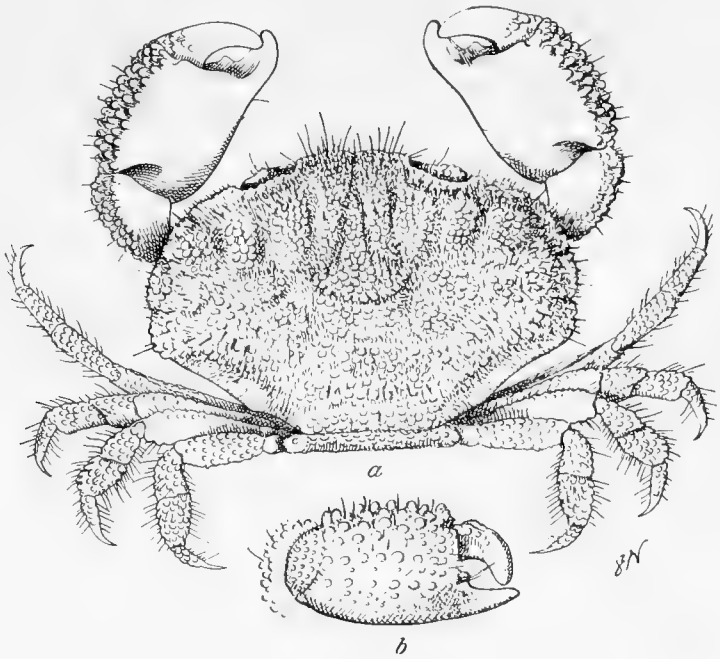

Fig. 54. *Actaea variolosa*; *a*. whole animal, *b*. outside of hand. The animal is drawn rather broader than it actually is.

38. *Actaea variolosa*, n. sp. (Fig. 54).

Diagnosis: "An *Actaea* whose length is about three-quarters of its breadth; the carapace egg-shaped, its areas numerous but separated by shallow grooves on the fore-part, wanting behind, the whole surface, except the bottom of the grooves in the fore-part, covered with rounded granules, which are largest in the branchial region and are interspersed with stout, golden-brown bristles; the front bent strongly downwards, prominent, fairly deeply notched in the middle; four indistinct side-lobes; the chelipeds equal, granular; the hands rather large, somewhat swollen, nearly square; the fingers very short, rounded, smooth save for a few small granules on the base of the moveable one, each with but one tooth, which is very blunt and lies quite at the base where it is almost hidden by tufts of strong hairs; and the outer surface of all the walking legs covered with granules like those of the cheliped but with no dimples."

Length: 6 mm. Breadth: 8 mm. Colour in spirit: white, bases of fingers black.

The species is allied to *A. obesa* A. M.-Edw., 1865, but differs in the shape of the hands.

Taken on the shore in Male Atoll.

39. ? *Actaea pulchella* A. M.-Edw., 1865. Alcock, III. p. 140.

The specimen which I have with some doubt assigned to this species has a very distinct coloration of mottled white and orange-yellow. As in Milne-Edwards's figure (*Nouv. Arch. Mus. Hist. Nat.* I., Pl. XVII., fig. 5), it is only the first of the side lobes of the carapace that can be described as indistinct, though both Milne-Edwards and Alcock apply this term to all of them. If Milne-Edwards's figure be not correctly drawn, then my specimen represents another, and probably a new species.

Dredged in 25 fathoms in North Male Atoll.

40. *Actaea granulata* (And.), 1825. Alcock, III. p. 151.

Dredged in Haddumati, Fadifolu, Mahlos, and South Nilandu Atolls, in 19—50 fathoms. In two cases taken in coral stocks (one alive, one dead). Possibly it lives in such positions, rather than under stones.

41. *Actaea flosculata* Alc., 1898. Alcock, III. p. 151.

Taken on the reef in Miladumadulu and dredged in Suvadiva and South Nilandu Atolls, in 19—38 fathoms. One of the South Nilandu specimens is noted to have come from a block of *Pocillopora*. Neither this nor the species akin to it seem suited to an exposed life.

42. *Actaea spinosissima* n. sp. (Fig. 55).

Diagnosis: "An *Actaea* nearly akin to *A. flosculata*, but with the following differences from that species: (1) Only the spines on the back have the characteristic petaloid shape. Those at the sides and on the limbs are sharp thorns. (2) The posterolateral edge of the back is not marked by a row of small beads, as in *A. flosculata* and in *A. perspinosa* (see below). (3) The hinder edge has a thickened rim, which is wanting in the above-mentioned two species, and the whole arrangement of the tubercles on the field behind the post-gastric

furrow is different, as will be seen by comparing the figures. (4) The peculiar tubercles on

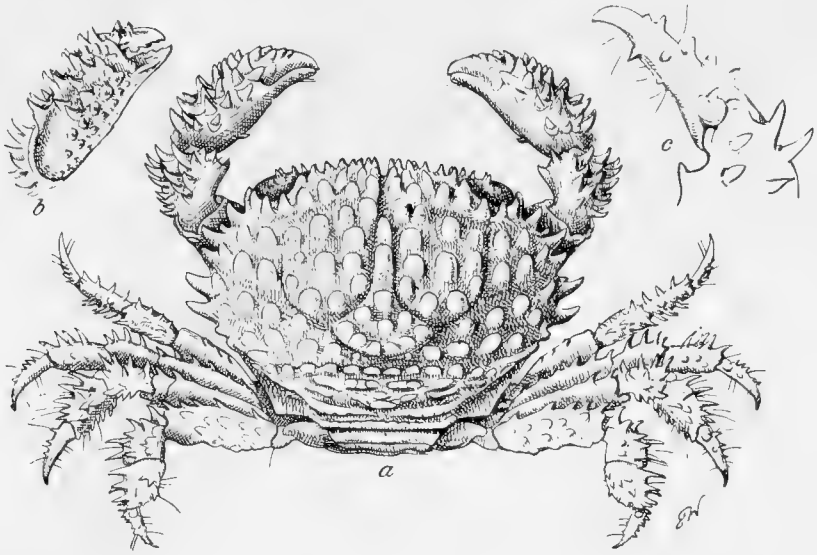

FIG. 55. *Actaea spinosissima*; *a.* whole animal, *b.* outside of hand, *c.* end of walking leg enlarged.

the outside of the hand of *A. flosculata* are replaced in *A. spinosissima* by sharp thorns, and the teeth on the apposed edges of the fingers are less stout."

Length: 4 mm. Breadth: 5·2 mm. Colour in spirit: white.

Dredged in Mahlos Atoll, in 23 fathoms.

43. *Actaea perspinosa*, n. sp. (Fig. 56).

Diagnosis: "An *Actaea* nearly akin to *A. flosculata*, but differing from it in that, in place of the characteristic petaloid spines of the latter species, it is covered with stout, sharp thorns of an entirely different shape."

From *A. spinosissima* it differs in the points indicated above, and from *A. acantha* A.-M. Edw., 1861, and *A. hystrix* Miers, 1886, in the greater size and smaller number of the spines.

Length: 4 mm. Breadth: 5·5 mm. Colour in spirit: pure white.

Dredged in Miladumadulu Atoll in 25 fathoms.

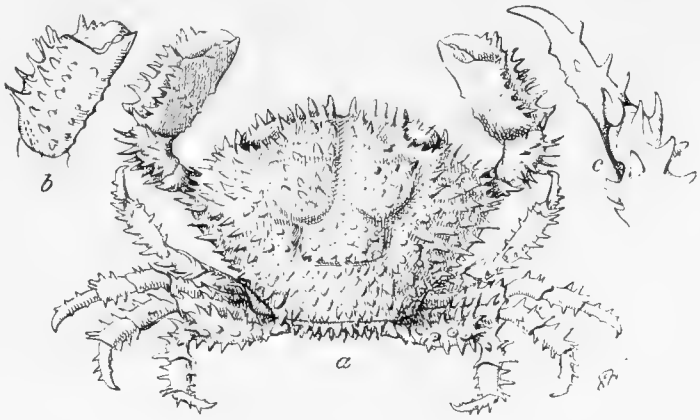

FIG. 56. *Actaea perspinosa*; *a.* whole animal, *b.* outside of hand, *c.* end of walking leg enlarged.

44. *Actaea fossulata* (Girard), 1859. Alcock, III. p. 148. (Fig. 41 *A.*)

The bridge across the hollow on the carpopodites of the walking legs is not always to be found.

Taken on the reef at Hulule, Male Atoll, and in Funadu Velu, Miladumadulu.

45. *Actaea cavipes* (Dana), 1852. Alcock, III. p. 147.
Dredged in the lagoon at Minikoi, in 7—9 fathoms.

Genus *Daira* de Haan, 1833.

46. *Daira perlata* (Hbst.), 1790. Alcock, III. p. 155.
Taken on the shore in Minikoi and Goifurfehendu Atolls.

Genus *Lophozozymus* A. M.-Edw., 1863.

47. *Lophozozymus dodone* (Hbst.), 1801. Alcock, III. p. 108.
Dredged in 4 fathoms in Male Atoll.

Genus *Zozimus* Leach, 1818.

48. *Zozimus aeneus* (Linn.), 1764. Alcock, III. p. 164.
Taken on the shore in Male and Minikoi Atolls.

Genus *Lophactaea* A. M.-Edw., 1862.

49. *Lophactaea anaglypta* (Heller), 1861. Alcock, III. p. 102.
Taken on the reef at Hulule, Male Atoll.

50. *Lophactaea cristata* A. M.-Edw., 1865. Alcock, III. p. 100.
Taken in Funadu Velu, Miladumadulu Atoll.

51. *Lophactaea fissa* Henderson (1893). Alcock, III. p. 103.

Alcock seems to have overlooked the fact that, besides the wide gaps in the side edge of the carapace, this species is separated from *L. granulosa* by the presence of a thick coating of long yellow hairs. No doubt because this coating hides the granules of the carapace it is not shown in Henderson's figure (*Tr. Linn. Soc. Zool.* 2. v., pl. XXXV. fig. 8), though he describes it.

Taken on the reef at Goidu, Goifurfehendu Atoll.

52. *Lophactaea granulosa* (Rüppell), 1830. Alcock, III. p. 101.
Dredged in Felidu and South Male Atolls.

53. *Lophactaea semigranosa* (Heller), 1861. Alcock, III. p. 101.
Taken in Funadu Velu, Miladumadulu Atoll.

Genus *Atergatis* de Haan, 1833.

54. *Atergatis floridus* (Rumph). Alcock, III. p. 98.
Taken on the reef at Hulule, Male Atoll, under stones.

Subfamily **Carpilinae.**

Genus *Phymodius* A. M.-Edw., 1863.

55. *Phymodius ungulatus* (H. M.-Edw.), 1834.

Phymodius ungulatus, Ortmann, *Zool. Jahrb. Syst.* VII. p. 464 (1893); Alcock, III. p. 162 (1898).

Phymodius monticulosus, Alcock, III. p. 163 (1898).

I am quite unable to distinguish between these species, or to assign my specimens to either of them rather than to the other. All the characters vary, as it seems independently, and the descriptions given by several authors do not always agree. Until examination of a long series of full-grown males have shown whether there exist varieties corresponding to the above two names, and if so exactly in what points they differ, I prefer to follow Ortmann in joining the species absolutely, without keeping varietal names.

These crabs, which were taken on the reef in Hulule and Goifurfehendu Atolls and in lagoons in 3—7 fathoms in Minikoi and Miladumadulu Atolls, live in coral stocks and under stones.

56. *Phymodius sculptus* (A. M.-Edw.), 1873. Alcock, III. p. 164.

Taken on the reef in Male and Goifurfehendu Atolls.

Genus *Chlorodius* H. M.-Edw., 1834.

The members of this genus are often found in coral stocks.

57. *Chlorodius laevissimus* Dana, 1852. Alcock, III. p. 161.

In one specimen the teeth on the inner side of the fingers are wanting in the small chela and obsolescent in the large. The colour of many specimens is yellow, rather than white.

Taken on the reef in Goidu and Fadifolu Atolls, and dredged in South Nilandu and Mahlos Atolls in 22—25 fathoms.

58. *Chlorodius barbatus* Borradaile, 1900. (Fig. 41 *D.*)

Chlorodius barbatus, Borradaile, *Proc. Zool. Soc.* 1900, p. 587, pl. XLI. fig. 4 (1900).

Taken on the reef, and in lagoons down to 9 fathoms, in Minikoi, Goifurfehendu, and Miladumadulu Atolls.

59. *Chlorodius niger* (Forsk.), 1775. Alcock, III. p. 160.

Taken in Male, Fadifolu, Goifurfehendu, Felidu, North Male, and Minikoi Atolls on the reef and in lagoons down to 25 fathoms.

Genus *Euxanthus* Dana, 1851.

60. *Euxanthus exsculptus* (Hbst.), 1790; var. *rugosus* Miers 1884. (Fig. 41 *C.*)

Euxanthus melissa, Alcock, III. p. 110.

Since Miers speaks of a specimen of some size, it is likely that this is at least a variety,

and not merely a young form. I am inclined to think that it will prove to be a distinct species. The specimen before me measures 14 mm. in length and 21 in breadth. The brown colour of the fingers does not spread over the palm. Taken on the reef at Hulule, Male Atoll.

Genus *Carpilodes* Dana, 1851.

61. *Carpilodes stimpsoni*, A. M.-Edw., 1865. Alcock, III. p. 82.

Taken on the reef at Goidu, Goifurfehendu Atoll.

62. ? *Carpilodes pediger* Alc., 1898. Alcock, III. p. 83.

Two small male specimens in the collection may either be the young of this species or belong to *C. ruber*. The colour is that of *C. pediger*. They were dredged in Miladumadulu and Fadifolu Atolls in 20 and 23 fathoms respectively.

63. *Carpilodes ruber* A. M.-Edw., 1865.

Carpilodes ruber, A. Milne-Edwards, *Norw. Arch. Mus.* p. 228, pl. XI. fig. 4 (1865).

Dredged in 25 fathoms in South Nilandu Atoll.

64. *Carpilodes vaillantianus* (A. M.-Edw.), 1862. Alcock, III. p. 85.

Taken on the reef in Male and Goifurfehendu Atolls, in Funadu Velu, Miladumadulu, and in Minikoi lagoon. In the latter locality a specimen was found among the leaflets of the *Halimeda*-weed, where its bright red colour could not be in the least protective.

65. *Carpilodes monticulosus* A. M.-Edw., 1873. Alcock, III. p. 86.

This species, which lives under stones, was taken on the reef at Male, Goifurfehendu, and Minikoi Atolls.

66. *Carpilodes pallidus* Borradaile, 1900.

Carpilodes pallidus, Borradaile, *Proc. Zool. Soc.* 1900, p. 586, pl. XL. fig. 1.

This species is allied to *C. monticulosus* and to *C. cariosus*. It differs from the former in that: (1) There is no narrow transverse ridge behind the mesogastric lobule. (2) The furrows of the carapace are not so deep. (3) The colouring is quite different.

From *C. cariosus* it differs in that: (1) The lobules are not pitted, and the carapace has therefore not a worm-eaten appearance. (2) There is no transverse ridge behind the mesogastric lobule, and the branchial lobules are not broken up into smaller ones. (3) The furrows between the lobules are rather shallow. (4) Counting the groove which marks off the mesogastric lobule and that which runs within the hinder edge, there are altogether three grooves behind the lobule in question, but the middle of the three is shallow, and may consist of two separate dimples, hardly connected across the middle line. (5) The notch between the first two lobules of the edge may be rather indistinct. (6) The pink colour of the legs does not tend to orange (as in most of my specimens of *C. cariosus*), and even in the most brightly coloured specimens there is no trace of colour on the carapace.

Taken on the reef at Hulule, Male Atoll.

67. *Carpilodes cariosus* Alc., 1898. Alcock, III. p. 86.

The colour in most of my specimens is not pink but orange-yellow[1]. One small male from Miladumadulu, however, exactly agrees with Alcock's description of the colouring, and at the same time differs from the yellow-marked specimens in having less extensive patches of colour on the back, and in that the lobules of its carapace are somewhat more compact and less irregular in shape. It is possible that this is the true *C. cariosus*, while the other specimens belong either to a distinct species or to a variety.

Dredged in Miladumadulu, Suvadiva, Mahlos, Fadifolu, Male, and South Nilandu Atolls, in 20—40 fathoms.

Genus *Carpilius* Desm., 1825.

68. *Carpilius maculatus* (Linn.), 1764. Alcock, III. p. 79.

This species was seen both at Minikoi and in the Maldives. It may be found wedged into holes on the reef, just above low water-mark, exposed to the full force of the surf.

69. *Carpilius convexus* (Forsk.), 1775. Alcock, III. p. 80 (Fig. 41 *B*, 42 *A*).

Taken in Fadifolu, Male, Minikoi and North Male Atolls on the reef and in lagoons down to 35 fathoms.

Subfamily **Etisinae.**

Genus *Chlorodopsis* A. M.-Edw., 1873.

70. *Chlorodopsis spinipes* (Heller), 1861. Alcock, III. p. 169.

Taken on the reef in Male and Minikoi Atolls.

71. *Chlorodopsis woodmasoni* Alc., 1898. Alcock, III. p. 171.

Taken on the reef in Male, Fadifolu and Goifurfehendu Atolls, and dredged in 6 fathoms in Male Atoll.

72. *Chlorodopsis frontalis* (Dana), 1852.

? *Etisodes frontalis*, Dana. *U.S. Expl. Expd. Crust.* I. p. 187, pl. IX. fig. 3 (1852).

[Not *Etisodes frontalis*, Borradaile, *Proc. Zool. Soc.* 1900, p. 588 (1900) = *Leptodius sanguineus* H. M.-Edw., 1834, juv.]

The collection contains specimens of a crab which resembles Dana's species in all but the following points: (1) The forepart of the carapace derives its roughness, not from minute granules, but from minute dimples. (2) The carapace is a little broader than in Dana's figure. (3) The chelipeds are not entirely "unarmed," for the wrist bears two blunt teeth on the inside.

The front and the upper edges of the legs of the last four pairs are finely toothed. The fore edge of the meropodite of the third maxilliped is but slightly hollowed. The length of the carapace is very little more than $\frac{3}{4}$ of the breadth.

I have placed this species in the genus *Chlorodopsis* because the fronto-orbital breadth is a little *more* than half the greatest breadth, and because of the outline of the fore edge of the meropodite of the third maxilliped. The front is not broad enough to justify its being

[1] *C. vailliantianus* also often tends to orange rather than crimson, when preserved in spirit.

placed in the subgenus *Cyclodius*, being *less* than half the breadth of the carapace. In any case the species seems to be a transitional one.

The specimens mentioned under the name of this species in the *P. Z. S.* for 1900 were small individuals of *Leptodius sanguineus*.

Taken on the reef on Male Atoll and dredged in 25 fathoms in South Nilandu Atoll.

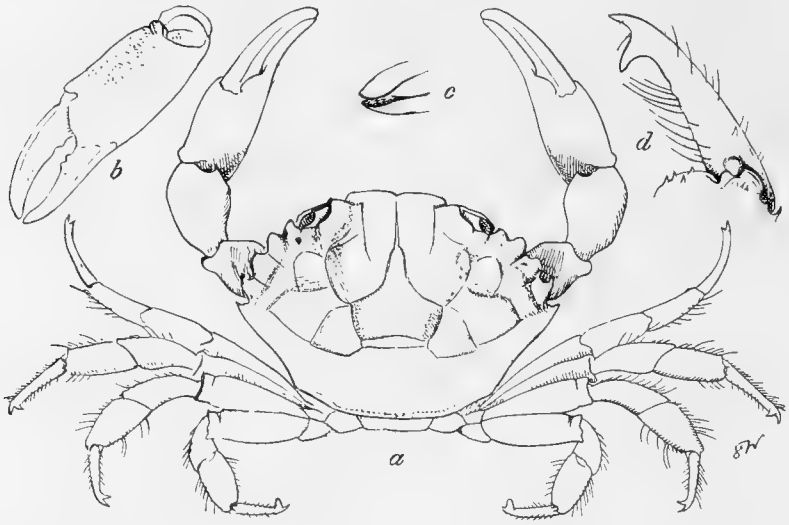

Fig. 57. *Chlorodopsis espinosus*; *a*. whole animal, *b*. outside of hand, *c*. ends of fingers to show hoof-like tips, *d*. end of walking leg enlarged.

73. *Chlorodopsis espinosus*, n. sp. (Fig. 57).

Diagnosis: "A *Chlorodopsis* whose length is just under $\frac{3}{4}$ of the breadth, the carapace hairless, of even surface but minutely granular, areolated as in *C. frontalis* (Dana); the front slightly arched, slightly notched in the middle, with thickened edge; the anterolateral edge with five sharp teeth (including the orbital angle), of which the two hindermost are thorn-like; the hinder edge slightly arched; the orbital gap very narrow, so that the prolongation of the basal joint of the antenna is hard to see; the fore edge of the meropodite of the third maxilliped only slightly concave, with a small projection at its inner end; the chelipeds equal, without tubercles or thorns except one sharp thorn at the inner angle of the wrist, the hand narrow, with a faint groove above and a groove down each finger, the fingers as long as the upper edge of the palm, gaping, with a few sharpish teeth and hoof-like ends; and the walking legs hairy, with spines on the end-joints, and a double end-claw."

Length: 8 mm. Breadth: 12 mm. (Largest specimen.) Colour in spirit: white; the fingers brown with white tips.

This species differs from most *Chlorodopsis* in the absence of spines from the back and chelipeds.

Taken in Funadu Velu, Miladumadulu Atoll.

74. ? *Chlorodopsis* (*Cyclodius*) *ornata* Dana, 1852. Alcock, III. p. 171.

I have assigned several small specimens to this species, but am uncertain whether they are not really the young of *Phymodius ungulatus*. They agree with Alcock's definition, except

in that the basal joint of the antenna does not fill the orbital gap, though the flagellum is not placed at its apex, a small process extending inwards towards the orbit as shown in Dana's figure (*U. S. Expl. Expd. Crust. Atlas*, Pl. XII. figs. 11 c, 11 d).

Taken on the reef in Male, Goifurfehendu and South Mahlos Atolls.

Genus *Etisodes* Dana, 1851.

75. *Etisodes anaglyptus* (H. M.-Edw.), 1834. Alcock, III. p. 133.

Taken on the reef in Goifurfehendu Atoll and dredged in 3—9 fathoms in Minikoi lagoon.

76. *Etisodes electra* (Hbst.), 1801. Alcock, III. p. 133.

In young specimens the lobes of the front are shorter, and not so equal as in old individuals, the middle lobes being distinctly broader than the outer. I doubt the specific distinctness of this form from *E. anaglypta.*

Taken on reefs and in lagoons in Male, Goifurfehendu, Miladumadulu, Fadifolu and Minikoi Atolls.

Genus *Etisus* H. M.-Edw., 1834.

77. *Etisus laevimanus* Randall, 1839. Alcock, III. p. 131.

Alcock quotes only figures 1 a—b on Dana's plate X., seeming thus to exclude figs. 1 f—h, which Dana labels as young females of the same species. My specimen, a female, exactly resembles these latter figures.

Taken on the reef at Hulule, Male Atoll.

Subfamily **Eriphiinae.**

Genus *Domecia* Eyd. and Soul., 1841.

78. *Domecia hispida* Eyd. and Soul., 1841 var.? (Fig. 41 e.) See Alcock, III. p. 230.

My specimens agree with the figures and descriptions of *D. hispida*, but have no hairs on the carapace.

This is a true coral crab, like *Trapezia* and *Melia,* and lives among the branches of living corals. It was taken on the reef at Goidu, Goifurfehendu Atoll, and seen also in Minikoi.

Genus *Eriphia* Latr., 1817.

79. *Eriphia laevimana* Latr., 1817. Alcock, III. p. 214.

This species, which was taken at Minikoi, lives in holes in the rocks and is rather active in its movements.

80. *Eriphia scabricula* Dana, 1852. Alcock, III. p. 216.

Taken on the reef in Minikoi and Addu Atolls. Lives under stones and in coral stocks.

Subfamily **Trapeziinae.**

This group of little, square-bodied crabs, with a broad front and a smooth, usually polished, cuticle (Figs. 41 f, 56), is very characteristic of the Indopacific region, to which its members

are restricted, and within which they are everywhere abundant on coral reefs. They find shelter on various sessile animals, especially branched corals, from which they are usually not to be dislodged except by breaking up the stock, and it is very remarkable that they are found only on living corals, and in these only on those branches which are still alive. Yet they do not eat or in any way damage their host, contenting themselves with deriving protection from its stinging-cells[1]. In correspondence with this habitat, their legs are rather slender, and have end-joints which can be moved through a considerable arc, so as to form with the next joint a kind of hook, serviceable for grappling the branches of the host. These end-joints (Figs. 42 *B*, 58 *c*) are remarkable and interesting structures when the habitat of the crabs is borne in mind. Besides the peculiar flange working on the joint before, which has been described above on p. 242, and is probably an adaptation to clambering, there are several other modifications, which seem intended to give the animals a better foothold on the rugged and yet slimy surface of the coral. Thus the joint is covered with hairs, and among these are a number of stout, moveable prickles. The claw at the end of the joint is bent sharply forming a hook, and is smooth and pointed in *Quadrella*, while in *Trapezia* it is broad and shovel-like, and bears above two rows of structures resembling the prickles but rounded at the end. It is likely that the smoothness of the bodies of these crabs is due to the same cause as that of other semiparasitic Decapods, such as the mussel-prawns and crabs (*Pontonia* and *Pinnotheres*), and that this cause is the need of inconveniencing as little as possible the animals which give them shelter. *Trapezia* and *Tetralia* especially affect corals, but *Quadrella* has been taken on Alcyonarians of various kinds, and even among pearl-mussels[2].

The Trapeziinae are exceptional among Xanthids on account of their tendency to form varieties, and present the feature, unusual in crabs, of definite colour forms. It is possible that some of these forms may be physiological phenomena of the same kind as the colour-phases of prawns[3], but others are associated with structural features, and cannot well be of this nature. It is also important to note that, in *Trapezia*, they bear no relation to the colour of the coral. For the present it were well that none of them were overlooked, and I have therefore revived, in two cases, colour names which had been dropped, without, however, intending any implication as to the nature of the phenomena.

The synonymy of this group is extremely intricate, and the authority followed here is Ortmann, in his late revision [*Zool. Jahrb. Syst.* x. ii. p. 201 (1897)].

Genus *Trapezia* Latr., 1825.

81. *Trapezia ferruginea* Latr., 1825 (Fig. 41 *F*, 42 *B*).

i. Var. *typica* Ortm., 1897, Alcock, III. p. 220.

On reefs and in lagoons down to 35 fathoms in Goifurfehendu, Male, Fadifolu, Addu, Minikoi, South Nilandu, Suvadiva, and South Male Atolls.

ii. Var. *dentata* (Mackay), 1838. Ortmann, *loc. cit.* p. 204.

On reefs at Male, Goifurfehendu and Fadifolu Atolls and in Suvadiva lagoon in 25 fathoms.

[1] I am much obliged both to Mr Stanley Gardiner and to Mr Forster Cooper for information confirming these statements. From first to last a very large number of coral stocks were broken up by the members of the expedition, and in none of these were *Trapezias* found anywhere but among the living branches, nor was there any evidence of damage to the coral caused by them.

[2] Smith, *Proc. Boston Soc. Nat. Hist.* XII. p. 288 (1869).

[3] Gamble and Keeble, *Q. J. M. S.* XLIII. Pt. 4.

iii. Var. *guttata* Rüppell, 1830. Alcock, III. p. 221.

On the reef in Goifurfehendu and in the lagoons of Mahlos, Suvadiva and North Male Atolls down to 25 fathoms.

iv. Var. *maculata* (Mackay), 1838. Alcock, III. p. 221.

On the reefs in Goifurfehendu, Male, Fadifolu and Minikoi Atolls, and in the lagoons at Suvadiva and South Nilandu down to 25 fathoms.

82. *Trapezia cymodoce* (Hbst.), 1801. Alcock, III. p. 219.

The name *T. coerulea* was given by Heller in 1861 to specimens of this species in which the blue tinge, found to a greater or less extent in many individuals, was very conspicuous. The intermediate cases, however, between pure brown examples and those in which blue predominates, are so numerous, and form such a complete series, that it is impossible to keep *coerulea* even as a varietal name.

On reefs and in lagoons down to 35 fathoms in Male, Minikoi, Goifurfehendu, Fadifolu, South Nilandu, Suvadiva and Felidu Atolls.

83. *Trapezia digitalis* Latr., 1825. Ortmann, *loc. cit.*

i. Var. *typica* = *T. digitalis*, Alcock, III. p. 222.

Dark-brown specimens.

Taken on the reef at Goidu, Goifurfehendu Atoll.

ii. Var. *formosa* Smith, 1869. (*Proc Bost. Soc. N. H.* XII. p. 286.)

This variety differs so sharply from the dark-brown true *digitalis* that it seems to deserve a separate varietal name. In structure the variety is like *digitalis*, but it somewhat resembles *T. ferruginea* in the shape of the front. This feature, however, varies considerably in *digitalis*. The earliest name for the orange-coloured form is *formosa* Smith. *T. corallina* Gerstaecker, 1856, is a coral-red crab.

84. *Trapezia rufopunctata* (Hbst.), 1790. Alcock, III. p. 222.

Taken on the reef in Male and Fadifolu Atolls, and in 19 fathoms in South Nilandu lagoon.

Genus *Tetralia* Dana, 1851.

85. *Tetralia glaberrima* (Hbst.), 1790. Alcock, III. p. 223.

The black colouring on the front of this species varies in breadth from an almost imperceptible line, through bands of greater breadth, to a suffusion of the whole carapace and limbs with dark coloration, and no purpose would be served by keeping Dana's name *nigrifrons*. But the colouring of the legs will, I think, be found to fall into definite varieties. The walking legs, in short, may be either: (1) Uniformly yellow. (2) Uniformly dark brown. (3) Yellow banded with dark brown across the middle of each joint. (4) Yellow with a sharp black spot at the end of the meropodites and propodites. (5) Yellow with narrow brown longitudinal stripes.

An examination of a long series of specimens would probably give interesting results.

Taken on reefs and in lagoons down to 35 fathoms in Goifurfehendu, Fadifolu, Male, Felidu, and Minikoi Atolls.

Genus *Quadrella* Dana, 1851.

86. *Quadrella coronata* Dana, 1852. Var. *granulosa* n. See Alcock, III. p. 266.

All the specimens of *Quadrella coronata* in the collection belong to a new variety, which differs from the type in the following features: (1) The carapace is distinctly broader than long. (2) The chelipeds are only about $2\frac{1}{2}$ times as long as the carapace. (3) The chelipeds are frosted over with tiny granules set in short rows athwart the limb. On the underside of the hand the granules are less regular in arrangement, and, projecting in profile, give the inner (lower) edge of the hand an irregular, fine denticulation. (4) The colour in spirit is a uniform pale flesh-colour, purplish in places.

By the first three of these features the new variety is allied to var. *maculosa* Alc., but it differs from that variety in the following points: (1) The fore edge of the arm is not serrate, but bears about ten long thorns. (2) The coloration in spirit is different.

The following key shows the principal characters which separate the known varieties of *Q. coronata*:

I. Carapace as long as broad. Chelipeds polished. Colour in spirit uniform milk-white. [Fore edge of arm spined. Chelipeds $2\frac{3}{4}$ times the length of the carapace.]

Var. A, *type* Dana, 1851.

II. Carapace broader than long. Chelipeds more or less frosted over with granules. More or less colour on the body.

A. Fore edge of arm spined. Colour in spirit uniform pale flesh-colour. [Chelipeds $2\frac{1}{2}$ times the length of the carapace.]

Var. B, *granulosa* n.

B. Fore edge of arm serrate or finely denticulate. Colour arranged in a pattern.

i. Fore edge of arm serrate. Chelipeds $2\frac{1}{2}$ times the length of the carapace. Colour in a network of fine lines.

Var. C, *reticulata* Alc., 1898.

ii. Fore edge of arm finely denticulate. Chelipeds $2\frac{3}{4}$ times the length of the carapace (?). Colour in tiny purple dots.

Var. D, *maculata* Alc., 1898.

Var. *granulosa* was taken on a Gorgonacean dredged in 39 fathoms in Suvadiva Atoll and on a red Alcyonarian dredged in 25 fathoms in the same Atoll, and was dredged in 23 fathoms in Mahlos Atoll.

87. *Quadrella bispinosa*, n. sp. (Fig. 58.)

Diagnosis: "A *Quadrella* which is near akin to *Q. coronata* but differs from it in the following points: (1) The carapace is distinctly broader than long. (2) There is a spine on the anterolateral edge of the carapace, rather farther from the spine at the outer angle of

the orbit than from that which marks the junction of the antero- and postero-lateral edges, and rather smaller than the latter spine. (3) The upper, inner angle of the orbit is not spiniform, but is somewhat raised. The minute teeth which edge both the upper and lower rims of the orbit are, on this angle, increased in size and set farther apart, so that one or two of them can just be seen with the naked eye. (4) The chelipeds are frosted over with tiny granules as in some varieties of *Q. coronata*. The granules are somewhat larger underneath the hand. (5) The arm is rather shorter than in *Q. coronata*. (6) There are few thorns on the end-joints of the legs, but these joints are very hairy. (7) The colour in spirit is a rich orange-brown, paler on the walking legs and fingers.

A female with eggs was dredged in 25 fathoms in Addu Atoll.

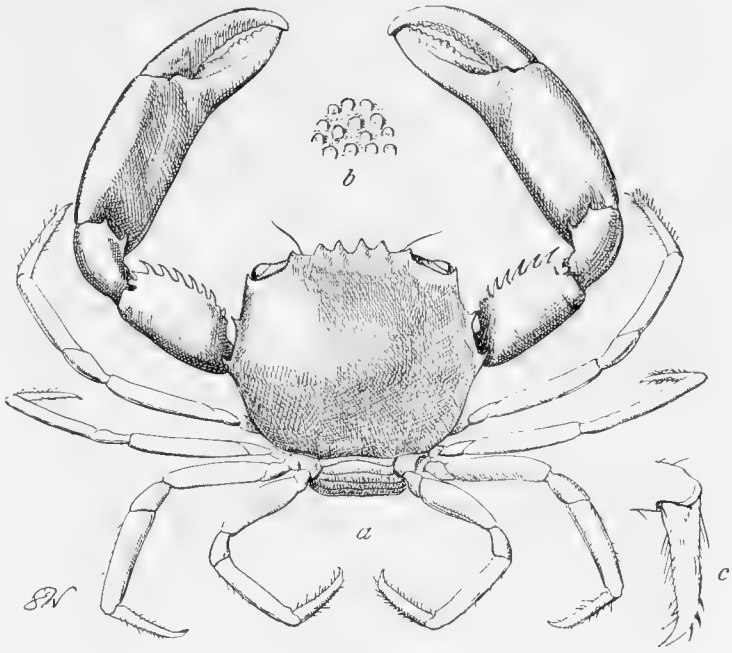

FIG. 58. *Quadrella bispinosa*; *a*. whole animal, *b*. part of outside of hand enlarged to show the scales, *c*. end of walking leg enlarged.

Subfamily **Oziinae.**

It is somewhat remarkable that the collection contains no example of this subfamily, whose genera (*Ozius*, *Epixanthus*, *Euruppellia* and *Baptozius*) contain several very common species which have been recorded from surrounding localities such as India, Ceylon, the Red Sea, and the Seychelles. Both Alcock (*loc. cit.*) and Ortmann (*Zool. Jahrb. Syst.* VII.) occasionally report species from the Maldives or Laccadives, but neither of them mentions a member of the Oziinae from those islands.

Genera *incertae sedis.*

Genus *Caecopilumnus*, n.

Among the decapods taken on the reef at Naifaro in Fadifolu Atoll is a small, *Pilumnus*-like crab whose orbital region has undergone a remarkable transformation, so that the animal appears to be absolutely blind. In a few words, this transformation consists in the orbits becoming very small, almost on the underside of the carapace, and completely filled by the eyestalks, while the small cornea lies on the underside of the stalk and is hidden in the orbit, so that the outline of the body is quite unbroken over the area where the open orbit should lie.

I propose to establish for this crab a new genus, under the name of *Caecopilumnus*, with the following characters: (1) *Carapace* roughly square, convex both fore and aft and from

side to side, hairy, and granular. (2) *Front* narrow, triangular with rounded apex, hollowed and grooved above. Front-orbital breadth small. (3) *Anterolateral edge* irregularly set with small spines, passing evenly into posterolateral, without orbital angle. (4) *Orbits* small, completely filled by eyestalks, not closed. (5) *Eyes* with relatively large end-joint but small cornea, which is on the underside at the free end. The upper side is granular and hairy like the carapace, but the underside is smooth and its cuticle transparent. (6) *Antennae* with rather

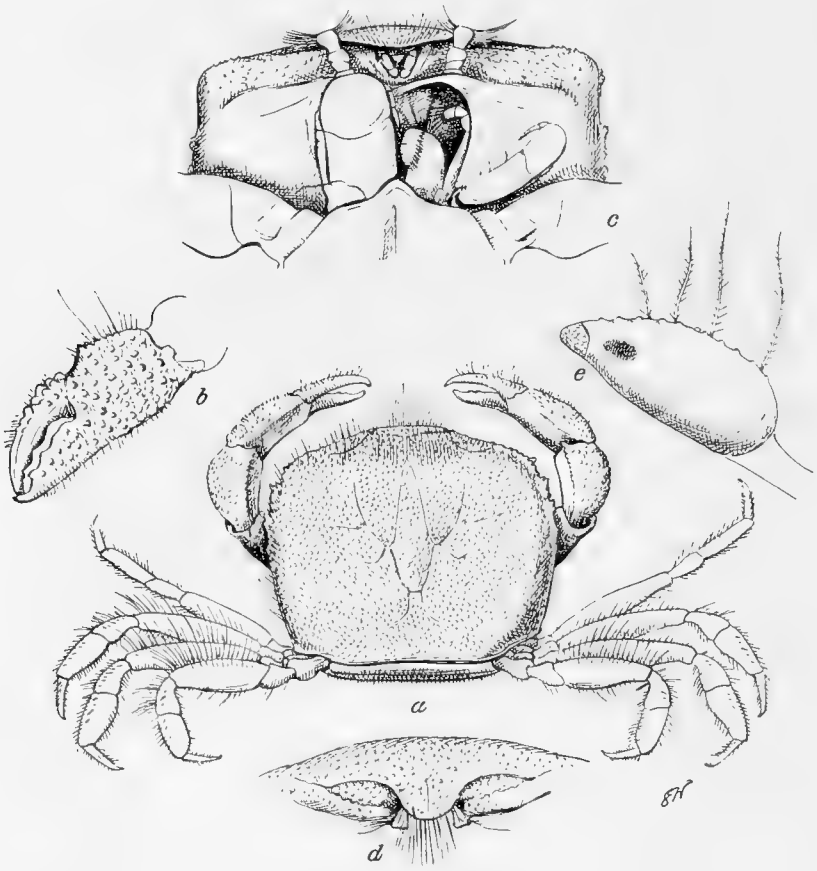

Fig. 59. *Caecopilumnus hirsutus*; *a.* whole animal, *b.* outside of hand, *c.* view of underside with roof of mouth laid bare, *d.* front view to show orbits closed by eyestalks, *e.* underside of eye enlarged, showing small cornea and mass of pigment within stalk. The hairs have been taken off the right side of the body.

broad basal joints, which do not completely fill the orbital gap. (7) *Third maxillipeds* with broad, squarish ischiopodite and meropodite, the latter having its fore edge rounded, and narrow exopodite. The carpopodite is attached distally to the meropodite. (8) *Endostome ridges* present and distinct, but not reaching the fore edge of the mouth. (9) *Chelipeds* equal, granular, with pointed fingers. (10) *Walking* legs stout and of moderate length.

The single specimen being a female, it is impossible to describe the characters of the male.

As to the habits, nothing is known, save that the crab was taken on the reef. There is nothing in its appearance to suggest a parasitic existence except the reduction of its eyes. Probably the peculiar conformation of the orbits is due to some circumstance which makes it

necessary to guard against the entrance of foreign bodies or enemies. Whether the eyestalks can be raised, upon occasion, so that the small eyes are exposed, it is impossible to say, but in the spirit specimen they are certainly so firmly fixed that they cannot be moved without breaking the carapace. The specimen is not well enough preserved to allow of statements being made as to the retina, but a small mass of pigment can be seen through the transparent underside of the eyestalk, at some distance from the cornea.

The systematic position of the genus is doubtful, especially in view of the fact that the male is not known. If it belong to the Xanthidae, it is perhaps more closely related to the Menippinae than to any other subfamily, but it may quite possibly be a Catometope allied to the Rhizopinae, and especially to the species which Miers referred doubtfully to *Typhlocarcinus* under the name *T. integrifrons* [*Ann. Mag. N. H.* (5), VIII. p. 260 (1881)].

1. *Caecopilumnus hirsutus*, n. sp. (Fig. 59).

Diagnosis: "A *Caecopilumnus* with the carapace moderately convex from side to side, strongly so fore and aft, granular and pubescent all over, the front strongly bent downwards, its sides sloping inwards to a groove in the middle, fringed with long hairs, which are also found all over the orbital region and eyestalks and along the sides of the carapace; the orbit very small, without orbital tooth or spine or notches in the rim; the anterolateral edge passing with an even sweep into the posterolateral behind, and in front fading away at a point behind and above the outer angle of the orbit, which thus comes to lie to a great extent on the underside of the body; the granules of the carapace enlarged along the anterolateral edge into small spines, arranged in four irregular sets; the hinder edge hollowed; the regions rather faintly marked; the eyestalks large relative to the orbits, which they entirely fill, fitting close against the thin, non-prominent rims, and thus complete the outline of the carapace, simulating the carapace in their granulation and hairs; cornea small and hidden on the underside of the eyestalk; chelipeds equal, granular, pubescent and hairy, these features extending to the fingers, the fingers compressed and grooved, with interlocking teeth on their apposed edges, and sharp, crossing tips; and walking legs of moderate length, very stout, especially the second and third, which have very long propodites, covered with long hairs but without spines."

Length: 8 mm. Breadth: 9 mm. Colour in spirit: white.

Genus *Maldivia*.

A white Gorgonacean, dredged in eight fathoms of water, in North Male, bore a minute but very interesting symbiotic crab, whose peculiarities justify the setting up of a new genus for it. The following are the characters of this genus: (1) *Carapace* hexagonal, swollen, a little longer than broad, hairless, roughened with granulations which pass into spines at the sides, and with indications of the regions. (2) *Front* broad, triangular, widely grooved, bent strongly downwards. (3) *Anterolateral edge* toothed, about equal to posterolateral. *Hind edge* wavy. (4) *Orbits* large, very slanting, not fully closed. (5) *Abdomen* of male seven-jointed. (6) *Endostome ridges* present, but not very strong. (7) *Eyes* large. (8) *Antennae* with slender basal joints which do not touch the front, and long flagella. (9) *Merus of third maxilliped* about as long as broad, without a notch in the fore edge, which is straight. (10) *Chelipeds* stout, *Pilumnus*-like, fingers not hollowed at the tip. (11) *Walking* legs moderately stout.

The genus resembles *Pilumnus* in the shape of the hands and the endostomial ridges.

The form of the carapace, the presence of endostomial ridges and the symbiotic habits recall *Quadrella*. The front and the spinate region at the side of the granulated carapace, and again the endostomial ridges, show a certain resemblance to *Caecopilumnus* described above, though the eyes and orbits are very different. The form of the antennae points to its true position being among the Menippinae, perhaps in the neighbourhood of *Pilumnus*.

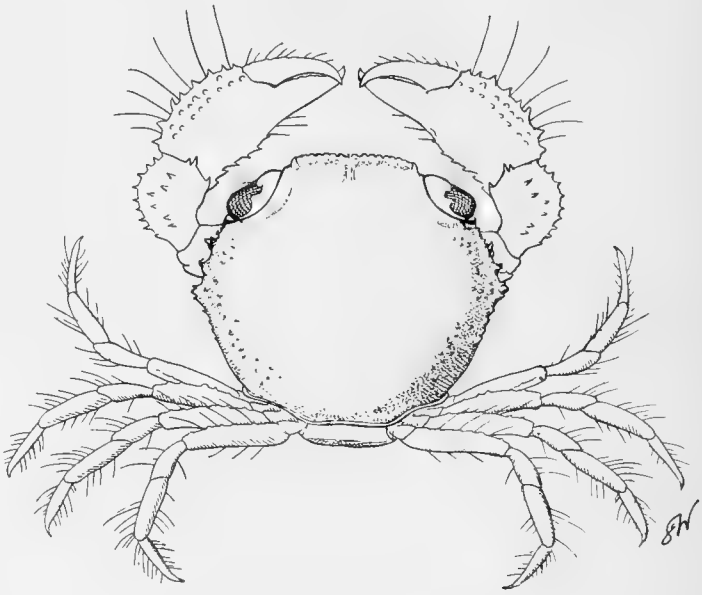

Fig. 60. *Maldivia symbiotica*, found on a gorgonian, whole animal greatly enlarged.

2. *Maldivia symbiotica*, n. sp. (Fig. 60).

Diagnosis: "A *Maldivia* whose carapace is roughened with small tubercles, which in places, as on the anterolateral edge, pass into spines; the latter edge with four lobes, including the orbital lobe, each lobe bearing several spines, of which one is larger than the rest, while the lobes decrease in size from behind forwards; the chelipeds equal, bearing on the outside spines set in rows, a row along the upper edge being specially long, the fingers shorter than the hand; the walking legs moderately stout, bearing some long hairs."

Length: 1·5 mm. Breadth: 1·6 mm. Colour in spirit: white.

Family **Atelecyclidae.**

Subfamily **Thiinae.**

Genus *Kraussia* Dana, 1852.

1. *Kraussia rugulosa* (Krauss), 1843.

Kraussia rugulosa, Dana, *U.S. Expl. Expd. Crust.* p. 302, pl. 19, fig. 1 (1852).

Taken on the reef in Male, Goifurfehendu and Minikoi Atolls.

2. *Kraussia integra* (de Haan), 1837. Alcock, IV. p. 97.

A small specimen from Mahlos Atoll shows characters which recall *K. nitida* Stimps., 1858, in that the frontal lobes are subdivided, though not so deeply as in Stimpson's species, and the carapace is somewhat narrower than in adult specimens of *K. integra*. The teeth on the dactylopodites of the legs are small.

Taken on the reef in Male and dredged in 24 fathoms in Mahlos Atoll.

Family **Hapalocarcinidae.**

This interesting little family of symbiotic crabs, of which, in one case, only the females are known, is, as Calman has shown [*Tr. Linn. Soc. Zool.* (2), VIII. p. 43 (1900)], quite *incertae sedis*, and is taken here for convenience alone, and not on account of any relationship to the Xanthidae. It is discussed at length in Calman's paper. For some remarks on the importance of these crabs as affording by their holes a foothold for destructive boring organisms in the coral blocks, see a paper by Mr Stanley Gardiner in this part of the present publication.

Genus *Hapalocarcinus* Stimps., 1857.

1. *Hapalocarcinus marsupialis* Stimps., 1857. Calman, *loc. cit.*

Galls containing specimens of this crab were found on *Pocillopora* in the lagoon at Minikoi and on the reef at Hulule, Male Atoll.

Genus *Cryptochirus* Heller, 1861.

2. *Cryptochirus coralliodytes* Heller, 1861.

Cryptochirus coralliodytes, Heller, *S. B. Ak. Wiss. Wien*, XLIII. i. p. 366, pl. II. figs. 33—39 (1861); Semper, *Animal Life*, London, 1881, pp. 217, 221—223; Calman, *loc. cit.* p. 47.

Mr Stanley Gardiner has kindly given me the following note on this species: "A block of *Leptoria tenuis* which had a large number of round holes on the surface, up to 4 mm. across, was broken up. The holes, when traced in, were nearly all found to be occupied by a symbiotic crab [*Cryptochirus*]. In two holes, however, were crabs of the ordinary form [*Pseudozius*, see above, p. 241]. The holes varied in depth from 1—30 mm., the coral itself being in the latter position 48 mm. thick. Normally the animal would appear to live close to the surface—some slightly projected, with the carapace as a kind of shield closing the hole. When the block becomes more or less dry, they retreat into the bottom of the holes. I found some deserted holes, perhaps due to an accident in breaking the coral, but the crabs certainly could not wander, on account of the small size of the entrances of the holes. It is obvious that the crab must have taken up its abode on the coral, which afterwards enclosed it. [This refers to the inner hole, not to the funnel round it.] These commensals are extremely common in *Leptoria* from the lagoon at Minikoi, but are never found in specimens from the outer reef. They are rare on other corals, occasionally occurring in massive astraeids from the lagoon at Minikoi, but not apparently in branching corals, fungoids, or perforate corals."

ON THE FISHES FROM THE MALDIVE ISLANDS.

I. DREDGED. II. FRESH-WATER.

By C. TATE REGAN, B.A., *Assistant at the Natural History Museum, S. Kensington.*

The Collection of Fishes from the Maldive Islands has been divided into two series. The first consists of the specimens dredged or trawled within the lagoons of the atolls. The second contains a few specimens taken from fresh-water pools on some of the islands.

The use of formalin as a preservative has rendered the fin rays very brittle, so that in most of the specimens the fins are more or less damaged.

I take this opportunity of gratefully acknowledging my indebtedness to Mr Boulenger, who has very kindly looked through the collection under notice, and confirmed my identifications.

I. DREDGED FISHES FROM WITHIN THE LAGOONS.

There are 321 specimens, belonging to 65 species. They are mostly small, the lagoons probably being nurseries for young fish. This has made identification a very difficult matter in many cases, so that some specimens have been referred only to their genus, and many, which seem without doubt to belong to hitherto undescribed species, have been only briefly described, and have not been given specific names.

A list of the species follows. For convenience of reference I have kept to the arrangement of families in Günther's *Study of Fishes.*

ACANTHOPTERYGII.

Fam. **Percidae.**

1. *Apogon auritus,* C. and V. Suvadiva, 44*f.* (fathoms).

2. *Apogon elliotti,* Day. (*Apogon nigripinnis,* Gthr. (Part); *Apogon arafurae,* Gthr.)

Günther identified specimens belonging to this species with *Apogon nigripinnis,* C. and V., and later described a somewhat large specimen from the Challenger Collection as a new species.

Apogon arafurae[1]: Day distinguishes between this species and *Apogon nigripinnis*, C. and V., from which it differs in many important characters.

In the specimens in the British Museum Collection, and in those from the Maldives, the length of the snout is $\frac{2}{3}$ to $\frac{3}{4}$ of the diameter of the eye, and in the Challenger specimen, described as *Apogon arafurae*, the eye diameter is equal to the length of the snout, which is contained 4 times in the length of the head, this being due to the fact that the eyes become relatively smaller in larger fish. Day's statement that the length of the snout is $\frac{1}{2}$ the diameter of the eye is probably, therefore, inaccurate.

Suvadiva, 44 *f.*, and Mulaku, 27 *f.*

3. *Apogon nigripinnis*, C. and V. Haddumati, 40 *f.*

A male fish, 47 mm. in total length, had its mouth full of eggs; and a specimen in the British Museum Collection shows the same phenomenon, which is, no doubt, a case of protection by the parent.

4. *Apogon septemstriatus*, Gthr. S. Nilandu, 36 and 30 *f.*

5. *Apogon fasciatus*, White. S. Nilandu, 30 *f.*

6. *Apogon* sp. N. Male, 35 *f.*

D. VII, 19; A. II, 8; L. lat. about 25.

This species is represented by two very small specimens, each 15 mm. in total length. The head is nearly half the total length. The body is dark brown, with a black band at the base of the dorsal, and a broad black longitudinal band ventrally. They cannot with certainty be said to belong to a hitherto undescribed species.

7. *Anthias cooperi*, n. sp.

D. x, 16; A. III, 7; Sc. 52, $\frac{3}{15}$; L. lat. 50.

Depth of body three times in total length, length of head $3\frac{1}{3}$ times. Snout scaly, shorter than the eye, the diameter of which is slightly greater than the interorbital width, and is contained three times in the length of the head. Lower jaw slightly projecting, scaly. Maxillary scaly, extending to below the centre of the eye, the width of its extremity $\frac{2}{3}$ the diameter of the eye. Two or three spines at the angle of the preopercle; sub- and interopercle serrated; two opercular spines. Dorsal spines increasing in length to the fourth, rest subequal; no notch between spinous and soft portions; base scaly. Ventrals a little longer than the pectorals, not quite so long as the head. Anal spines strong, the first shortest, the second longer than the third; soft portion scaly at the base, pointed, the third ray longest. Caudal moderately emarginate. Caudal peduncle as long as deep. Lateral line curved. Coloration uniform, in spirit.

This species is allied to *Anthias cichlops*, *squamipinnis* and *townsendi*, from all of which it differs in having more numerous scales, and in having spines at the angle of the preopercle; in this latter feature it resembles *Anthias formosus* and *margaritaceus*, from which it differs in the important character of having the lateral line curved, not forming an angle below the hinder dorsal rays. Length of the specimen, 47 mm.

Haddumati, 40 *f.*

[1] Day, *Fishes of India*, I. pp. 60 and 63.

8. *Epinephelus sexfasciatus*, C. and V.

Three specimens less than 30 mm. in total length have a prominent spine at the angle of the preopercle, equal in length to ½ the diameter of the eye. A somewhat larger specimen, 48 mm. long, has the normal adult arrangement.

Haddumati, 35 *f.*

Fam. **Mullidae.**

9. *Upenoides tragula*, Richardson. Mulaku, 27 *f.*

Fam. **Cirrhitidae.**

10. *Cirrhitichthys oxycephalus*, Blkr. Haddumati, 40 *f.*

Fam. **Scorpaenidae.**

11. *Cocotropus roseus*, Day. N. Male, 35 *f.*

12. *Minous monodactylus*, Bl. Schn. S. Nilandu, 36 *f.* N. Male, 35 *f.*

13. *Pelor didactylum*, Pall. Suvadiva, 30 *f.*

14. *Amblyapistus macracanthus*, Blkr. Suvadiva, 30 *f.*

15. *Pterois zebra*, C. and V. Haddumati, 35 *f.*, and Kolumadulu, 35 *f.*

Fam. **Acanthuridae.**

16. *Naseus* (? *Keris*) sp. Suvadiva, 37 *f.*

D. VI, 29; A. II, 30.

A single specimen, 37 mm. in total length, closely resembles *Keris amboinensis*, Blkr., but differs in having the first dorsal spine longer than the others. Probably, like *Keris amboinensis*, it is the young form of a species of *Naseus*.

Fam. **Trachinidae.**

17. *Percis punctulata*, C. and V. N. Male, 35 *f.*

18. *Champsodon vorax*, Gthr. Suvadiva, 30 *f.*, and Mulaku, 27 *f.*

19. *Percophis* sp.

D. VII or VIII, 30—35; A. 30—35; Sc. 52.

A single badly preserved specimen, 35 mm. in total length, undoubtedly belongs to this genus, which has not before been known to occur in the Indian Ocean, only one species, *Percophis brasilianus*, from the coast of Brazil, having been described.

Depth of body 12 times in the total length, length of head four times. A longitudinal band along the middle of the side. The shape and proportions of the body are exactly the same as in *Percophis brasilianus*, which has, however, much smaller scales.

Kolumadulu, 33 *f.*

Fam. **Pediculati.**

20. *Antennarius nummifer,* Cuv. Haddumati, 35 *f.*

Fam. **Cottidae.**

21. *Platycephalus asper,* C. and V. Mulaku, 27 *f.*, and N. Male, 35 *f.*

22. *Platycephalus tuberculatus,* C. and V. Kolumadulu, 35 *f.*, and Haddumati, 40 *f.*

23. *Platycephlus spinosus,* Schleg. Kolumadulu, 35 *f.*

In this specimen, as in that in the British Museum Collection, the number of scales in a longitudinal series is 33, not 40 as given by Schlegel.

24. *Platycephalus subfasciatus,* Gthr. Mulaku, 27 *f.*

Fam. **Cataphracti.**

25. *Pegasus draconis,* Linn. Haddumati, 40 *f.*

Fam. **Gobiidae.**

26. *Gobius caninoides,* Blkr. Mulaku, 27 *f.*

27. *Gobius ornatus,* Rüpp. S. Nilandu, 36 and 30 *f.*, Felidu, 34 *f.*, Mulaku, 27 *f.*, and Kolumadulu, 33 *f.*

28. *Gobius semidoliatus,* C. and V. N. Male, 35 *f.*

29. *Gobius ophthalmotaenia,* Blkr. S. Nilandu, 36 *f.*, and N. Male, 35 *f.*

30. *Periophthalmus* sp. S. Nilandu, 35 *f.*

One specimen, 33 mm. long. The ventral fins are not united. Probably a young specimen of *Periophthalmus chrysospilos.*

31. *Callionymus longicaudatus,* Schleg. S. Nilandu, 36 and 30 *f.*

32. *Callionymus lunatus,* Schleg. Suvadiva, 44 *f.*, and Haddumati, 40 *f.*

33. *Callionymus* sp. Suvadiva, 37 *f.*

D. IV, 7; A. 6. Length of the head about three times in the total length. Gill opening small, superior. Preopercular spine with four posterior teeth. Eye diameter about three times in the length of the head. Brownish, with darker bands or blotches, and with a series of narrow transverse bands on the gill membranes. The single specimen is 24 mm. in total length, and probably belongs to a hitherto undescribed species.

Fam. **Blenniidae.**

34. *Petroscirtes* sp.

D. 26; A. 16. This fish was dredged at Berriamfuri, N. Mahlos, in the lagoonlet, at a depth of four fathoms, in a Gastropod shell. Mr Gardiner says, "I kept this fish alive for some hours in a basin, it would swim round, always returning to its house. The favourite position was with the head just projecting out of the mouth of the shell."

The specimen is 28 mm. long.

35. *Clinus* sp. Haddumati, 40 *f.*

D. 24; A. 16; V. 1, 3; Sc. 30, 11.

The depth of the body is equal to the length of the head and is contained $3\frac{1}{2}$ times in the total length. Snout shorter than the eye, the diameter of which is twice the interorbital width, and is contained $3\frac{2}{3}$ times in the length of the head. The single specimen is 30 mm. in total length, and probably belongs to a species not before described, and differing from nearly all other species of *Clinus* in the large size of the scales.

ACANTHOPTERYGII PHARYNGOGNATHI.

Fam. **Pomacentridae.**

36. *Dascyllus melanurus*, Blkr. Felidu, 34 *f.*

37. *Amphiprion sebae*, Blkr. S. Nilandu, 30 *f.*, and N. Male, 35 *f.*

38. *Pomacentrus punctatus*, Quoy and Gaim. Suvadiva, 43 *f.*, and Haddumati, 40 *f.*

Fam. **Labridae.**

39. *Labroides dimidiatus*, C. and V. Felidu, 34 *f.*

40. *Julis schwanefeldii*, Blkr. Mulaku, 27 *f.*

41. *Cheilinus* sp. Mulaku, 27 *f.*

Four specimens 28—45 mm. long may be young specimens of *Cheilinus calophthalmus.*

42. *Cheilinus* sp. Mulaku, 27 *f.*, and N. Male, 35 *f.*

Several young specimens less than 30 mm. long may belong to *Cheilinus ceramensis.*

43. *Cheilinus* sp. Suvadiva, 43 *f.*

Two very small specimens may belong to *Cheilinus celebicus.*

ANACANTHINI.

Fam. **Pleuronectidae.**

44. *Rhomboidichthys grandisquamis*, Schleg.

Describing this species[1], Schlegel says, "The pectorals are not elongated. The males have a spine on the maxilla and another on the anterior margin of the lower eye. The interorbital width is equal to the diameter of the eye in the males, and is half the diameter of the eye in females. The body is more elongated in the females."

With regard to these features in the specimens from the Maldives: The pectorals are elongated in some, and not in others, without relation to size or sex. All the males have a maxillary spine, but some are without an antorbital spine. The females have neither spine. The interorbital width varies from $\frac{3}{4}$ to $1\frac{1}{2}$ diameters of the eye in males, and $\frac{1}{3}$ to $\frac{1}{2}$ diameter in females, and, as a rule, the eyes are relatively further apart in the larger specimens. The greatest depth of the body is not more in males than in females, but the eyes being wider

[1] Schleg., *Fauna Japonica, Poiss.*, p. 183.

apart in the former, the head and anterior part of the body is broader, so that the females appear more elongated.

This species is distinguished from *Rhomboidichthys poecilurus*, Blkr., by the absence of a pair of black spots on the caudal, and by the greater size of the maxilla, which is contained $2\frac{2}{3}$ times in the length of the head.

Suvadiva, 44 *f.*, S. Nilandu, 36 and 30 *f.*, Felidu, 34 *f.*, and Mulaku, 27 *f.*

45. *Rhomboidichthys poecilurus*, Blkr. (*Rhomboidichthys grandisquama*, Gthr.; and *Rhomboidichthys spilurus*, Gthr.)

Bleeker, describing this species, gives the number of scales in a longitudinal series as about 45. Günther distinguishes between two species, *Rhomboidichthys grandisquama*, with 40 scales in a longitudinal series, which he identifies with *Rhombus grandisquama*, Schleg., in reality a quite distinct species; and *Rhomboidichthys spilurus*, with 48 scales in a longitudinal series, and the eyes closer together.

In the 13 specimens from the Maldives the scales vary from 40—48 in a longitudinal series, nearly all intermediate numbers being found. The males have a knob on the maxilla, and the interorbital width equal to the diameter of the eye. The females have no maxillary knob, and the interorbital width is about $\frac{1}{2}$ the diameter of the eye. In immature fish the eyes are closer together.

This species is distinguished from *Rhomboidichthys grandisquamis* in that it has a pair of black spots on the caudal, in the middle of the upper and lower margins respectively, and has a smaller mouth, the length of the maxilla being contained $3\frac{1}{3}$ times in the length of the head.

Suvadiva, 44 *f.*, and 34 *f.*

46. *Rhomboidichthys intermedius*, Blkr. Suvadiva, 44 *f.*, and Felidu, 34 *f.*

47. *Rhomboidichthys pantherinus*, Blkr. Suvadiva, 43 *f.*, and S. Nilandu, 36 and 30 *f.*

48. *Brachypleura xanthosticta*, Gthr. Suvadiva, 44 *f.*, and Mulaku, 27 *f.*

49. *Cynoglossus brachycephalus*, Blkr. Mulaku, 27 *f.*

50. *Samaris maculatus*, Gthr. Suvadiva, 45 *f.*

In the Challenger Report this species is described, from one specimen, as having three series of dark spots, five along the dorsal profile, four along the lateral line, and five along the ventral profile. In two small specimens from the Maldives, each 29 mm. in total length, these spots are connected by dark lines, the colour being preserved better.

Samaris cristatus, Gray, differs from *Samaris maculatus* in having a somewhat smaller head and deeper body, and in the elongation of the anterior dorsal rays, but the two specimens in the British Museum Collection have dark spots feebly visible in the same position as in *Samaris maculatus*. These specimens are males, and that named *Samaris maculatus* is a female, and apparently the small specimens from the Maldives are females, so that it seems possible that the differences are not specific, but sexual. The elongation of the anterior dorsal rays is characteristic of the males in the allied genus *Brachypleura*, and in many other fishes of this family.

In *Samaris maculatus* the length of the head is 4 times in the total length, the depth of the body $2\frac{3}{5}$ to 3 times.

In *Samaris cristatus* the length of the head is $4\frac{1}{2}$—5 times in the total length, the depth of the body $2\frac{1}{2}$ times.

51. *Solea poropterus*, Blkr. Mulaku, 27 *f.*

PHYSOSTOMI.

Fam. **Scopelidae.**

52. *Saurus varius*, Lacep. S. Nilandu, 36 *f.* and 30 *f.*, Felidu, 34 *f.*, Kolumadulu, 33 *f.*, and N. Male, 35 *f.*

53. *Saurida nebulosa*, C. and V. S. Nilandu, 36 *f.*, Felidu, 34 *f.*, and N. Male, 35 *f.*

54. *Saurida tumbil*, Bl. Suvadiva, 44 *f.*, Felidu, 34 *f.*, and Kolumadulu, 33 *f.*

LOPHOBRANCHII.

Fam. **Syngnathidae.**

55. *Syngnathus* sp. Haddumati, 35 *f.*

D. 23. Osseous rings 15—16 + 35—40. Length of the head 8 times in the total length. Snout a little shorter than the rest of the head. A bony ridge crosses the opercle. Edges of osseous rings serrated. Dorsal fin commences behind the anus. Brown vertical bands on the body.

Two specimens, each 55 mm. long.

56. *Ichthyocampus belcheri*, Kaup. Suvadiva, 44 *f.*

Fam. **Solenostomidae.**

57. *Solenostoma paradoxum*, Pall. Mulaku, 27 *f.*

Bleeker has described small specimens of a species of *Solenostoma* with a slender snout, in which the caudal peduncle is longer than the base of the second dorsal, and named them *Solenostoma brachyurum*. One of these is in the British Museum Collection. Günther has written in the Museum Catalogue, "Considering that we know nothing of the changes which *Solenostoma* undergoes during its growth, it is to be regretted that Dr Bleeker did not examine these specimens more carefully, but merely attached a new name to them."

The specimen from the Maldives seems undoubtedly of the species *Solenostoma paradoxum*. The snout is more slender and the caudal peduncle relatively longer than in the adult. Probably the badly preserved specimen labelled *Solenostoma brachyurum* in the British Museum Collection also belongs to this species, in which case the changes during growth can be shown thus:

	Total Length	$\frac{\text{Depth of Snout}}{\text{Length of Snout}}$	$\frac{\text{Length of Caudal Peduncle}}{\text{Base of Second Dorsal}}$
(Specimen in Brit. Mus.)	50 mm.	$\frac{1}{9}$	$\frac{2}{1}$
(Maldive specimen)	67 mm.	$\frac{1}{8}$	$\frac{3}{2}$
(Specimen in Brit. Mus.)	97 mm.	$\frac{1}{6}$	$\frac{7}{8}$

PLECTOGNATHI.

Fam. **Sclerodermi.**

58. *Balistes niger*, Mungo Park. Haddumati, 40 *f.*

59. *Monacanthus nasicornis*, Schleg. Suvadiva, 37 *f.*

60. *Monacanthus oculatus*, Gthr. S. Nilandu, 30 *f.*

61. *Monacanthus choirocephalus*, Blkr. Suvadiva, 43 *f.*, and Mulaku, 27 *f.*

62. *Monacanthus* sp. Suvadiva, 45 *f.*

D. 24; A. 24. Dorsal spine barbed. Ventral spine moveable. The specimen is too small for determination of the species.

63. *Ostracion cornutus*, Linn. N. Male, 35 *f.*

The specimen is 24 mm. long, and differs from the adult in having a well-developed spine on the back, in the lesser development of the antorbital and ventral spines, and in having a more projecting snout. A similar specimen in the British Museum Collection is labelled *Ostracion cornutus.*

Fam. **Gymnodontes.**

64. *Tetrodon* sp. S. Nilandu, 36 *f.*

D. 8 or 9; A. 6 or 7. The back is broad, snout equal in length to the diameter of the eye and also to the interorbital width. A simple perforate nasal tentacle on each side. Body covered with three-rooted spines, except on the tail. Purplish brown above, lighter beneath; small brown spots on the back. The single small specimen almost certainly belongs to a hitherto undescribed species.

65. *Tetrodon valentini*, Blkr. Haddumati, 40 *f.*

II. FISHES TAKEN IN FRESH-WATER POOLS.

There are 14 specimens belonging to 6 species, two of which have not been described before. They are mostly marine fishes which are known to ascend estuaries into fresh-water, or are allied to fishes with this habit, only one being a true fresh-water fish. A list of the species follows.

ACANTHOPTERYGII.

Fam. **Percidae.**

1. *Gerres maldivensis*, n. sp.

D. IX. 10, A. III. 8; Sc. $40\frac{4}{10}$.

Depth of body $2\frac{1}{3}$ times in the total length, length of head $2\frac{3}{4}$ times. The length of the snout is equal to the interorbital width and $\frac{3}{4}$ the diameter of the eye, which is contained $2\frac{2}{3}$ times in the length of the head. The maxilla extends to below the first third

of the eye. The caudal peduncle is nearly as high as long. The second dorsal spine is the longest, and is $\frac{2}{3}$ the length of the head; from it they decrease in length to the fifth, the rest subequal. The second anal spine is longer than the third. Pectorals $\frac{4}{5}$ the length of the head. Ventrals do not quite reach the anal. Caudal deeply forked. Light, with indistinct dark vertical streaks. Length of specimen, 73 mm.

Fishes of this genus commonly ascend estuaries into fresh water. A fresh-water pool, surrounded by mangroves, in the centre of Landu, Miladumadulu Atoll.

Fam. **Gobiidae.**

2. *Gobius criniger*, C. and V.

From the lake, Kendikolu, Miladumadulu Atoll.

Fishes of this species are common in backwaters.

Fam. **Mugilidae.**

3. *Mugil coeruleomaculatus*, Lacep.

Fishes of this genus commonly ascend tidal rivers, and a few, but not those of this species, are entirely fresh-water.

From the mangrove lake, Landu, Miladumadulu Atoll.

PHYSOSTOMI.

Fam. **Cyprinidae.**

4. *Barbus vittatus*, Day.

A true fresh-water fish, from the bathing pool, Hulule, Male Atoll, and from the mangrove lake, Landu, Miladumadulu Atoll.

Fam. **Clupeidae.**

5. *Chanos salmoneus*, Bl. Schn.

Fish of this species ascend rivers, and have been introduced and thrive in fresh-water tanks in India. From the lake, Kendikolu, Miladumadulu Atoll.

6. *Chanos gardineri*, n. sp.

D. 14, A. 9; P. 16, V. 11; Sc. 70—$75\frac{11}{15}$.

Depth of body $4\frac{3}{4}$ times in the total length, length of head $3\frac{1}{4}$ times. Snout shorter than the eye, the diameter of which is equal to the interorbital width, and is contained $3\frac{1}{4}$ times in the length of the head. The scales are enlarged on the back just behind the head, and on the abdomen. Dorsal highest in front, the longest ray $\frac{2}{3}$ the length of the head, margin concave, two rows of scales at the base. Pectorals rounded, more than $\frac{1}{2}$ the length of the head. Ventrals rounded, arising beneath the posterior $\frac{1}{3}$ of the base of the dorsal. Anal scaly at the base, margin concave. Caudal deeply forked, its longest ray equal to the length of the head. Caudal peduncle twice as long as high.

The colour is probably similar to that of *Chanos salmoneus*, but owing to preservation of the specimens in formalin this cannot be certainly stated.

The head is much larger, and the body shorter, not so deep, and less compressed than in *Chanos salmoneus.* The scales are less numerous, and the pectorals and ventrals rounded, not pointed. Of all the supposed species of *Chanos* which have been described under various names, and are now generally regarded as varieties of *Chanos salmoneus,* none are found to correspond with this species. Whenever proportional measurements are given the length of the head is described as $\frac{1}{4}$ of the total length without the caudal, or as $5\frac{1}{2}$ times in the total length with the caudal. The depth of the body is never less than $5\frac{1}{2}$ times in the total length, with the caudal. The pectorals are always described as pointed. In some cases the scales are given as less than 80 in a longitudinal series, *i.e.* in *Chanos pala,* Cantor. and *Chanos orientalis,* Blkr., but this is the only point of agreement. Sometimes no characters of specific importance are given, *e.g. Leuciscus zeylonicus,* Bennett.

The conclusion is that this species is very distinct, and has not been described before.

There are three specimens, 116, 104, and 74 mm. in total length, from the north pool of Hulule island, Male Atoll.

THE MARINE TURBELLARIA,

WITH AN ACCOUNT OF THE ANATOMY OF SOME OF THE SPECIES.

By Frank Fortescue Laidlaw, B.A. (Cantab.), *Demonstrator and Lecturer in the Owens College, Manchester.*

(With Plates XIV. and XV. and Text-Figures 61—73.)

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I. SYSTEMATIC LIST, WITH NOTES ON THE ANATOMY OF THE SPECIES.

ACOTYLEA. I. Family Planoceridae.

1. *Planocera armata*, sp. n. (Pl. XV. figs. 10, 11, and 12).

One specimen from 40 fathoms, Suvadiva Atoll. Rubble and broken coral bottom.

Total length about 25 mm., total breadth about 15 mm. Tentacles from ant. margin 5 mm. Mouth aperture about 13 mm. behind anterior margin. Male gonopore about 5 mm. behind mouth. Female gonopore about 1 mm. behind male.

Colour white with small pigmented patches, scattered rather numerously near the dorsal surface. Tentacles about 2 mm. apart, bilobed at the tips; each with a dense cluster of eyes at its base. Brain compact, lying under a median branch of the gut. There is a cluster of eyes over the brain between the tentacles (Fig. 61).

The epidermis is composed of very small cells, crowded with a finely granular secretion. I can find no trace of rhabdites. The basal membrane is thick, and occasionally pierced by processes from gland-cells, lying beneath the integument. The muscle layers consist of a thin, outer, longitudinal layer, followed by two layers of diagonal fibres. These are succeeded by a circular layer which is much thicker on the ventral than on the dorsal side. Lastly on the ventral side only is an inner longitudinal layer.

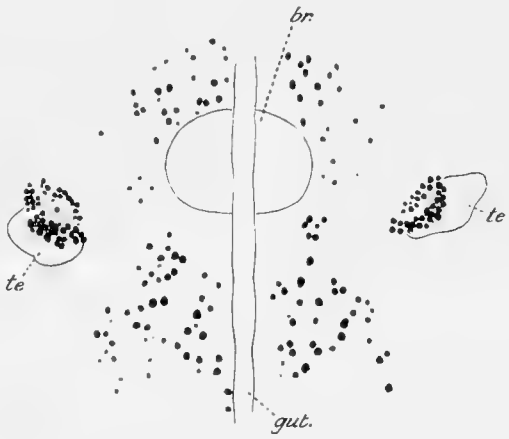


Fig. 61. Eye-spots of *Planocera armata*. *te*. tentacles, *br*. brain.

The pharyngeal aperture is median. From the main gut some seven pairs of gut branches are given off. These again ramify into numerous smaller branches as they run outwards.

The small pigmented patches, referred to in the short account of the external characters given above, are found in section to be due to the presence of dark bodies in certain remarkable, dorsal diverticula given off from the gut branches (Pl. XV. fig. 10). The gut branches themselves are lined with very elongated columnar epithelial cells lying on a delicate basal membrane from which they are frequently, in my sections at least, torn away. The epithelium of the diverticula on the other hand, though similar in appearance, is structurally much reduced and obscured by the dark bodies referred to above.

These dark bodies are of three kinds. Firstly, there are numerous rather large, black, spherical bodies, which are evidently produced in the gut epithelium itself. With a high power different stages of the development of these bodies are readily distinguishable. They commence as small, lightly-staining masses, which increase in size, and at the same time take a deeper stain. Of their ultimate fate nothing can be said at present. They are scattered pretty regularly through the gut tissue and probably have but little or no share in giving the diverticula their characteristic appearance. Secondly, in and about the diverticula there are small masses of little rod-shaped bodies, probably bacteria. These do not occur generally throughout the gut, but only in the diverticula themselves or in their immediate neighbourhood; in the latter case they invariably have an appearance of streaming into the diverticula. Lastly, I have found in one or two diverticula only, a quantity of exceedingly fine, granular, pigment-like substances.

The significance of these bodies and of the diverticula themselves is obscure. The latter may be compared directly with the gut diverticula of such a form as *Thysanozoon brocchii*. Diverticula of a precisely similar character occur in a species of *Planocera*, as yet undescribed, collected by Mr Gardiner at Rotuma, whilst Lang's [9] figure of *Pl. villosa* suggests very strongly that a similar feature occurs in this species, though it is true that Lang appears to regard the pigment patches as merely epidermal.

Mention should be made here of the fact that von Plehn [10] has figured the occurrence of marginal pores opening from the gut in an undescribed Planoceroid. In the species described next the large spherical bodies of the gut epithelium are present, but there are no diverticula and neither of the other kinds of dark bodies.

Genital apparatus. The characters are shown somewhat diagrammatically in Pl. XV. fig. 11. In the female system the accessory vesicle (*a. v.*) of the vagina is thread-like and extends back as far as the level of the female aperture (♀). After receiving on its ventral side the common duct from the two uteri (*c. d.*), the vagus (*va.*) follows a winding course through the enormous shell glands (*s. g.*), and runs into a large bursa copulatrix (*b. c.*), whose lumen has many folded walls, appearing in part at any rate to be glandular. As in other typical members of the genus the terminal parts of the male apparatus are enclosed in an outer muscular sheath (*o. s.*), in which lie the penis and the prostate (*pr.*) as well as the duct. A remarkable feature of the penis, and one that separates this species sharply from other known *Planocera*, is the presence at the end of that organ of six large chitinous hooks (*c. h.*) and at its upper end of a chitinous ring or collar (*c. r.*). The lumen of the penis is lined by a very large number of small chitinous spines (*c. s.*). These vary from ·05 to ·07 mm. in length. The space between the penis and outer sheath is occupied by a very loose parenchymatous tissue.

Female organs. At its hinder end the accessory vesicle (*a. v.*) is difficult to trace owing to its extremely small size. The lining cells are not ciliated. As it passes forward it increases in size and a very few circular muscles appear about it. After receiving the short common duct (*c. d.*) from the uteri, which are also lined with non-ciliated epithelium, the vagina (*va.*), as it must now be called, continues to run forwards for some little distance. It then turns first ventralwards and then backwards. As it turns back it widens out so that its lumen is wide from side to side but narrow dorso-ventrally. In this part of its course it receives the secretion of the relatively enormous shell-glands (*s. g.*), which have a characteristic granular appearance and stain very lightly. The vagina continues to run backwards, passing right through the shell-glands until it lies right under the front end of the bursa. Here its lumen becomes circular in section. It now makes a Z-shaped turn upwards, and runs into the hinder end of the large bursa copulatrix (*b. c.*). As the vagina passes into the bursa its lining epithelium undergoes a marked change. Up to this point it consists of a fairly well-defined, cubical epithelium with deeply staining nuclei, apparently non-ciliated. As it passes into the bursa it becomes irregular and much folded; the protoplasm stains more deeply, and the nuclei can with difficulty be distinguished. From its proximal, anterior end the epithelium lining the bursa (*g. l.*) retains these characters almost to the gonopore, in the neighbourhood of which it merges into a columnar non-ciliated epithelium, continuous with the epithelium of the surface. The epithelium of the bursa is secreting very actively a remarkable 'glairy' substance, which occupies nearly the whole lumen of the bursa. Outside this epithelium the bursa is built up of a thick muscle layer of circular fibres. The folding of the wall lining the lumen of the bursa is no doubt, as Lang suggests, to permit of the distension of the organ. The secretory character of its wall is, so far as is known, confined to this species, and without homologue in the bursa of any Polyclad I am acquainted with. This peculiarity combined with the very remarkable nature of the penis indicates that this species is one of the most specialized in the whole order.

Male apparatus. The gonopore opens into an antrum masculinum whose walls closely resemble those figured by von Graff for his *Pl. simrothi* [6]. Little spherical masses of granular secretion given off from the cells lining the antrum lie scattered in its cavity. The outer sheath (Pl. XV. fig. 12, *o. s.*) is composed of two layers of muscle fibres, an outer longitudinal

and an inner circular layer. At its anterior proximal end it is pierced by the ductus ejaculatorius running into it from the small muscular vesicula seminalis (*v. s.*). At the same end lies the large prostate gland (*pr.*), whose duct joins the ductus ejaculatorius some way before entering the penis. Retractor muscles run from the upper end of the penis, and from the distal part of the ductus to join the outer sheath.

A transverse section through the distal lower limit of the penis is represented somewhat diagrammatically in fig. 13. The irregular lumen is seen to be lined with short chitinous spines (*c. s.*) and the section passes through the bases of the six large hook-like structures (*c. h.*). Outside the spines and hooks is a narrow layer of hyaline protoplasm, and beyond this the irregular, diagonal, intrinsic muscles of the penis (*p. m.*) in close contact with the muscles of the outer sheath, here rather feebly developed. The small cavities (*a. m.*) are parts of the antrum masculinum. The irregularity of the lumen is probably due to shrinkage. Further forward a transverse section shows the hyaline layer rather more clearly defined, and outside it is a broad muscle layer composed of diagonal fibres which are closely packed together on the inside, but loosely arranged to the outside, so that no very clear boundary can be distinguished between the muscles and the parenchyma, which have divided the intrinsic muscles of the penis from those of the outer sheath.

At the level of the chitinous 'collar-like' structure the sections have unavoidably been torn. Consequently I cannot be certain of the relationship of the collar to the penis or to the retractor muscles, but some of the latter seem to be attached to it. The collar itself, seen in the animal when cleared in oil of cloves before it was cut into sections, appeared as a ring of chitinous material, its upper, anterior end wider than the lower, and its outer surface decorated with a rectangular sculpturing. On account of the tearing of the sections it is also impossible to say whether the ductus ejaculatorius entered the penis by passing through the collar or to the outside of it.

In a transverse section in front of the penis but before the level of the prostate, the ductus ejaculatorius can be seen running through the middle of the section. It has a narrow lumen lined with ciliated epithelium. Outside this is a thin layer of circular muscle fibres followed by a longitudinal layer. From this longitudinal layer a number of bundles of retractor muscles are given off, exactly similar to those connected with the hinder end of the penis itself. In sections at this level many of them lie cut across obliquely amongst the parenchyma which here fills the wide space between the ductus and the outer sheath. The ductus runs nearly straight back to the prostate. Just before entering the latter it divides into a wider part running to the gland and a narrower part continuing to the vesicula seminalis, after piercing the wall of the outer sheath. It is interesting to find here a little peculiarity which evidently also occurs in *Pl. pellucida* (see von Graff's figure [6]), *i.e.* the duct from the vesicula does not open immediately into that from the prostate, but is actually prolonged for a short distance inside it. This prolongation is probably of the nature of a valve. Each of these two parts making up the ductus ejaculatorius is provided only with circular muscle fibres; but, whereas those of the prostatic part are few in number, those of the part running to the vesicula though few at first increase rapidly in number as the vesicula is approached.

The prostate (*pr.*) is a large gland, lying in close contact with the outer sheath at its anterior end; in fact the circular muscles of the sheath completely enfold it, and form a muscular wall for it. On the inside it is lined with a much-folded glandular epithelium. The vesicula

seminalis lies outside the outer sheath. It is small, with thick muscular walls composed of circular fibres. The vasa deferentia before joining it are much swollen and full of spermatozoa; they are lined with a cubical ciliated epithelium, and have no nuclei. The vesicula itself contains no spermatozoa.

2. *Planocera langii*, sp. n. (Pl. XIV. fig. 1, and Pl. XV. fig. 13).

One specimen from Minikoi. "White transparent form." Body flat, oval; margin folded.

Total length about 20 mm. Front margin to mouth opening 11 mm. Front margin to male aperture 13·5 mm. Male to female aperture about ·3 mm. Tentacles about 7 mm. from the anterior margin, and about 1·5 mm. apart.

Tentacular eyes numerous, small, lying at the base of either tentacle in a dense cluster. Tentacles slightly bilobed at their ends. Behind the tentacles is a single pair of small eyes, lying over the brain. Colour white, with a few small black chromatophores lying scattered round the pharynx region dorsally. There are in addition a number of exceedingly small black spots consisting apparently of pigment granules visible on the dorsal surface above the hinder part of the pharynx. These granules lie in the parenchyma, and are not of course comparable in any way to the diverticula described in the previous species. Similar granules occur in an undescribed species of *Planocera* from Rotuma.

Genital apparatus. An examination of the accompanying Figure 62 shows that the present species differs strikingly so far as these organs are concerned from *Pl. armata*. In fact it seems impossible to homologize the bursa copulatrix of the one with that of the other. The female aperture (♀) leads into a spacious antrum femininum into which the shell-glands (*sh. gl.*) open. From the antrum a short passage runs dorsalwards. It quickly divides to form the vagina which runs backwards, and the bursa copulatrix (*b. c.*) which extends forwards alongside the penis, lying at rather a higher level than the vagina (see fig. 13). The latter after a short distance bends ventralwards, and at the same time receives the separate openings of the uteri (*ut.*). Beyond this the character of its lining epithelium alters completely, and the organ is continued backwards as an elongated vesicle, which may be called the receptaculum seminis (*r. s.*), homologous with the accessory vesicle of *Pl. armata*. A remarkable feature of the male apparatus is the presence of a pair of vesiculae seminales, dilations of the terminal parts of the vasa deferentia with thick muscular walls. Compared with *Pl. armata*, this species has a long 'outer sheath' with feeble walls. The penis is long and twisted, without retractor muscles. The chitinous spines lining its lumen are relatively few, and there are neither chitinous hooks nor ring. The penis extends right back to the level of the prostate, which communicates with it by a short wide duct.

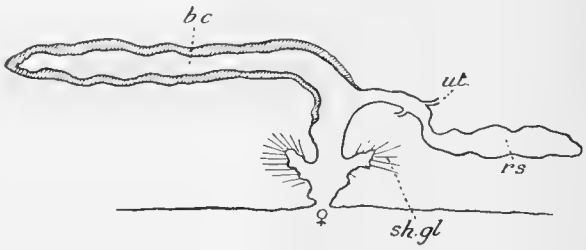


Fig. 62. Female apparatus of *Planocera langii* (diagrammatic). For explanation of lettering see text.

Female organs. The receptaculum seminis (= accessory vesicle) is lined by a regular, columnar, ciliated epithelium, resting on a fine, basal membrane. All the nuclei lie at the lower extremity of their cells, close to the membrane. They have a lightly staining ground-substance with scattered chromatin granules. The protoplasm is faintly granular. The receptaculum lies

rather near the ventral surface. As it approaches the vagina it makes a sharp turn up and the appearance of the epithelium changes; circular muscle fibres make their appearance, and, after receiving the uterine openings, the organ is continued forward as the vagina, the epithelium here consisting of a short, columnar, ciliated facies. The nuclei are homogeneous and darkly-staining; the protoplasm is hyaline. The bursa copulatrix extends forward as far as the front end of the male apparatus. Its inner walls are much folded and lined with cubical non-ciliated epithelium. Outside this it has moderately thick muscular walls composed of circular fibres. The undescribed species from Rotuma, to which I have already referred, bears a strong resemblance so far as the female apparatus is concerned to *Pl. langii.* In it the receptaculum seminis is crowded with spermatozoa.

Male apparatus. The outer sheath consists in this species of circular fibres only. From the antrum masculinum for about a quarter of its length, which is roughly a millimetre, it is continuous with the intrinsic muscular wall of the penis, and traversed by scattered, radial fibres running from the latter.

After this a split appears between it and the intrinsic muscles of the penis, leaving a space round the latter. At the upper anterior end the prostate as in the other *Planocera* lies in close contact with the outer sheath. The few muscle-fibres surrounding the prostate do not seem to be derived from the outer sheath. Lastly the sheath is pierced at two points by the ducts running to the penis from the vesiculae seminales.

The penis is approximately a millimetre in length. It is a cylindrical, tube-like organ, its lumen lined with chitinous spines, which are a little hooked and not very thickly set. The diameter is roughly equal throughout its entire length. The muscular wall consists of a well-defined, rather thick layer of circular fibres crossed by radial fibres. The penis is continued right up to the level of the prostate, which communicates with it by a short, wide, muscular duct, opening into it at the same point as do the ducts from the vesiculae.

At a point about one-third of the total length of the penis from the male aperture the chitinous spines are interrupted by the appearance of two curious folds of the inner wall (Pl. XV. Fig. 13, *pl.*). These folds are margined with chitinous material. It is possible that they may be to some extent comparable to the chitinous hooks or collar of *Pl. armata,* but their function is quite unknown to me. Behind them the spines are continued again up to the level of the opening of the prostate duct. As already stated each of the vasa deferentia is dilated before entering the outer sheath to form a vesicula seminalis, and the dilated part has muscular walls composed of circular fibres. The ducts running from the vesiculae to the penis are also muscular.

Before passing to consider the species belonging to the next family I may briefly notice the presence of a large Planoceroid represented by a single damaged specimen in the collection, which I am not able to describe. Its total length is probably about 45 mm. A pair of dorsal tentacles are visible. It is perhaps a *Stylochoplana.* I could only find indications of a single genital aperture, the genital organs being quite immature.

II. Family Leptoplanidae.

3. *Leptoplana pardalis,* sp. n. (Pl. XIV. fig. 9, and Pl. XV. fig. 14).

Several specimens from the reef, Goidu, Goifurfehendu Atoll, and from Minikoi, Laccadive Group.

Average length about 48 mm. Eyes distant 10 mm. from the anterior margin. Mouth opening about 20 mm. from the anterior margin. The male aperture lies about a millimetre in front of the female, the latter is about 15 mm. from the hinder end of the body.

The colour (in spirit specimens) is pale yellow. On the dorsal surface this is thickly studded with rosette-like clusters of brownish-black chromatophores. On the mid-dorsal line in the middle third of the back these chromatophores form a continuous band; near the margin the clusters are replaced to some extent by single chromatophores.

The eyes are arranged in two clusters of 'tentacle-eyes' of moderate size, each containing about a score of eyes. In front of them lie on either side about as many more eyes scattered irregularly. The gut branches anastomose.

This interesting species combines to some extent the characters of *Discocelis* with those of *Leptoplana*. The presence of a pair of receptacula seminis developed from the accessory vesicle of the vagina resembles the condition found in *Discocelis tigrina*, whilst the absence of marginal eyes and the widely separated gonopores forbid us to refer it to that genus. On the whole it is most conveniently placed in the genus *Leptoplana* as at present constituted, the male organs resembling those of other species of that genus.

Female apparatus. (See Figure 63.) The vagina (*va.*) runs back from the female aperture (♀) and receives the common duct (*c.d.*) from the uteri.

These latter extend forward from the short common duct, each being formed of two distinct sections. Firstly there is a duct-like part, consisting of a narrow tube lined with cubical, ciliated epithelium, surrounded by a few circular muscles (*u. d.*). This opens at about the level of the male aperture into a wide, irregular, glandular part, the pair extending forward on either side of the pharynx, and in one of the specimens, examined by sections, containing eggs. The walls of this glandular part (*u. gl.*) are much folded, and their epithelium is secreting actively and full of globules of a finely granular substance. Cell outlines are not visible.

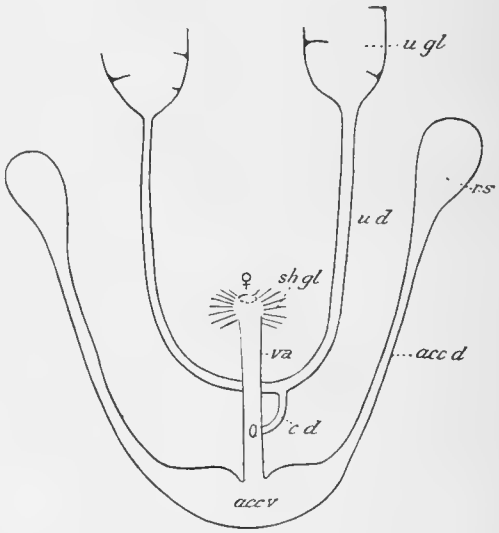


Fig. 63. Female apparatus of *Leptoplana pardalis* (diagrammatic). For explanation of lettering see text.

Behind the entrance of the common duct from the uteri the vagina, whose lumen is lined by cubical, ciliated epithelium surrounded by circular muscle fibres, runs back for a short distance, and finally opens into a crescentic accessory vesicle (*acc. v.*) with its horns directed forward. From either horn a narrow duct (*acc. d.*) runs forward, ending in a spherical dilatation (*r. s.*) which probably functions as a receptaculum seminis. The cubical epithelium, lining the accessory vesicle and the ducts opening into it, is not ciliated. In one specimen the receptacula are crowded with spermatozoa, surrounding a mass of what appears to be a granular secretion.

Considerable interest attaches to this species in that the walls of part of the uteri themselves are glandular. Glands in connection with the uteri are as a rule only present in certain Cotylea, such as *Diposthus*, *Pericelis* and various Euryleptidae, where they occur in

diverticula from the uterus. The accessory vesicle on the other hand only occurs in the Acotylea. In *Discocelis* it is glandular.

Male apparatus. The vasa deferentia dilate at their terminations to form a pair of moderately wide vesiculae seminales whose walls are surrounded by a thin layer of circular muscle-fibres. These vesiculae open into a short and narrow ductus ejaculatorius (Pl. XV. fig. 14, *d.e.*) lined with ciliated epithelium and provided with rather thick muscular walls. This duct narrows suddenly as it enters the muscular penis (*pe.*), which projects as a bluntly conical muscular mass into the antrum (*a.m.*). The antrum is lined with non-ciliated epithelium and its walls are muscular, forming the muscle sheath; I can find no trace of gland-cells in the epithelium.

Amongst the six specimens of this species collected at Minikoi is one which differs from the rest in coloration, being much darker. After a careful examination I have come to the conclusion that this difference is chiefly due to the expanded condition of its chromatophores, though they may be slightly more numerous. Unfortunately it is not possible to say whether this specimen was collected under different conditions from the others. Since examining these specimens I have received from Mr Gardiner three others, which I believe to be specifically identical with them, from Funafuti in the Pacific.

4. *Leptoplana*, sp.

One specimen from Minikoi. Damaged.

The arrangement of the eye-spots is that of a typical *Leptoplana*. There are a pair of small compact 'tentacle-eye'-groups, and in front of these the scattered brain-eyes.

Genital apparatus. The female aperture lies about two mm. behind the male, unfortunately the hinder part of the female apparatus is missing, but it bears a fairly close resemblance so far as can be determined to that of *L. vitrea* as figured by Lang. The shell-glands are very numerous, their secretion takes the form of enormous numbers of minute rhabdite-like bodies, similar to those found in *Pericelis* (see below). These rhabdites can be seen making their way into the lumen of the vagina. In the neighbourhood of the terminal parts of the genital apparatus the unripe shell-glands are so numerous as to give the tissue a characteristic appearance. They resemble closely those of *L. alcinoi* figured by Lang ([9] T. 14, Fig. 2), but in the latter species they are pyriform, whilst in the species under consideration they are spherical.

As they ripen and become filled with the small rhabdite-like bodies, the cell outlines become obscured, and finally the cells seem to disappear as though they had ruptured to permit of the escape of the contained rhabdites.

The walls of the vagina are lined with ciliated epithelium, and, as it passes back from the antrum, a fairly strong muscle layer developes about it. After running for a short distance backwards the vagina turns upwards and a little forwards and then finally backwards, receiving the separate openings of the uteri. Thence it continues back, first as a narrow tube, but further back appearing to open into a wide accessory vesicle; owing to the displacement of the organs at the hinder end of the body it is extremely difficult to follow. The uteri run forward, and for the first millimetre or so of their length have muscular walls, further on the muscles disappearing.

In the male apparatus the vasa deferentia open into a muscular vesicula seminalis, resembling in shape that of *L. vitrea.* From the front end of the vesicula the ductus ejaculatorius runs backwards and downwards for some distance; its lumen is rather wide and it is lined with glandular prostatic cells, outside which lies a layer of circular muscular fibres. This part of the apparatus resembles rather that of *L. pallida* than of *L. vitrea.* The rest of its structure is practically identical with that of *L. vitrea.* The duct narrows, and runs vertically upwards, then turns downwards and backwards again, extending parallel to the first part of its downward course. It is here very narrow, surrounded by a compact layer of circular fibres, outside which lie less compact, diagonal fibres. It opens finally into the antrum masculinum. These muscles form the penis.

As this specimen is in an imperfect condition I cannot describe it fully, though I believe it to be quite distinct from any named species.

III. Family Cestoplanidae.

5. *Cestoplana? maldivensis,* sp. n.

A single specimen from the reef of Minikoi, Laccadive group.

Total length about 15 mm., breadth 5 mm. Body flat, anterior end pointed, posterior end tapering a little. Colour (in spirit specimen) uniform dull brown. The hinder end of the body of the single specimen has unfortunately been so much damaged that it is impossible to determine the characters of the sexual organs.

The pharynx has the position typical for *Cestoplana,* and the mouth opening is about 4 mm. from the hinder end, whilst the male aperture is certainly not more than 2 mm. from the extremity.

From the two species of the genus previously known, viz. *C. rubrocincta* (Grube) and *C. faraglionensis* (Lang), the present species is separated by its relatively short and wide body. Another more striking difference is afforded by the arrangement of the eye-spots. In *C. maldivensis* there is a complete series of these round the margin of the body (see Fig. 64), on the posterior two-thirds of the body being few and distant, but on the anterior margin on either side as far back as the level of the brain thickly scattered. In addition to these in the apex of the triangular anterior end of the body lie a small number of eyes scattered over an area which stretches back for about half the distance from the apex to the brain; and further from the middle of the hinder end of this area two irregular parallel lines, each of a single row of eyes, extend back as far as the brain, which lies at about the end of the first sixth of the body.

The uteri can be traced forward through the hinder two-thirds of the body, and are crowded with eggs. Until it is possible to examine the genital apparatus of this species in a better-preserved specimen I prefer to leave it in the genus *Cestoplana,* although there can be no doubt that it differs strikingly from typical members of that genus.

Fig. 64. *Cestoplana* (?) *maldivensis.* × 7.

COTYLEA. IV. Family PERICELIDAE, nov.

6. *Pericelis byerleyana* (Coll.) (Pl. XIV. fig. 6, & Pl. XV. fig. 15, 16, & 17).

Typhlolepta byerleyana. Collingwood, Trans. Linn. Soc. Lond. (2) i. p. 92; Lang, Naples Monogr. p. 616.

Five specimens from Minikoi.

Collingwood's description of this species is as follows:—"Length $\frac{3}{4}$ inch, breadth $\frac{3}{8}$ inch. Body smooth, thin, the lateral parts very ample and puckered. Upper surface beautifully marbled with light brown rings, including roundish spaces of a whitish colour, smaller rings being between the interstices of the larger; most crowded and darkest in colour along the median line, and more delicate towards the side. Under surface of a pale grey, the dendritic markings in the centre of an opaque white. Its movements were very contorted and it did not exhibit much activity. One specimen from under a piece of coral on Pulo Barundum off the west coast of Borneo."

In Mr Gardiner's collection are five specimens agreeing with this description so far as it goes, save that three of them are of considerably greater size. They are however provided with tentacles on the anterior margin, and with eyes; but I believe that Dr Collingwood may well have overlooked these owing to the extreme folding of the edge of the body.

Owing to the fact that this species possesses both eyes and tentacles it must be removed from the genus *Typhlolepta.* Its characters, moreover, are such as to distinguish it from all other Cotylea sufficiently to make it the type of a new genus and family[1].

The family *Pericelidae* may be defined as follows:—"Cotylea with small widely separated tentacles, with a complete series of marginal eyes; penis single; pharynx central; margin of the body excessively folded." Genus *Pericelis.*

The nearest ally of this interesting form is, I consider, *Anonymus,* the only other Cotylean Polyclad in which there is a complete series of marginal eyes. *Pericelis* further has the anterior margin notched in the middle line just as in *Anonymus.*

The most striking feature of the species, when viewed with the naked eye, is the extreme folding of the margin of the body. In one of the larger specimens the length of the body along the middle line is 35 mm., and the breadth at its middle about 32 mm., whilst the 'rim' of the body when spread out is not less than 230 mm. in length. In this same specimen the small tentacles lie not less than 9 mm. apart. They are crowded with eyes, and eyes are scattered completely round the margin inwards for a depth of about 5 mm. In the middle of the anterior margin is a well-marked notch or indentation, about 5 mm. behind this in the middle line is the elongated cluster of brain-eyes.

Other measurements are as follows:—mouth opening about 18 mm. behind the anterior margin. The male gonopore lies about 4 mm. behind the mouth. The female gonopore about 2·5 mm. behind the male. Sucker 1 mm. behind the female orifice.

To Collingwood's account of the coloration nothing need be added. I have ventured to give a coloured figure of one of Mr Gardiner's specimens to show the position of the tentacles and brain-eyes. It illustrates too the extraordinary amplification of the lateral parts of the body.

[1] The species is evidently a widely distributed one. I have received recently a sixth specimen of it from Mr Gardiner from Rotuma in the Pacific.

The body is characterized by its tenuity, its average thickness is only from ·3 to ·4 mm. Along the middle line there is of course a considerable thickening over the pharynx and genital apparatus, forming a ridge such as usually occurs in a Polyclad.

On the dorsal surface the epidermis contains large numbers of rhabdites about ·01 mm. in length. These are absent from the ventral surface. In addition to the rhabdites, pseudorhabdites occur numerously in both the dorsal and ventral epidermis. They are pellet-like bodies composed of a coarsely granular material, and are rather longer and at the same time thicker than the rhabdites. They are of sufficient size and number to give the whole surface of the body a granular appearance when viewed with a simple lens. On the dorsal surface of the tentacles the character of the epithelium differs markedly from that found elsewhere (see fig. 17). No rhabdites and only a very few small pseudorhabdites occur, and the whole epithelium has a very regular columnar arrangement, the nuclei all lie at the same level, viz. at about the middle of the cell. The cilia are not modified in any way, nor does there appear to be any special sensory apparatus. On the ventral surface of the tentacles the arrangement of the epidermal nuclei is quite irregular, and pseudorhabdites are fairly numerous, though not so abundant as over the general surface of the body.

The basal membrane lying below the epidermis is moderately thick; immediately below it lies the pigment, which to a great extent obscures the dorsal musculature. On the tentacles the pigment presents the appearance of being contained in chromatophores, whilst over the general dorsal surface of the body it is more diffuse and may be intercellular. In the flattened lateral parts of the body the inner longitudinal ventral muscle-layer is very strongly developed and extends dorsalwards for fully one-half of the thickness of the body. The muscles are but feebly developed in the tentacles; the space lying below the body-wall is almost entirely occupied with nerve-tissue. The "sucker" has its disc covered with a non-ciliated columnar epithelium; the nuclei are scarcely distinguishable, and the basal membrane very thin. Amongst the muscles below the basal membrane lie elongated gland-cells, full of a finely-granular secretion. Processes from these cells pierce the basal membrane and make their way through the epithelium to the surface. No pseudorhabdites are found in the epithelium of the disc. The pharynx is much folded and of considerable size, resembling in its arrangement that of *Anonymus viridis*.

Genital apparatus. In the two specimens from which sections were prepared the genital apparatus was well developed (Fig. 65). The vagina (*va.*) is of the type usually found in the Cotylea; that is to say, it runs upwards from the gonopore (♀), dilating at the point where it receives the shell-gland secretion (*sh. gl.*), further on narrowing again. It then turns back and downwards for a short distance, finally terminating in the uteri (*ut.*).

It is in connection with the uteri themselves that some of the most interesting characters of this species occur. In the first place there are a number of small rounded vesicles (*ut. v.*) each connected with the uteri by a short stalk-like duct. These vesicles in some cases contain quantities of spermatozoa, surrounding what appear to be fragments of eggs (cf. Woodworth [20], p. 66). In addition at intervals along the uteri are gaps in the walls, through which project into the lumen of the uteri cells, bearing a close resemblance to the yolk-cells of *Dendrocoelum lacteum* figured by Ijima [8] (see especially Pl. XXI. figs. 7–10, *loc. cit.*). This character is of importance, as hitherto no Polyclad possessing any organs comparable to the Triclad yolk-glands had been described.

The penis is muscular and directed backwards. It is conical in shape, and tapers to a fine point, which projects into a long and extremely narrow antrum masculinum (*a. m.*). At its anterior, proximal end the penis receives on either side the vasa deferentia (*d. e.*), crowded in the specimens with spermatozoa.

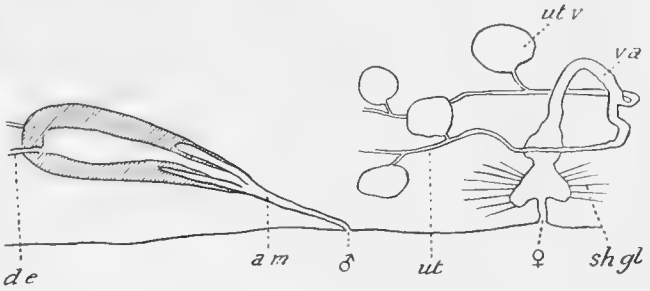


Fig. 65. Genital apparatus of *Pericelis byerleyana* (diagrammatic). For explanation of lettering see text.

Female apparatus. The shell-glands are large and extend for a considerable distance laterally. Their secretion is in the form of an immense number of minute, spindle-shaped, rhabdite-like bodies, which are each about a quarter of the size of the epidermal rhabdites. These are of peculiar interest as bearing on the morphology of the rhabdites of Turbellaria, and strongly supports the view taken by Woodworth [19] and others.

The vagina is narrow and lined with ciliated epithelium, surrounded by a very narrow layer of circular muscle-fibres, thicker at its hinder end, where it turns downward to receive the uteri the vagina has rather a thicker muscle layer. Outside the muscle-fibres lie a number of nuclei probably belonging to gland-cells. The epithelial lining of the uteri, if present, is so reduced that I have not been able to distinguish it. The walls of the uterus apparently consist of a ring of muscle-fibres surrounded as in the case of the vagina with gland-cells (see fig. 16). The uterine vesicles (see Fig. 65, *ut. v.*) are lined with a cubical, or somewhat columnar, non-ciliated, secretory epithelium. It rests on an extremely delicate basal membrane, and there is no muscular coat. The character of the lining epithelium of these vesicles recalls that of the receptaculum seminis of *Planocera langii.*

The vesicles are connected with the uteri by ducts of varying length, some so short that the vesicle is almost sessile on the uterus (fig. 15). They are similar in structure to the uteri themselves but smaller. The vesicles are fairly numerous, eleven opening into the uterus of one side between the level of the mouth opening and the vagina. So far as I can find they do not extend forward in front of the mouth. As already stated these vesicles frequently contain spermatozoa, surrounding a 'lump' of material, which appears to consist of small, round, hyaline cells with black nuclei, which do not resemble eggs. In the homologous vesicles of *Diposthus corallicola* Woodworth and in certain Euryleptidae spermatozoa are found surrounding fragments of what Woodworth and Lang suppose to be eggs, but in the present instance these 'lumps' are certainly not fragments of eggs. The ovaries contain ripe eggs. The oviducts themselves are indistinguishable.

Certain remarkable structures, as has already been stated, occur in connection with the uteri which bear a fairly close resemblance to the yolk-glands of certain Tricladida. The only structure with which they can be compared in the Polyclads are the 'rosette-like glands' of *Cycloporus papillosus*, described by Lang [9]. These differ firstly in that they open into the oviducts, and secondly in having the character of glandular diverticula from the oviducts. In *Pericelis* on the other hand there are numerous gaps in the walls of the uteri (Pl. XX. figs. 15 and 16), through which project deeply staining pyriform cells, which do not seem to be of a definite secretory or glandular character, with oval black nuclei. On the whole these organs of *Pericelis*

approximate more closely to the yolk-glands of the Triclads than to any structure previously known amongst the Polyclads. It is possible, however, that they are connected with the cell-like bodies found in the uterine vesicles as described above.

Male apparatus. The vasa deferentia are crowded with spermatozoa. They enter the walls of the penis some little distance behind its anterior end, narrowing as they do so. For the first third of its length its lumen is lined by glandular cells, and filled with a coarsely granular secretion (see Fig. 66). For the rest of its length it has a cubical ciliated epithelium, as also has the antrum masculinum. The wall of the penis is composed chiefly of circular fibres, interspersed with a few radial. The antrum becomes extremely narrow as it approaches the gonopore, and the latter is correspondingly minute.

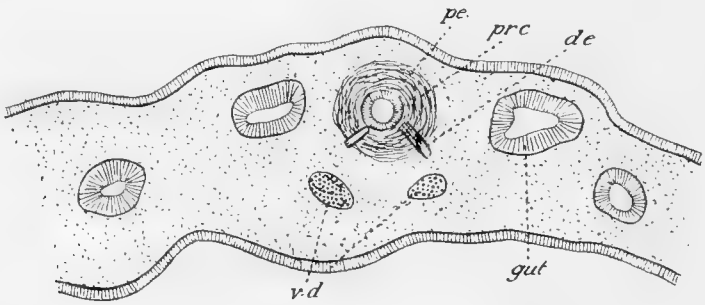


Fig. 66. Section across the base of the penis of *Pericelis byerleyana*.
pe. = penis, *pr. c.* = glandular cells, *v. d.* = vasa deferentia, *d. e.* = vas deferens entering penis.

Leaving the specialized *Prosthiostomum* out of account I believe that all other Cotylea save *Anonymus* have a special muscular prostatic organ connected with the penis by a short duct. Consequently *Pericelis* is more nearly related to *Anonymus* in the structure of the terminal parts of this organ than to the rest of the Cotylea.

V. Family Pseudoceridae.

7. *Thysanozoon plehni*, sp. n. (Pl. XIV. fig. 7, and Pl. XV. fig. 19).

Three specimens "from the reef-flat" Minikoi, with "brown to slate-black papillae."

Total length about 23 mm. Total breadth about 17 mm. 'Mouth opening' about 5 mm. behind the anterior margin. ♂ aperture 4 mm. behind the 'mouth.' ♀ aperture 1 mm. behind the male. Sucker 2 mm. behind the female aperture.

The ground-colour of the body in the spirit specimen is a dull pale yellow. On the dorsal surface lie a considerable number of black, rather pointed papillae; the small marginal tentacles are also black. Brain-eyes in a single small cluster; tentacle-eyes arranged along the anterior side of the tentacles (Fig. 67).

The muscle-layers of the body-wall are but feebly developed. The dorsal papillae contain no gut diverticula, only a loose parenchyma. Their epithelium is composed of very long, columnar cells, loosely connected with each other, containing clusters of rhabdites which vary in length from ·01 to ·0275 mm. In addition to the rhabdites the epithelium of the papillae secretes a small number of pseudorhabdites, bodies of about the same length as the larger rhabdites, but two or three times as broad and of a finely granular texture. They occur nowhere save on the papillae (Pl. XV. fig. 19). At the tip of each papilla is a small

'plug-like' mass of tissue derived in part from the parenchyma and in part from the epidermis, which differs from the tissue surrounding it in being denser and in staining more deeply. It occurs in every papilla through which my sections pass, but I cannot offer any suggestion as to its significance.

Fig. 67. Tentacles and eyes of *Thysanozoon plehni.*

Behind the level of the pharynx, which resembles that of other species of the genus, the main gut gives off numerous branches. *These do not all arise from it in the same plane,* but at the same time no branches are given off from the ventral side. Von Plehn [10] in describing two new species, which she calls *Thysanoplana indica* and *Thysanoplana marginata,* pointed out that a similar peculiarity occurs in those species, but to a much greater extent, for in them apparently the branches may in addition originate from the ventral side of the main gut. I have also found—from a careful examination of a series of sections in the Laboratory Cabinet of the Owens College Zoological Department—that in the neighbourhood of the male aperture of *Thysanozoon brocchii,* and for some little distance behind it, the gut branches do not all rise in exactly the same plane, though only from the lateral walls of the main gut. It is in the same neighbourhood, viz. in that part of the body where the main gut is largest, that this feature is most marked in von Plehn's species of *Thysanoplana* as well as in *Thysanozoon plehni.*

Genital organs. Excepting in detail these resemble very closely those of other species of the genus, and especially those of *Th. auropunctatus* (Coll.) as figured by von Stummer-Traunfels [14]. The terminal parts of the female ducts are in no way peculiar. The eggs, like those of other species of the genus, exhibit large centrosoma.

Male apparatus. The vasa deferentia unite to enter the vesicula seminalis by a short common duct ("gemeinschaftlicher Einmündungsgang" of von Stummer-Traunfels), which runs dorsalwards to open into the lower side of the vesicula near its hinder end. The vesicula extends forwards and a little downwards for the greater part of its length, but close to its anterior end it curves suddenly downwards and narrows into the duct to the penis. This duct is long, more than twice the length of the vesicula, and after a tortuous course enters the base of the penis, where it is joined by a very short duct running from the small prostate gland, which lies close above and behind the penis. It is lined with secretory epithelium, and has a compact muscular wall composed of diagonal fibres. The penis is armed with a short tubular chitinous stylet and projects into a cavity, whose walls form the penis-sheath. This cavity opens immediately below the penis into the antrum masculinum, which in turn opens to the exterior by the male gonopore.

It is of some interest to find that, whereas the gonopore is situated on the middle line, the penis with the penis-sheath lies very decidedly to one side of it, the right side. But the cavity of the antrum is extended fairly equally both to the right and to the left of the middle line. This peculiarity perhaps indicates that this species is descended from a form in which, as in many other species of *Thysanozoon,* the penis is paired, and that one of the pair, the left in this instance, has disappeared leaving the right penis to open unsymmetrically into the symmetrical antrum. In Lang's Monograph, T. 30, fig. 17, a diagrammatic figure is given of the terminal male apparatus of *Pseudoceros maximus*—a species belonging to a closely-allied genus—which possesses a pair of penes. If we picture one of these penes to be atrophied, the diagram would represent very closely the appearance seen in a section of the present species passing through the penis and antrum masculinum.

Thysanozoon plehni is on the whole most closely related to *Th. obscurum* described by von Stummer-Traunfels [14] from Amboina.

Genus *Pseudoceros.*

A. Forms with a pair of penes.

8. *Pseudoceros gardineri* sp. n. (Pl. XIV. fig. 4).

One specimen from Hulule, Male Atoll.

Total length about 35 mm., total breadth about 22 mm. Mouth opening 8 mm. behind the anterior margin. Female gonopore about 5 mm. behind the mouth. Sucker 7 mm. behind the female gonopore.

The margin is much folded. Body flat, oval with a prominent mid-dorsal longitudinal ridge. Colour: dorsal surface a delicate gray with scattered irregular black marks of varying size dotted over the surface; under surface grayish-white.

The marginal tentacles are sharply pointed, large and prominent. The eyes, which are exceedingly numerous, are grouped as follows. A large compact cluster containing about 200 eye-spots lies over the brain. This is circular in shape save for a slight notch in the middle of its hind margin. On the dorsal surface of either tentacle near the middle line and close to the anterior margin is a group of eyes, rather more scattered than those of the brain-cluster. On the outer side of each of these clusters is a second still more diffuse group. On the ventral surface of the tentacles, almost immediately under the more medially placed dorsal group, are two roughly square compact patches; from the outer side of each of these a small 'wing' runs on to the ventral side of the tentacles (Fig. 68). The projecting 'wing' is concealed by marginal folds.

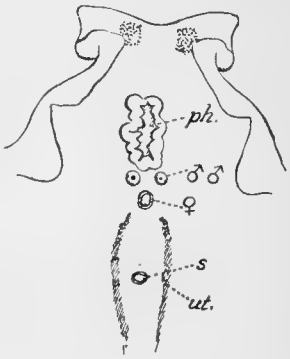


Fig. 68. Ventral surface of *Pseudoceros gardineri.* *ph.* = pharynx, *s.* = sucker, *ut.* = uterus, ♂ ♂ = penes, ♀ = female aperture.

9. *Pseudoceros punctatus* sp. n. (Pl. XIV. fig. 5).

One specimen from Hulule, Male Atoll.

Total length about 30 mm., breadth about 17 mm. Mouth about 5 mm. from anterior margin. Female gonopore 4 mm. behind mouth. Sucker 4 mm. behind female gonopore.

Body oval, flat, with well-marked, median, longitudinal ridge. Colour pale grayish-yellow, plentifully spotted on the dorsal surface with small black chromatophores.

The tentacles are pointed as in the preceding species.

The eyes over the brain form a very small cluster of some 25—34 minute eyes. At the base of each tentacle, on the dorsal side and close to the anterior margin, is a small, ill-defined cluster of eyes, and there are also a few scattered eyes on the outer sides of the tentacles. On the ventral side of the tentacles are a pair of small clusters near the middle line and a few scattered eye-spots along the tentacle fold.

The species is readily distinguished from the preceding by its possessing much more distinctly defined and more regular chromatophores, as well as by the relative fewness of its eyes. It yet resembles it especially in the shape of the tentacles, which are more like those found in certain Euryleptidae than those of most Pseudoceridae.

B. Forms with a single penis.

10. *Pseudoceros gamblei* sp. n. (Pl. XV. fig. 18).

Several specimens from Minikoi, Laccadive Group, 'milk-white' or 'transparent flesh colour' with purple or dark-blue rims.

Total length about 12 mm., breadth 6 mm. Mouth opening about 2 mm. behind the anterior margin. Female aperture about 1 mm. behind mouth. Sucker about 1 mm. behind the female aperture.

A small circular cluster of eye-spots lies over the brain about 1·2 mm. behind the anterior margin. There is a row of eyes along the margin of the tentacles both on the dorsal and ventral sides, which is continuous across the middle line (Fig. 69).

Sections were cut transversely through the anterior region of the body of a semi-adult specimen. Rhabdites appear to be absent in the epithelium, and the muscle layers of the body-wall are feebly developed. The testes lie, as is usually the case, on the ventral side of the gut, and the ovaries which are immature can be recognised on the dorsal side. The penis is that of a typical Pseudoceroid. The vasa deferentia before uniting to form the muscular ductus ejaculatorius are each dilated to form a vesicula, which is crowded with spermatozoa (Pl. XV. fig. 18).

A feature of the species is the curious shape of the pharynx, which has its hindmost folds produced backwards to form wing-like projections on either side, extending as far back as the level of the female aperture (Fig. 69).

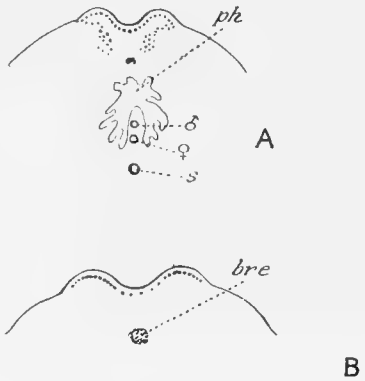


Fig. 69. Anterior end of *Pseudoceros gamblei*. A. from ventral; B. from the dorsal side.
ph. = pharynx, *br.e.* = 'brain-eyes,' *s.* = sucker, ♂ = penis, ♀ = female aperture.

11. *Pseudoceros tigrinus* sp. n. (Pl. XIV. fig. 3).

One specimen from Minikoi, Laccadive Group.

Total length about 17 mm., breadth 11 mm. Mouth aperture about 4 mm. from anterior margin. Male aperture about 5 mm. from anterior margin. Sucker about 3 mm. from male aperture.

Ground colour orange-pink, margin and tentacles black.

On the dorsal side, on either side of the middle line a black band runs from the anterior margin to within a short distance of the posterior margin. These two bands meet each other across the middle line at their anterior and posterior extremities. In addition to these black, triangular patches project inwards at intervals along the margin; these like the two median bands have on them a few rather large, circular, pink spots, and between these the black is thickly flecked with very small white spots.

The position of the eye-spots is completely concealed by the pigmentation of the body, which readily serves to distinguish the species.

The remaining specimens referable to this genus, some eighteen in number, are all very similar to one another in appearance, being of black colour with yellow margins. Two distinct

forms can be recognised. The first of these has a narrow pale yellow border and its ground colour is a greenish-black. The second has a broader orange border and its ground colour is rather a velvety-black.

Excepting for the above difference it is difficult to find any distinguishing characters. Measurements are of little value owing to the varying degrees of contraction of the several specimens, and the dense pigmentation makes it impossible to determine the arrangement of the eye-spots, especially those of the tentacles, with any degree of accuracy.

I believe the form with the pale narrow yellow margin is identical with *Proceros buskii* of Collingwood, found by him in Singapore Harbour. In his description [4] he gives the colour of the body as a rich velvety olive-green, but in his figure the body is shown rather as black. The appearance of the margin in his figure of *Proceros buskii* agrees with that of my specimens. I feel therefore justified in identifying them with Collingwood's species.

12. *Pseudoceros buskii* (Collingwood).

Proceros buskii Collingwood [4], p. 91, Pl. I. fig. VI.

Pseudoceros buskii Lang. Naples Monogr. p. 547.

Ten specimens from Hulule and Minikoi.

Length about 22 mm. Breadth about 12 mm. Mouth opening 5 mm. behind anterior margin. Sucker 8 mm. behind mouth.

Colour black or greenish-black with a narrow pale-yellow margin. Eyes on the tentacles and in a small cluster over the brain; only visible in sections.

The other eight specimens which have a broad orange margin are I think allied to *P. buskii* on the one hand and on the other to *P. velutinus* Lang, a species recorded from Ceylon. I think it advisable to refer them for the present at any rate to a new species under the name of *Pseudoceros flavomarginatus*.

13. *Pseudoceros flavomarginatus* n. sp.

Eight specimens from Minikoi, Laccadive Group.

Length about 25 mm. Breadth about 15 mm. Mouth aperture about 5 mm. behind the anterior margin. Sucker about 7 mm. behind the mouth.

Colour velvety-black with an orange margin about 1·5 mm. wide.

Eye-spots occur on the tentacles and over the brain.

It will be noticed that this species is a little longer than *P. buskii* and that perhaps the relative position of certain organs is different. But, as already remarked, much importance cannot be attached to measurements.

VI. Family Prosthiostomidae.

14. *Prosthiostomum elegans* sp. n. (Pl. XIV. fig. 8, Pl. XV. fig. 20).

A single specimen, dredged off hard sand, at 30 fathoms, in the lagoon of Suvadiva Atoll.

Length of body about 18 mm., breadth 4·5 mm. Anterior margin rounded, posterior end of the body pointed.

Colour, in the spirit-specimen, pale primrose-yellow. From immediately behind the level of the brain, on either side of the longitudinal mid-dorsal ridge, extends a row of chocolate-

brown chromatophores, about 12 in each row. In addition to these there is a single small chromatophore on either side of the brain (see Pl. XIV. fig. 8). Under surface entirely primrose-yellow.

A number of minute eyes are scattered round the anterior margin of the body. There are also two groups lying over the brain. These form a V-shaped cluster; the apex of the V is directed forwards, and each of its limbs, narrowing from behind forwards, is made up of some 15 eye-spots, which are rather larger than those of the margin[1].

The margin is not folded. In shape this species approaches *P. dohrni*, Lang, and its structure is closely similar to that of *P. siphunculus* (Delle Chiaji), fully described by Lang. It differs however sufficiently from both and from other species admitted by Lang in colour and in details of the arrangement of the eyes.

It was necessary to examine the specimen by serial sections. I append some details of its anatomy:—

Body-wall. The epidermis consists of a columnar ciliated epithelium, containing but few rhabdites. It rests on a moderately thick basal membrane. The musculature of the body-wall is more strongly developed on the ventral than on the dorsal side. Immediately within the basal membrane lies a thin layer of longitudinal muscle-fibres, next to these circular fibres followed by diagonal fibres. Lastly, on the ventral side only is an inner longitudinal layer.

Pharynx. The pharynx is of course tubular as throughout the family. My sections were only cut a little further forward than the proximal end of the pharynx, and at this end its lumen is triradiate in transverse section (Fig. 70, *A*). This triradial appearance occurs in other species of the genus). It shows some differences in detail from the proboscis of *P. siphunculus* described by Lang [9].

The outer and inner walls are lined with extremely flattened pharyngeal epithelium (Fig. 70, *B*, *o. e.* and *i. e.*). A large number of radial fibres (*ra. m.*) extend right across the wall from

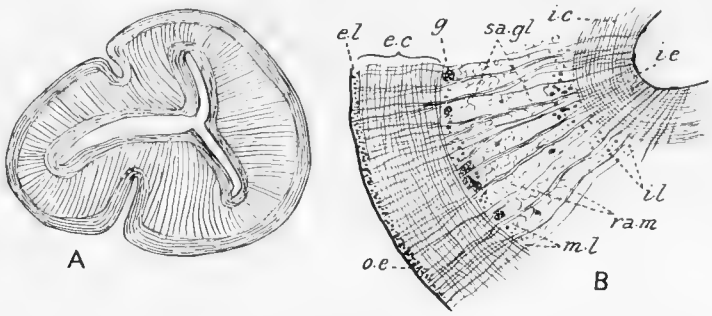


Fig. 70. Transverse section through the pharynx of *Prosthiostomum elegans*.
A. An entire section showing the triradiate lumen. B. Part of the same more highly magnified.
For explanation of lettering see text.

the inner to the outer epithelium. Immediately within the outer epithelium (*o. e.*) is a narrow layer of longitudinal muscle-fibres (*e. l.*), succeeded by a much wider circular layer (*e. c.*). In *P. siphunculus* this circular layer is succeeded by a longitudinal layer, which Lang calls the retractor muscle layer. This layer is present in *P. elegans*, but is only poorly developed (*m. l.*). Amongst the fibres composing it occur a certain number of ganglion cells (*g.*). Below

[1] In fig. 8 the marginal eyes are drawn proportionately too large.

the inner pharyngeal epithelium (*i. e.*) is a thick inner circular muscle layer (*i. c.*) followed by a narrower inner longitudinal layer (*i. l.*). Between this latter and the median longitudinal, or retractor muscle layer (*m. l.*) lie the salivary glands (*sa. gl.*), occupying fully one-half the width of the proboscis. Whilst passing through these the radial muscle-fibres are gathered up into more or less compact bundles.

Gut. The gut-diverticula are precisely similar in structure and arrangement to those of *P. siphunculus*. Their walls are crowded with exceedingly minute bacteria-like structures, which are entirely absent from other parts of the body. In the main-gut, however, I have found what appears to be a distinct kind of bacterial organism in various stages of growth (Fig. 71). The smallest, presumably the youngest stages, are rod-like; as the organism increases in size it gradually acquires a dumb-bell appearance, until finally it consists of two nearly equal sub-spherical masses united by a short stalk. Its subsequent fate I have not been able to trace.

Fig. 71. Bacteria-like organism from the gut of *Prosthiostomum elegans*.

Genital apparatus. Of the female organs only the vagina and shell-glands are developed; they are precisely similar to those of *P. siphunculus*, and in fact of most Cotylea. The male organs are in full functional activity. In this species the relative size of the terminal parts of the male apparatus is much greater than in *P. siphunculus*, otherwise they are very similar in the two species.

The two large vasa deferentia run inwards and forwards at their distal ends to open into the vesicula seminalis, a large sac with muscular walls, composed of circular fibres, lined on the inside with a flattened epithelium. The vasa deferentia do not open into the extreme hind end of the vesicula, but pass into its walls on either side a short way in front of its hinder extremity, and then run backwards in its walls for a short distance before opening into it. This arrangement may act as a valve to prevent 'regurgitation' of the sperm, when the vesicula is contracted suddenly. From the anterior end of the vesicle a ductus ejaculatorius runs forward to enter the penis. It is lined on the inside with a flattened non-ciliated epithelium, outside which is a very thin layer of circular fibres.

Immediately in front of the vesicula, lying side by side above the ductus, are two large spherical vesicles with thick muscular walls composed of circular fibres; outside the muscular layer is a sheath of specialized parenchyma, rather denser than the ordinary tissue. These vesicles are called by Lang 'accessory vesicles.' Their lumen, which is fairly spacious, is lined with a flattened epithelium, bearing a few cilia. Each is provided with a short duct —relatively much shorter than in *P. siphunculus*—which runs forwards, twisting greatly as it goes, lying for the most part dorsal to the ductus ejaculatorius. These accessory ducts, as they may be called, differ greatly from the latter. They are in the first place much narrower, they have a relatively thicker outside wall of circular fibres, and the epithelium through which they run is tubular, that is to say the ducts are intracellular. They pierce right through the muscular coats of the accessory vesicles. "Sie sind innen von einem verschwindend niedrigen Plattepithel ausgekleidet, in welchem die Zahl der einzelnen Epithelzellen andeutenden Kerne so gering ist, dass auf einen Querschnitt des Canales nie mehr als ein Kern zu liegen kommt, so dass man hier auch von durchbohrten Zellen sprechen kann." (Lang [9], p. 276.)

The ductus ejaculatorius (which for convenience I will simply call the ductus) as it approaches the base of the penis is joined by the two accessory ducts, which enter its walls and run forward in them for some distance, lying immediately to the outside of the epithelium of

the ductus itself. After entering the penis the two accessory ducts open into the ductus. The penis is curved downwards and a little backwards; it consists essentially of the end of the ductus, protected by a tapering chitinous tube or stylet, with a narrow lumen, projecting into the antrum masculinum. It can be protruded and withdrawn through the male gonopore by the action of muscle-fibres, attached to the base of the chitinous stylet.

The antrum consists of a small dorsal and a much larger ventral chamber separated from each other by a circular fold of its wall. The roof of the dorsal chamber is of course formed by the attachment of the basal part of the penis to the body. Its walls are lined with a flattened non-ciliated (?) epithelium, through which the secretion of a large number of gland-cells is being poured. These gland-cells lie beneath the epithelium, and may collectively be called the prostate glands. The walls of the dorsal chamber form the 'penis-sheath.' The ventral chamber of the prostate is lined with ciliated epithelium continuous with that of the surface of the body. Its walls have a muscular coat, consisting of an inner circular and an outer longitudinal layer of fibres.

The accessory vesicles are both full of the coarsely granular secretion (fig. 20, *s.*) of the gland-cells of the dorsal chamber of the antrum, and the same secretion is present in the accessory ducts. This secretion cannot be the product of the accessory vesicles themselves, and must reach them through their ducts. But it can only enter the ducts by passing from the antrum through the external opening of the penis stylet, and travelling up the penis to the opening of the accessory ducts into the ductus, and then turning down there. This Lang observes can come about in one of two ways. We may suppose that the secretion may be driven up the accessory ducts by contraction of the walls of the antrum, the male aperture and the ductus behind the openings of the accessory ducts being closed; or the secretion may be drawn into the accessory vesicles by a pumping action of the vesicles themselves. The latter is perhaps the more probable method[1].

The species appears to be most closely related to von Plehn's *P. nationalis* from the coast of Labrador [11].

15. *Prosthiostomum cooperi* sp. n. (Pl. XIV. fig. 2).

Two specimens, one semi-adult, the other immature, from Hulule, Male Atoll.

The larger individual is 17 mm. long and about 5·5 mm. broad.

Colour, milky white, margin of the body much folded. The adult has a series of fine black circular markings, arranged roughly in two parallel rows running down the middle of the back, from immediately behind the brain eyes, almost to the end of the body.

The anterior margin is rounded, the posterior pointed. The anterior marginal eyes are numerous and extend back along the margin considerably beyond the level of the brain eyes. These latter are arranged in two long, almost parallel series, which diverge slightly from each other at their ends.

Body-wall much as in *P. elegans*, but the rhabdites are much more numerous.

Genital apparatus. In both specimens the female organs are undeveloped. In the semi-adult the male apparatus is mature, but unfortunately rather displaced owing to the specimen having been damaged.

[1] An examination of Lang's diagram of the genital organs of *Prosthiostomum siphunculus* will enable the foregoing account to be much more easily followed, see Lang [9] T. 30, fig. 20.

The general arrangement of the terminal organs is similar to that in *P. elegans*, and the relative size of the parts is equally great. The vesicula seminalis lies transversely; this is probably owing to displacement. Its lumen, like that of the accessory vesicles, is relatively very small and the walls thick. The vasa deferentia unite before entering the vesicula, which lies transversely in the body possibly owing to displacement. The two accessory vesicles lie closely pressed together, and are bound up in a common sheath of specialized parenchyma. The glandular cells of the dorsal chamber of the antrum are well developed, but there is no secretion present either in the accessory vesicles or ducts.

The following table records the distribution of known species of this genus:—

	Mediterranean Sea	Atlantic Ocean		Indian Ocean[1]	Pacific Ocean		Polynesia
		English Channel	East Coast of North America	Maldives	Japan	Hong Kong	
1. P. siphunculus ...	*	*	...	...	...	...	...
2. P. dohrni	*	...	...	...	...	...	...
3. P. pellucidum[2] ...	*	...	...	...	...	...	...
4. P. sparsum	...	...	...	...	*	...	...
5. P. obscurum	...	...	...	...	...	*	...
6. P. tenebrosum ...	...	...	...	...	...	*	...
7. P. cribriarium ...	...	...	...	...	*	...	...
8. P. constipatum ...	...	...	...	...	*	...	...
9. P. elegans	...	...	...	*	...	...	...
10. P. cooperi	...	...	...	*	...	...	...
11. P. gracile	...	...	*	...	...	...	...
12. P. grande[3]	...	...	...	...	*	*	*
13. P. nationalis[4] ...	...	...	*	...	...	...	...

[NOTE. ON A SPECIMEN FROM CEYLON.

I take this opportunity of figuring and describing very briefly a typical *Cestoplana* obtained by Mr Stanley Gardiner off the Weligama reef, Ceylon.

Cestoplana ceylanica sp. n.

Very closely allied to *C. rubrocincta*.

Length about 65 mm., breadth 9 mm.

Anterior end of the body pointed. Colour (in the spirit specimen) dull gray with traces of a darker margin.

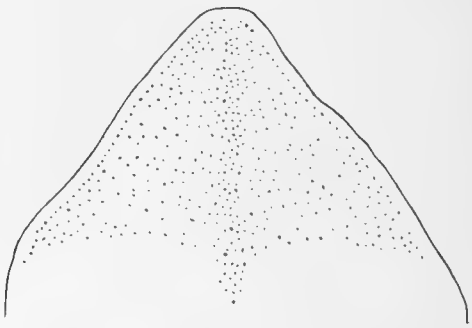


FIG. 72. Anterior end of *Cestoplana ceylanica*.

[1] Add an undescribed species from Ceylon.

[2] Doubtful species.

[3] It is possible that under this name more than one species is included by Lang, in fact different authors have described species from these three localities as distinct, but their descriptions are insufficient.

[4] See von Plehn [11].

Eye-spots (see Fig. 72) much as in *C. rubrocincta,* but the hinder margin of the eye-bearing area is straighter.]

II. NOTES AND CONCLUSIONS.

Most of the species described above have been examined by means of serial sections, the only satisfactory method of dealing with preserved specimens of this group. In some cases, however, I found it practicable to diagnose species sufficiently without having recourse to sections. This was especially the case with various specimens belonging to *Pseudoceros.*

I have not attempted to deal at all fully with the anatomy of any specimen described in the foregoing account, partly because space did not permit of my doing so and partly because Lang's Monograph has rendered it unnecessary. For fuller information concerning the anatomy of certain species of *Planocera* reference may be made to von Graff [6], and a very full account of the genus *Thysanozoon* has been given by von Stummer-Traunfels [14].

Planocera and a new Genus. Lang divides the genus Planocera as defined by him into two groups, A and B. These groups may briefly be defined as follows:—

A. Five to seven pairs of branches from the main gut. Penis cylindrical, its lumen lined with chitinous spines; lying in a muscular outer sheath. Female apparatus provided with a muscular bursa copulatrix.

B. Gut branches numerous. Penis styliform; no bursa copulatrix.

The really striking anatomical distinctions between the two groups argue equally marked physiological differences. That such exist is, I believe, shown by the fact that Wheeler [16] has proved that in *Pl. inquilina,* a species belonging to group B, hypodermic impregnation frequently occurs, in fact that in some cases the vagina may have no function other than that of a passage for the escape of fertilized eggs. A similar phenomenon may occur in other members of group B. On the other hand in group A the structure of the penis would preclude the possibility of hypodermic impregnation, whilst the presence of a large muscular bursa copulatrix indicates that fertilization is the result of a normal process of copulation. Such differences are quite sufficient to warrant the raising of the two groups to generic rank. The name *Planocera* must be retained for 'group A,' whilst for 'group B' I venture to suggest the name *Hoploplana.*

In Fig. 73 copied from Lang the arrangement of the genital organs of *Hoploplana insignis* is shown. If this figure be compared with Pl. XV. fig. 12, the difference between a true *Planocera,* such as *Pl. armata,* and *Hoploplana* will be apparent.

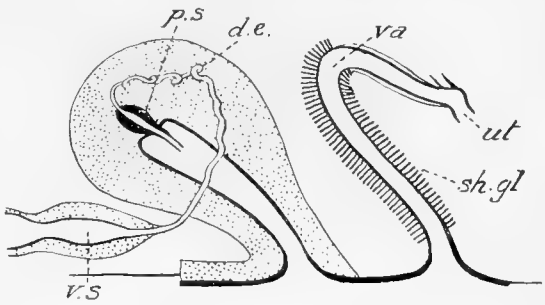


Fig. 73. Genital apparatus of *Hoploplana insignis* (after Lang). *va.* = vagina, *ut.* = uterus, *sh. gl.* = shell-gland, *v. s.* = vesicula seminalis, *p. s.* = penis, *d. e.* = ductus ejaculatorius.

The genus *Planocera* then as restricted may be defined in the same terms as group A is defined above, as Planoceroids with—Five to seven pairs of branches from the main gut. Penis cylindrical, its lumen lined with chitinous spines; lying in a muscular outer sheath. Female apparatus provided with a muscular bursa copulatrix.

It is obvious that *Pl. langii* differs more from any one of the other *Planocera* than they differ amongst themselves. The most pronounced differences are of course for the male apparatus the presence of paired vesiculae seminales, for the female the character of the bursa copulatrix, which appears to develope as an outgrowth from the vagina. I am inclined to suppose that an organ of a similar character occurs in Verrill's genus *Heterostylochus* [15]. In describing it he says of the female organs that, "a long narrow median duct runs far forward from the female orifice and expands into a flask-shaped seminal receptacle or spermatheca near the male organs; a swollen egg-duct also connects with the female orifice." The spermatheca may perhaps be the same organ that I have called the bursa copulatrix. Its true character may be judged from its appearance as shown in Pl. XV. fig. 13.

THYSANOZOON and THYSANOPLANA. Von Stummer-Traunfels [14] has recently suggested a modified definition of the genus *Thysanozoon* Grübe: "Pseudoceriden mit spitzohrähnlichen faltenförmigen Randtentakeln, mit zottenförmigen dorsalen Anhängen in welche bisweilen Divertikel der Darmäste hineintreten, ohne jedoch daselbst auszumünden: mit einfach oder doppelten männlichen Begattungsapparate."

The genus is thus made to include a number of tropical species, several new species being described in an interesting review of the genus by this author, who has also given a series of beautiful figures of most of the species. He finds that of all the species known to him only one, viz. *Thysanozoon brocchii*, has the dorsal papillae invaded by gut-diverticula. *Thysanozoon brocchii* and about six other species have paired male apparatus. *Th. auropunctatus* (Kel. Coll.) and several others have an unpaired penis.

Von Plehn [10] has described a new genus, *Thysanoplana*, containing two species evidently closely allied to *Thysanozoon*. It is separated from this genus on the following grounds. Firstly, "Im Gegensatz zu *Thysanozoon* der männliche Apparat ist unpaar." Secondly, "Hauptdarm mit zahlreichen vielfach übereinander entspringenden Darmastwurzeln." The papillae are stated definitely to be invaded by gut-diverticula.

Now if we accept von Stummer-Traunfels' amended definition of the genus *Thysanozoon*, it is evident that the first of the characters, viz. the unpaired male apparatus, will not serve to distinguish *Thysanoplana* from *Thysanozoon*, and as to the second I have found that a similar peculiarity, though much less marked, occurs in *Thysanozoon plehni* (mihi), whilst traces of the same occur even in *Thysanozoon brocchii* (see above). Accordingly in this case the generic name *Thysanoplana* cannot, I think, be maintained.

On the other hand, if we do not accept the amended definition and retain *Thysanoplana*, it will be necessary to subdivide *Thysanozoon* into several genera as follows:—

A. Species with gut-diverticula in papillae.
   - *a.* Penis unpaired (*Thysanoplana*).
   - *b.* Penis paired (*Thysanozoon brocchii*).

B. Species without gut-diverticula.
   - *a.* Penis unpaired (*Thysanozoon plehni*, etc.).
   - *b.* Penis paired (*Thysanozoon*, sp.).

The mode of origin of the gut-diverticula cannot, I consider, be employed as a generic character. On the whole it is simplest at present to refer all the described species to the

genus *Thysanozoon*, and consequently *Thysanoplana* must be referred to the synonymy of that genus. When it becomes advantageous to divide up the genus, the best guide to a correct grouping of the species will probably be found in the presence or absence of gut-diverticula in the dorsal papillae.

Distribution in the Indian Ocean. Great interest attaches to Mr Stanley Gardiner's collection owing to the fact that it is not only the first made in the neighbourhood of the Maldive and Laccadive Archipelagoes, but also that it is one of the largest ever made in the Indian Ocean; certainly the largest since the publication of Lang's Monograph. It is not of course possible on our present knowledge of exotic forms to discuss the distribution of marine Turbellaria, yet a few points are worthy of remark in connection with these specimens.

Firstly, it will be noted that the Euryleptidae are entirely lacking in the collection. We must not assume therefore that they are altogether absent from the reefs of the Archipelago, but we are certainly justified in supposing them to be of considerable rarity in that neighbourhood. This is the more remarkable when we remember that the Euryleptidae are well represented on the coast of Ceylon, and are known to occur in most seas.

I quote here an extract from Mr Gardiner's notes: "I have no lists, nor can I find any account of the Turbellaria round continental tropical coasts, on which to base any comparisons as to the relative abundance of the group in the Maldives. From a limited examination of some reefs at Weligama and off the Jaffna coast of Ceylon I am inclined to think that they are very much less abundant in the Maldives, both in number and variety of species."

Secondly, the relatively high percentage of Pseudoceridae in the collection is striking. In addition to the five or six species of *Pseudoceros* given in the systematic part there are fragments of a specimen, which must I believe be referred to this genus, but is too much broken to describe.

Probably the Prosthiostomidae and Cestoplanidae will prove to be abundant over the whole of the Indian Ocean, and we may expect to find, especially in the latter family, forms of great interest. I have in my possession a collection of Turbellaria made by Mr Evans near Penang. This collection contains not less than two new Cestoplanoids, one of them a very remarkable creature with a complete series of marginal eyes which are much more numerous than those of *Cestoplana maldivensis*; its body also is relatively much longer.

Lastly, the occurrence of *Pericelis byerleyana* and of *Leptoplana pardalis* in the Tropical Pacific as well as in the Maldives' Archipelago is of interest. Two other widely distributed species, *Leptoplana tremellaris* and *Thysanozoon brocchii*, are known, but both of these occur in north temperate as well as in tropical seas.

Parasites. In none of the specimens in this collection, of which I have cut serial sections, have I found any gregarine parasite such as that which is found commonly in *Leptoplana tremellaris*[1]. On the other hand I would call special attention to the occurrence in two species, viz. *Planocera armata* and *Prosthiostomum elegans*, of bacteria or bacteria-like structures, which in both cases, but especially in the former, appear to occur only in certain definite situations.

Gut-Diverticula. Similar gut-diverticula to those found in *Planocera armata* occur also in other Planoceroids. Whilst morphologically they are not unlike the diverticula which invade

[1] I have not been able to identify this species. *Discocelis tigrinia* is infested with *Ophiodina discocelidis* Mengazzini, which is probably closely allied to it.

the dorsal papillae of *Thysanozoon brocchii*, it may be questioned whether their function is similar. In *T. brocchii* on the one hand these diverticula may assist in the aeration of the tissues. In *Planocera armata* on the other hand it is difficult to suppose that they can have this function; I think it possible that they may rather be concerned in some way with nitrogenous secretion.

The function of the dorsal papillae of certain species of Thysanozoon, which contain no gut-diverticula, is also obscure. In *Thysanozoon plehni* the curious plug-like mass of tissue at the upper end of the diverticulum is to some extent suggestive of being connected with the function of excretion.

Relationships of the Cotylea. In dealing with *Pericelis*, *Thysanozoon* and *Prosthiostomum* in the systematic part of this paper I have given a fairly full account of the male genital apparatus of each, so that it is possible to compare and contrast the three chief forms that this organ assumes in the Cotylea. The arrangement of the eye-spots in *Cestoplana maldivensis* and *Pericelis byerleyana* completely round the margin of the body is so far as at present known only paralleled in *Anonymus virilis*, *Cryptocelis*, and perhaps in *Heteroplana newtoni*. I believe that this marginal distribution of the eye-spots is to be regarded as a primitive character derived from a radially symmetrical ancestor.

In the *Cotylea* other indications of a radial structure are most strongly developed in *Anonymus virilis*. Such indications are the sub-central mouth and the numerous male organs grouped around the single female aperture. The presence of organs in this species bearing a general resemblance to nematocysts is probably also an ancestral character, so that if we adopt the usual theory and assume that the Polycladida are derived from an ancestor possessed of radial symmetry we are justified in regarding *Anonymus* as nearer to this ancestral form in certain respects than are the other Cotylea.

Intermediate between *Anonymus* and the higher Cotylea stands *Pericelis byerleyana*, the most interesting type in Mr Gardiner's collection. This approaches *Anonymus* in having marginal eyes and a sub-central mouth. Like this genus too it has a median indentation of the anterior margin, whilst the structure of its penis approaches that of the latter more closely than that of other Cotylea. On the other hand the possession of tentacles, a single penis and uterine vesicles, ally it rather to the higher Cotylea, such as the *Pseudoceridae* and *Euryleptidae*, whilst the extreme folding of the margin, the wide separation of the small tentacles and the backward position of the genital apertures serve to distinguish it sharply from all its allies.

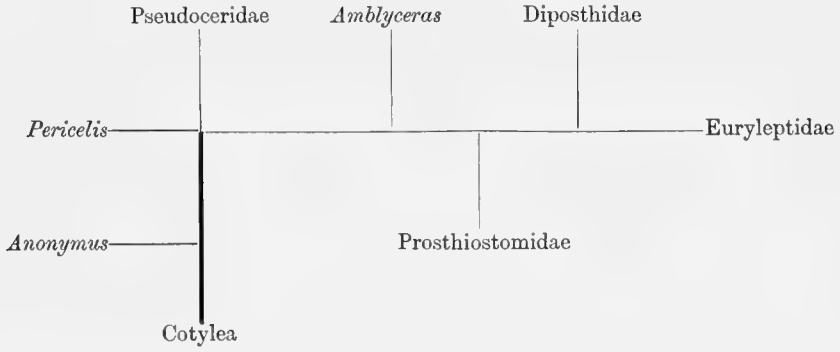
The marginal tentacles of *Pericelis* are of particular interest. They are of a simple and primitive character and indicate clearly the manner in which these organs have arisen in the Cotylea by the concentration of the marginal eyes on a pair of specialized folds of the margin. We can hardly doubt that this concentration has accompanied the acquisition of polarity in the organism in its development from a radially symmetrical ancestor. The fact that *Anonymus* has no tentacles, suggests the probability that this remarkable form is far more primitive than other Cotylea in that it has never acquired such organs.

A further development of the tentacles accompanied with the loss of the marginal eyes, save of such as have come into connection with the tentacles, gives us the condition found in the *Pseudoceridae* and *Euryleptidae*. The former family has a more primitive type of pharynx than the latter, in which it is tubular; in the *Pseudoceridae* it is not unlike that of *Anonymus* or *Pericelis*.

The *Prosthiostomidae* resemble the *Euryleptidae*, from which family they are probably derived, in possessing a tubular pharynx. They have no marginal tentacles, but the absence of these is probably secondary, perhaps a consequence of their elongated form. The structure of their male apparatus is very extraordinary, quite unlike that of other Polyclads.

Lastly, the family *Diposthidae* described by Woodworth [20] from the barrier reef of Australia is probably closely allied to the *Euryleptidae*, but unfortunately no account is given of the pharynx. *Amblyceras* is regarded by von Plehn [12] as intermediate between the *Pseudoceridae* and *Euryleptidae*.

The accompanying tree illustrates the presumed relationships of the Cotylea diagrammatically.



The characters of the terminal parts of the female apparatus give strong support to the view that the Cotylea constitute a perfectly natural group. In none of them is the vagina prolonged backwards beyond the point at which the uteri open into it to form an 'accessory vesicle' or receptaculum seminis; its walls are never developed to form a muscular 'bursa copulatrix,' and the shell-glands always open into it close to the gonopore. Whatever specialization of the female apparatus has been developed has occurred either in connection with the oviducts themselves as in *Oligocladus* or with the uteri as in *Pericelis* and *Diposthus*.

[The presence of an accessory vesicle in *Enantia*, as well as the arrangement of the eye-spots and the absence of a sucker form a combination of characters which forbid us to refer it, as Benham does [3], to Cotylea. In the possession of a gut anastomosis it does not by any means stand alone amongst the Acotylea, witness *Leptoplana pardalis*, *Planocera villosa*, *Eustylochus ellipticus*.]

Cotylea and Acotylea. The Acotylea can be distinguished broadly from the Cotylea by the fact that the former as a rule possess an accessory vesicle, a continuation of the vagina behind the point where it receives the uterine opening, though this is by no means invariably the case, *e.g.* the genus *Hoploplana*. But the most striking and most constant distinguishing feature (apart from the sucker) of the two divisions is afforded by the tentacles, when they are present. Those of the Cotylea have already been dealt with, and are of course universally marginal.

In the Acotylea marginal tentacles never occur; when they are present they lie dorsally immediately over the brain. In the *Leptoplanidae* and I believe in *Enantia* these tentacles, which in the *Planoceridae* always carry eye-spots, have been lost, the eye-spots connected with them have nevertheless been retained, at any rate in most cases. In the Cestoplanidæ so far as we know there are no traces of tentacles distinguishable (cf. the other elongated family,

Prosthiostomum). In speaking of the remarkable *Polypostia* Bergendal [1] remarks that 'tentacle eyes' can scarcely be distinguished. In passing we may notice that like *Anonymus, Polypostia* is provided with a number of male copulatory organs surrounding the female aperture. The fact is that some of the hinder pairs are not connected with the sperm-ducts. This is regarded by Lang as an indication that the penis in Polyclads is derived from glandular organs, which have only a secondary connection with the sperm-ducts. Whilst this is very probably true, it is possible that in *Polypostia* we have a stage in the disappearance of the multiple radially arranged penes that appear to be an ancestral character. In this connection reference may be made to the paired penes of certain *Pseudoceridae.*

Origin of Nuchal Tentacles. Of the origin of the tentacles of the Acotylea two views are held:—

(1) That adopted by Lang, who, following Chun, brings forward evidence for supposing the Polycladida to be derived from a Ctenophore-like ancestor; and homologizes the dorsal tentacles of the Planoceroids with the retractile tentacles of certain Ctenophores.

(2) That of Willey [17], who also derives the Polyclads from a radially symmetrical Ctenophore-like ancestor. He suggests that the dorsal tentacles of Polyclads are homologous with the sensory tentacles found in certain Ctenophores, and especially in Ctenoplana.

I here have to put forward a third suggestion, which differs completely from either of the preceding. Without questioning the probability of the origin of the Polyclads from a radial ancestral form, or the possibility of that form being also allied to a form ancestral to the Ctenophores, and avoiding any discussion as to the axial relationship of two groups, I consider that the tentacles of the Polyclads, whether marginal or nuchal,

(1) are a structure peculiar to the group;

(2) that they originated as marginal organs in connection with the eye-spots, somewhat in the way I have suggested above;

(3) that in the Cotylea they still retain this condition;

(4) that in the bulk of the Acotylea they have shifted back from the margin and come to lie dorsally.

This theory offers a more satisfactory explanation of the relationship of the Acotylea to the Cotylea than is possible on either of the two first. For, if we adopt either of these, we must suppose that the Cotylea are descended from forms which have lost all traces of the nuchal tentacles, and have in most cases acquired marginal tentacles. Now the *Leptoplanidae* have lost the dorsal or nuchal tentacles but have in almost every species retained evidence of their existence in the tentacle eye groups, whilst none of them have developed marginal tentacles, although some of them, *e.g. Discocelis,* have retained marginal eyes. On the other hand no Cotylean species ever exhibits any trace of a nuchal tentacle eye group.

On my theory there is no reason to regard the Cotylea as less primitive than the Acotylea; in fact the balance of evidence distinctly inclines to the opposite view. If we leave out of account the elongated, obviously highly specialized forms in either group, *i.e.* the *Prosthiostomidae* and *Cestoplanidae,* the Cotylea present far greater uniformity and less complexity of organization of the genital apparatus than we find in the Acotylea; whilst most

of the special features of the gut-branches of the Pseudoceridae (viz. dorsal diverticula of *Thysanozoon*, marginal pores of *Yungia*) are paralleled in the Planoceroids and in *Polyporus*.

Starting from a hypothetical, primitive, non-tentaculate form such as *Anonymus*, there is no difficulty in deriving both the Cotylea and Acotylea from it, if we admit that the tentacles in the two groups are homologous. There is no difficulty in supposing the margin of the body to have coalesced in front of the tentacles, and these latter to have moved back carrying their eyes with them, and come into connection with the dorsi-ventral muscles. As will be seen, this theory accounts readily for the presence of eye-spots in connection with nuchal tentacles.

There is a possibility that some of the more primitive Acotylea may be directly descended from forms that have never developed tentacles, but evidence on this point is lacking. On the whole I think that the balance of evidence inclines strongly to the view I have here advanced, which has the advantage of being better correlated with what is known of the anatomy of the group[1].

Natural History Notes. I append some interesting notes given me by Mr Gardiner:—

"All the forms were preserved with $HgCl_2$; but, however much they may be expanded, all contract when the corrosive sublimate solution is poured on them, hot or cold. Anaesthetization by cocaine was useless, for, without keeping the animal quiet and expanded, it caused the excretion of a large quantity of mucus and this prevented the fixing fluid from getting at the tissues. Usually in cocaine, too, the animal began to rot and break up before it was sufficiently quiet to be killed. Chloral hydrate seemed to have little effect and alcohol did not begin to act for some hours, and as soon as the animal became quiet it began to secrete mucus, a fatal difficulty. The best way to preserve would be, I believe, to drop specimens straight into a bottle of $HgCl_2$ on the reef itself or into strong—at least 10 per cent.—formaline, removing after 15—30 seconds into concentrated corrosive.

"It is almost impossible to get the *Thysanozoons* off the rocks, as they break up readily. With all forms the only really effective way is to tease them and make them project themselves into glass tubes. A large *Thysanozoon* (?) secreted an enormous amount of mucus, and broke up rapidly into separate pieces; its mucus collected a large amount of dirt, and killed the other animals in the bottle. It also extruded a quantity of faecal matter. The smooth-skinned forms do not secrete so much mucus, but really each form requires to be placed at once and killed in a separate vessel.

"I carefully examined for the food of these Platyhelminths and found them browsing on Tunicate colonies and sponges, whilst others had been eaten by them under the same stones. Weed was not generally touched, but dead animal-matter laid down under stones proved an attractive bait. They do not browse on *Cylicia*, *Coenopsammia*, nor any of the corals whose normal habitat is their own. Hydrozoa and Actinia too are not touched. Often at Hulule I turned over rocks which had Tunicate sponges and colonies of hydroids; but it was only the Tunicates that were generally attacked, the sponges being rarely touched.

"The Turbellaria live principally under stones and rock, especially where the latter is lying freely upon the reef. Sand is deleterious, and, if much of it is present, no forms will be found. When a rock is overturned the Planarians hurry off in all directions, some over

[1] I am aware that the embryological method lends no support so far as I know to this view, but neither does it make for either of the alternatives.

its edge, but the majority into any holes on its surface. If however the hand is placed over one, it will remain contented for some time in any damp spot and will not come into the light. That the latter in any strength is what the animals object to is clear, as in glass vessels they always get to the side away from it and hide under the lee of any stones which may be placed in the water.

"It is noteworthy that the Turbellaria do not generally occur on reefs or reef-patches within the lagoons, nor indeed where there is not an ample change of water. The animals are never found on growing coral, perhaps on account of the light.

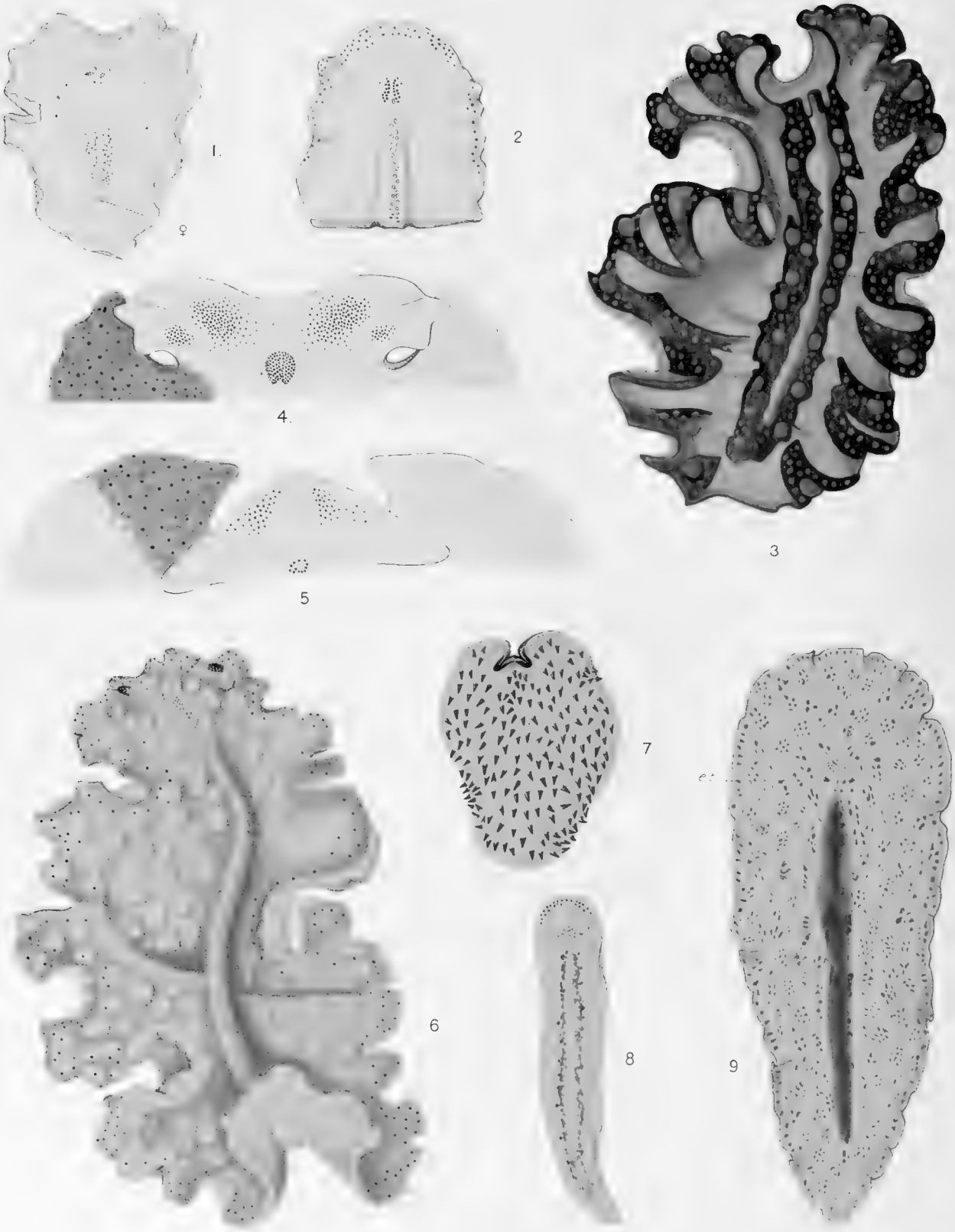
"The colours are in no sense protective, nor do I think they can be warning. I have never seen, either on the reef or in basins, any free-living animals attack them, though I have expressly placed various species together in glass beakers for this purpose.

"I would suggest that the pigment is respiratory. It is, I believe, quite true for each species. Under any rock mass it is common to find many Tunicate colonies of one species, and one species only. This may be white, red, pink, blue, or purple, yet the Turbellaria did not appear to me to differ in colour under different masses of rocks."

In conclusion, my thanks are due to Mr Stanley Gardiner for giving me the opportunity of undertaking this work, and to Dr Gamble for much assistance with regard to literature. To both these gentlemen I am indebted for useful advice and suggestions. I have also to thank Professor Hickson, both for permission to carry out my examination of this collection in the Zoological Laboratory at Owens College and for the kind interest he has displayed in the work.

III. LITERATURE.

1. Benham. *Treatise on Zoology*, Pt. iv. 1901.
2. Bergendal. *Köngl. Fysiogr. Sallskapet; Lund Handlingar Ny Följd.* 1892—93, Bd. 4.
3. —— *Rev. Biol. Nord France*, v. pp. 257—366.
4. Collingwood. *Trans. Linn. Soc. Lond.* ii. (Zool.) i. 1875.
5. Gamble. *Q. J. M. S.* xxxiv. p. 433 (1893).
6. Graff, v. *Zeitschr. wiss. Zool.* lv. 1893, p. 189.
7. —— *Mitth. naturwiss. Ver. für Steiermark*, Jahr 1889.
8. Ijima. *Zeitschr. wiss. Zool.* xi. (1884), p. 359.
9. Lang. *Naples Monogr.* xi. 1884.
10. Plehn, von. *Jena Zeitschr.* xxx. p. 137, T. viii—xiii.
11. —— *Ergebn. Plankt.-Exp.* Heft i. (1896).
12. —— *Jena Zeitschr.* xxxi. p. 90, T. v. (1898).
13. —— *Zool. Jahr. Syst.* xii. p. 448—452, 2 figs. (1899).
14. Stummer-Traunfels, von. *Zeitschr. wiss. Zool.* lx. p. 688, T. xxxv—xxxviii.
15. Verrill. *Trans. Connect. Acad.* viii. pp. 459—520.
16. Wheeler. *Am. Journ. Morph.* ix. p. 167 (1894).
17. Willey. *Q. J. M. S.* xxxix. pp. 323—342.
18. —— *Q. J. M. S.* xi. pp. 293—205.
19. Woodworth. *Bull. Mus. Harvard*, xxi. p. 1 (1891).
20. —— *Bull. Mus. Harvard*, xxxii. pp. 63—67 (1897).



Laidlaw - Turbellaria

F. Wilson, lithograph, sc

EXPLANATION OF PLATES.

♂ = male aperture.
♀ = female aperture.
a.d. = accessory duct.
a.m. = antrum masculinum.
a.v. = accessory vesicle.
b.c. = bursa copulatrix.
c = chitinous stylet.
c.d. = common duct.
c.e. = columnar epithelium.
c.h. = chitinous hooks.
c.r. = chitinous ring.
c.s. = chitinous spines.
d = gut-diverticulum (of *Planocera armata*).
d.e. = ductus ejaculatorius.
e.t. = tentacle-eyes.
h = hyaline layer.
hy = hyaline secretory bodies.
n = nervous tissue
o.s. = outer sheath.
p = pigment.
p.g. = pigment granules.
p.m. = pigment mass.
pe = penis.
pl = fold of lining wall of the penis.
pr = prostate gland.
p.r. = pseudorhabdites.
p.m. = intrinsic muscles of the penis.
p.s. = penis sheath.
r = rod-like bodies or bacteria.
r.m. = retractor muscles.
rh = rhabdites.
s = secretion.
s.g. = shell-glands.
s.p. = dark secretory bodies.
u = uterus wall.
u.g. = glands on the uterus.
u.v. = uterine vesicle.
va = vagina.
v.s. = vesicula seminalis.
ves.d. = duct from the uterine vesicle.
y = cells resembling yolk-glands.
x = 'plug-like' tissue at the tip of a dorsal papilla.

PLATE XIV.

FIG. 1. *Planocera langii* n. sp.

FIG. 2. *Prosthiostomum cooperi* n. sp. Anterior third of adult specimen.

FIG. 3. *Pseudoceros tigrinus* n. sp.

FIG. 4. *Pseudoceros gardineri* n. sp. Tentacles, eye-spots of the dorsal surface and part of the anterior margin.

FIG. 5. *Pseudoceros punctatus* n. sp. for comparison with the preceding species.

FIG. 6. *Pericelis byerleyana* n. sp.

FIG. 7. *Thysanozoon plehni* n. sp.

FIG. 8. *Prosthiostomum elegans* n. sp.

FIG. 9. *Leptoplana pardalis* n. sp.

PLATE XV.

FIG. 10. *Planocera armata.* Transverse section across one of the gut branches, showing on its dorsal side a pouch-like diverticulum. × 500.

FIG. 11. Longitudinal median section through the genital apparatus of the same, reconstructed from transverse sections. Somewhat diagrammatic. × 60.

FIG. 12. Transverse section across the penis of the same at the level of the chitinous hooks. × 110.

FIG. 13. Transverse section of the penis of *Planocera langi* at the level of the pair of large folds projecting into the lumen. The section also passes through outer sheath and the 'receptaculum seminis.'

FIG. 14. Transverse section through the penis of *Leptoplana pardalis.*

FIG. 15. Longitudinal section through part of the oviduct of *Pericelis byerleyana*, passing also through one of the accessory uterine vesicles.

FIG. 16. Section passing transversely through part of the oviduct of the same.

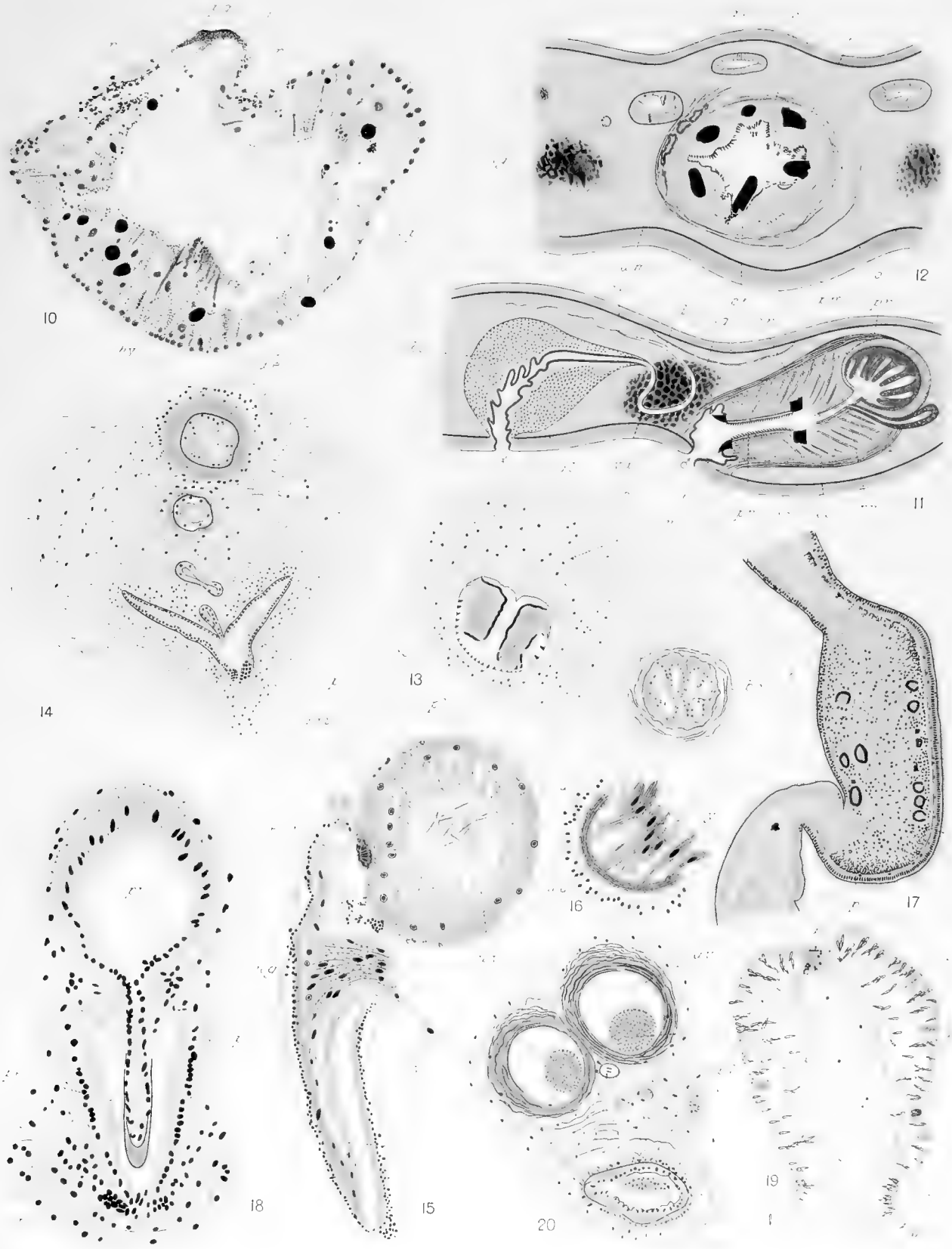
FIG. 17. Transverse section through a tentacle of the same showing the very regular columnar arrangement of the epithelium on the dorsal surface[1].

FIG. 18. Section through the penis of a specimen of *Pseudoceros gamblei.*

FIG. 19. Section through a dorsal papilla of *Thysanozoon plehni* showing the absence of any gut diverticulum; and the curious 'plug-like' mass of tissue (x) at the tip of the papilla.

FIG. 20. Section through the accessory vesicles of the penis and part of the antrum masculinum of *Prosthiostomum elegans.*

[1] Indicated by the lettering *c.e.*



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THE MALDIVE AND LACCADIVE GROUPS, WITH NOTES ON OTHER CORAL FORMATIONS IN THE INDIAN OCEAN (*continued*).

By J. Stanley Gardiner, M.A., *Fellow of Gonville and Caius College, and late Balfour Student of the University of Cambridge.*

(With Plates XVI. and XVII. and Text-Figs. 74 and 75.)

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(*To be continued.*)

APPENDIX A.

SECTION I. THE SEAWARD SLOPES OF ATOLL REEFS.

I HAVE already repeatedly referred to the subject-matter of this Section in the previous Chapters of this Report (pp. 38—44 and 177). I have also therein stated that the reef is growing up everywhere outside the atolls (p. 49) without really attempting to show or prove that such is the case—to a certain extent assuming the upgrowth to be a matter beyond dispute. I have done so for two reasons, (1) to simplify the subject-matter in the previous chapters, and (2) because I felt that without a special, more detailed, yet somewhat generalised account of the whole seaward slope it would be impossible to satisfactorily show the evidence on which the above deduction was based. In the following pages I have attempted such a description, but I freely recognise that our investigations of the seaward slope in the Maldives were scarcely sufficiently complete to really warrant my doing so.

The outer or seaward slope of any bank in the Maldives opposite its encircling surface reefs is usually covered with a dense growth of corals and other organisms down to the depth at which the steep commences. The edge of the reef, although broken up by fissures extending into it for some distance, is usually fairly well-defined. Beyond it the seaward slope, as deep as the eye can see, *i.e.* to about 15 fathoms, is generally much broken up by masses and buttresses of the rock, the latter extending out at right angles from the reef, as well as by large colonies of corals. At least the latter evidently continue further out to 25 or 30 fathoms, the lead down to these depths often resting for a moment and then dropping off again for an additional 2 or 3 fathoms. The bottom, however, so far as the actual masses of the reef rock are concerned, actually becomes more level with each additional fathom of depth, until beyond 30 fathoms the reef-platform in the slope of its foundation rock is almost or quite level.

The reef edge and the area immediately outside it are extremely difficult and dangerous to examine on account of the rollers, which, always breaking to some extent even in dead calm weather, are followed by a strong outrush of water. The surface of the rock in this position is fairly smooth, being generally covered with incrusting *Lithothamnion* or with great colonies of a yellow Zoanthid Actinian. On those masses and buttresses, that are exposed in the backwash preceding each breaker, the upper surface of the rock is generally pitted, a little green weed often growing in its hollows. The sides of the masses commonly overhang, and are usually covered with *Lithothamnion*. Down to 5 fathoms the corals are of stunted growth and are only found in such hollows as are more or less protected from the rushes of water, which follow each breaker. The bottoms of the channels between the ridges usually appear white in colour, as if silted with small pebbles or coarse sand. In addition large coral masses may occasionally be distinguished. The filling up then of the fissures between the buttresses and masses would naturally to some extent follow their upward growth.

The dominant organisms in the formation of the masses of rock between the surface and 5 fathoms are undoubtedly those of the genus *Lithothamnion*. Unfortunately we know little or nothing about the mode or rate of growth of these plants, but the rate can scarcely be nearly as rapid as that of corals. The latter organisms may then perhaps be of far greater importance than the number or bulk of their living colonies in this area would at first sight lead anyone to suppose. That the reef is growing up admits of no doubt. In the few fragments of rock, I obtained between 1 and 5 fathoms, the species of *Lithothamnion* show a definite, though perchance somewhat irregular, layered growth. Boring organisms, etc. in them are rare, and neither they nor the corals of the area show any rotting of any sort. In Fiji I saw a few masses of rock broken off the edges of reefs in hurricanes and hurled back on to the reef flats, *i.e.* true negroheads. In the Maldives on the other hand, such negroheads do not exist on those reefs which fringe the open ocean. Moreover I never saw any sign whatever of the breaking off of definite masses of rock, either large or small, to seaward of any ordinary reef, nor for at least a dozen yards within its edge[1]. The absence, too, from the seaward shores of islands of fragments of coral or recent rock except such as grow or form on the reef flats proves of how little importance in the Maldives the destructive action, even of heavy gales, is on the edges of the reefs.

The next zone, 5 to 10 fathoms, shows a transition to the third, 10 to 15 fathoms. In the latter buttresses and masses are scarcely recognisable as such. No overhanging rocks with definite channels or fissures between are found. There is, nevertheless, a tendency for lines of low elevations—in section transverse to the slope appearing as rounded undulations —to run out at right angles to the reef behind, but even these are not always very distinct. Occasionally hollows, 2 fathoms or more deep, with sandy bottoms are seen, generally considerably overhung by growing corals. Such pools are, however, rare on those sides of the reefs, which are fully exposed to the ocean, but the whole of this area is sometimes represented by a succession of them. This is notably the condition, where the slope is protected from the full force of the ocean, such as against channels between atolls and against the central basin of the group, the Great Maldive Sea.

[1] In this connection I do not refer to the breaking off of branches of corals, etc. by the undercurrent on the reef slope, which follows each breaker (see p. 24). Any loose material may assist to fill in the hollows and crevices on the reef surface, but by far the greater part is undoubtedly carried out over the edge of the steep, thus extending the whole reef further and further seaward.

Even where the reef lies against the open sea, it is freely studded between 10 and 15 fathoms with species of nearly all the massive genera of corals, forming rounded colonies up to a few feet in diameter, often dead in the centre. The branching genera are not perhaps as numerous; where they occur the facies of their growth is that of low spreading thickets with very occasionally a larger tree of some vigorously growing species of *Madrepora* or *Pocillopora,* casting defiance at all law and reaching to within 3 or 4 fathoms of the surface. The reef in the above-mentioned, protected situations in many places appears to be almost completely covered with growing corals, which interlock, strive and struggle with one another in the same way and quite as much as, or even more than, on the most luxuriant lagoon reef in the whole group[1].

Lithothamnion may appear almost non-existent in a surface view, but on all outer slopes at this depth (10 to 15 fathoms), wherever a bare space is to be seen,—not a pit overhung by corals—there at the least a thin coating of the incrusting species of this organism will certainly be found. Sometimes the forms of the genus seem to grow into rounded or nodular masses, 2 to 3 feet or more in diameter, and standing up on the basal rock, but all such that I have examined have a basis—a central nodule—formed by some coral or other organism, which they have overgrown and perchance killed. Even in small masses of less than a foot in diameter a thickness for the nullipore of 2 to 3 inches is not unusual. In reality nearly everywhere these calcareous plants are growing at the bases of the corals. The coral colonies are ordinarily dominant, but, when one becomes sickly, the species of *Lithothamnion* soon claim sway, and extinguish it. In addition small, coarsely or finely branching growths of the same genus are also found, but these facies are of little importance as reef builders. Indeed the main significance of *Lithothamnion* lies in the peculiar mode of growth of its incrusting species. Whatever is reclaimed from the sea by any coral organism is secured by these plants, and firmly anchored once for all time to the reef so far as the action of the external ocean is concerned.

Dredging on the outer reefs is such uncertain work even in a steamer—and in addition so dangerous in a sailing vessel as to be almost impossible—that we could not afford the time necessary to make a proper study of the organisms below the depth of 15 fathoms, above which we could see what we were doing. Such organisms, as we secured from it, were only obtained while attempting to ascertain its general topography, of which I have already given a sufficiently full account.

[1] It is quite impossible to collect and investigate an area such as this without extremely calm weather, tackle of the strongest description, and most important a steamship.

A *Priestman's grab,* such as can be used by hand, seldom secures a coral of any massive genus and only broken stems of branching genera. The smaller massive colonies spread outwards at their attached bases, and the grab cannot be fixed on them. Moreover there is always some roll of the sea even in the calmest weather, and, when a coral mass of even 8 or 10 inches in breadth is securely fixed in the grab, a whaleboat or small launch will be pulled under the approaching waves before it be released.

The genera of the corals from 0 to 5 fathoms, forming only small colonies and the zone being difficult to examine, could not be accurately determined. Finely branching species of *Pocillopora* were, however, evidently by far the most abundant.

The following is a complete list of coral genera observed from 5 to 15 fathoms outside the reefs, the first 10 arranged in the order of their importance as builders in this position:

1.	*Madrepora.*	*Symphyllia.*
2.	*Pocillopora.*	*Merulina.*
3.	*Astraeopora.*	*Mussa.*
4.	*Orbicella.*	*Fungia.*
5.	*Astraea.*	*Pachyseris.*
6.	*Prionastraea.*	*Domoseris.*
7.	*Montipora.*	*Seriatopora.*
8.	*Coeloria.*	*Stylophora.*
9.	*Pavonia.*	*Anacropora.*
10.	*Porites.*	*Dendrophyllia.*
	——	*Millepora.*
	Leptoria.	

The gradual passage of the outer slope of any reef into a fairly smooth platform points to the fact that the foundations of the existing, encircling surface reefs of the atolls are really laid at some depth below 25 fathoms. Many of the same genera of branching corals (Madreporaria)—perhaps even the same species—occur at 30 fathoms as are found at 10 to 15 fathoms, but their form of growth is quite different. At the lesser depth the coralla are dense and heavy, the branches relatively thick and massive, and the colonies of large size compared with the sickly growths obtained at the greater depth. The genera of corals found at 15 fathoms are also mainly those that occur on the reefs, but at 30 fathoms additional genera make their appearance. Leaving genera of simple or of semi-simple species out of account, *Dendrophyllia, Goniopora* and *Alveopora* all grow in great luxuriance. Our swabs came up nearly every time thickly crowded with the branches of *Dendrophyllia ramea*, and many masses and fragments of the others were secured. Of even greater importance off Addu atoll was the Alcyonarian *Heliopora coerulea*, which was secured in each of six dredgings from 25 to 45 fathoms. Its facies were staghorn, lamellate and almost massive, and the quantity secured would show that large areas of the bottom must be covered by its colonies. In two of the dredgings pieces of the Hydrocoralline *Millepora* were obtained, and the same coral was also found incrusting a fragment of dead *Anacropora*. *Halimeda* is abundant, and *Lithothamnion* of incrusting or low branching facies also occurs. The position of the latter, nevertheless, is largely taken by incrustations of white *Polytrema*, to the importance of which Chapman[1] has lately drawn attention. Dead blocks of coral or other rock are not infrequent, and are generally completely or in great part covered by this organism. Of other animals, of little or no importance in building up reefs, it is only necessary to remark that this area is essentially the home of Gorgonians and Crinoids, while Alcyonaceans are very common. No deposit of sand or small rubble, be it observed, is ever found at these depths.

The most striking character of the whole of the seaward slope to the commencement of the steep, *i.e.* the reef platform, off the atolls of the Maldive group, is the almost complete clothing of the bottom with organisms of various kinds. The bare rock is practically nowhere exposed to the sea, so that the possibility of the latter eroding or dissolving away the rock must be over the whole outer slope largely discounted. All the corals and calcareous organisms, obtained from the reef platform, markedly differ from those off surface reefs or from lagoons, in that boring organisms are almost completely absent. Indeed all indications of change point to the active growth upwards of the whole bottom in this region of the seaward slope rather than to the possibility of its being by any means washing away.

Section II. The Formation of Lagoons.

The matter dealt with in this Section has already been to some extent considered in the preceding Chapters, but the subject is of wide interest in view of the various theories that have been propounded to account for the formation of coral atolls. There are also a few points to which attention should be more particularly drawn in the conditions at the present time of some of the atoll lagoons in the Maldive group.

Addu atoll[2], firstly, is of interest in that its lagoon is filling up rather than increasing

[1] *Jour. Linn. Soc.* vol. XXVIII. pp. 1 and 161.

[2] The work in this atoll was carried on in the intervals of fever, and was not nearly as complete as I could have desired. As it is, I am indebted to Mr Forster Cooper and Capt. Molony for all the soundings and most of the information about the lagoon.

in size and extent. There is between the land, wherever it exists, and the lagoon basin a flat of some sort, covered with dark, muddy sand, gradually getting whiter further out from the land. The inner part of this is to some extent exposed at low tide, and off Midu in the north-east corner the exposed area attains a breadth at springs of about 700 yards. Further at ordinary low tide neither this village nor Huludu can be approached even in a small dinghey within several hundred yards on account of this platform. The outward edge of the flat against the lagoon is quite well-defined—being covered with growing corals, *Lobophytum* and other organisms—and lies at a distance of about $1\frac{1}{4}$ miles from the land; its depth in this part is such that it can be conveniently waded at low tide, *i.e.* about 4 feet. The high water mark is about 3 feet up the beach, and, the tide being about 4 feet, there is thus in this corner a great platform, extending out for $1\frac{1}{4}$ miles from the

Fig. 74. Addu Atoll. The map is based on the Admiralty Chart, altered in accordance with the observations of the Expedition. Mr Forster Cooper's soundings alone are marked. Scale 2 miles to 1 inch. (*For changes compare the Admiralty Chart on* p. 150.)

land, with a slope in this distance of about 5 feet. This, however, is not all. Absolutely in the corner, not stretching for any distance either to the west or south, is a strip of deeper water averaging nearly 300 yards in breadth, separated by a second reef from the lagoon. This outer reef varies from 10 to 50 yards in breadth, and is rather patchy and ill-consolidated with no definite flat. It is built up almost entirely of corals, and approaches the surface so closely that it can only be crossed at low tide through certain definite channels. The *false velu*, as the inner lake or basin may be termed, has a general depth of about 5 fathoms, against which the enclosing reef forms a sloping wall. Towards the

atoll lagoon the slope of this same reef is nearly perpendicular, the depth immediately attained being generally greater than 8 fathoms, whence the bottom slopes to over 20 fathoms in about 150 yards.

The lagoon flat against the land in Addu atoll presents elsewhere more or less the same characters, but the deep inner channel is not found. Its edge against the lagoon is well-defined, precipitous, covered with coral and at about the low tide level. Within it there may be a slight hollowing out for 2 or 3 feet, but this shallow basin partakes rather of the nature of a boat channel and is in no way comparable to a velu. An analogy to the north-eastern velu is only found in the north-west horn, where a portion of the bay has almost been cut off from the atoll lagoon by the growth of coral knolls. The upper part near its head is a fairly clear basin, covered on the bottom with muddy sand. Towards its mouth, where it opens into the lagoon, these coral heads stud the whole surface, arising perpendicularly—perhaps overhanging at the top—from 10 fathoms or even deeper. Many of the knolls have grown together, so that a passage to the head of the bay is at the present time difficult for a vessel of any size, if not impossible. A basin or false velu is thus being formed by the upgrowth of a reef within the lagoon. Without having seen the growth of shoals in this horn it would have been difficult or impossible to diagnose the formation of the outer lagoon reef off the other (north-east) horn of the atoll. The analogy is, however, so close that there can be no reasonable doubt, but that it arose in the same way.

The coral growth, taken as a whole, in Addu lagoon is most extraordinary, and in vigour quite surpasses anything in my experience elsewhere either in the Maldives or in the Pacific Ocean. On all sides of the lagoon the reefs appear to have grown out into its basin, and fresh patches of coral are everywhere off them being built up towards the surface. The reef patch, charted by Moresby in 1836 to the north of the south-east passage, has become joined to the reef, and the horns on both sides of this same channel have grown further into the lagoon. Mr Forster Cooper in addition found a shoal patch with 6 fathoms immediately where the same passage embouches into the lagoon. Otherwise in the southern channels I could see no change either in depth or breadth, but the natives report that the two northern ones are now impassable for their vessels, while they seem to have been regularly used when Moresby surveyed the atoll.

The bottom of the lagoon was found by my companion, Mr Forster Cooper, to be covered with rubble and sand, one small patch of mud only existing at 27 fathoms to the head of the north-east horn. The rubble consisted of coral masses and shells on which were growing large trees of *Dendrophyllia*, colonies of *Madrepora* and *Pocillopora*, *Polytrema*, *Polyzoa*, great masses of *Alcyonacea*, *Halimeda* and sponges. The sand consisted merely of finer fragments of coral and other organisms, *Halimeda* remains and a few free bottom-living Foraminifera. Sedentary and indeed all other organisms were on this class of bottom singularly scarce.

Mr Forster Cooper investigated with soundings all parts of the lagoon, paying more particular attention to those, which were charted as having more than 30 fathoms of water. Making every allowance for the possibility that the soundings may have been too low—of which, nevertheless, there was no indication—the greatest depth obtained by my companion was 32 fathoms, where 36 fathoms ought to have been found. Where 39 fathoms are charted, only 31 fathoms were obtained. Isolated soundings may mean nothing on account of difficulty of fixation—in this atoll intensified by considerable changes in the land. Eliminating all but

the most careful observations—many having been taken when dredging—23 are left, all of which show a decrease in depth of from 1 to 8 fathoms, the general reduction being 2 or 3 fathoms.

It will be clear from the above remarks that Addu atoll differs from all others in our group in the fact that it shows a decrease in depth in its lagoon. Minutely examining all the factors as given above and comparing as far as possible with the chart, I estimate that in the 65 years between Moresby's visit and my own there has been *at the least* a decrease in depth of 2 fathoms over the whole area of the lagoon proper, *i.e.* about 15 square miles. The whole lagoon is about 22 square miles, and there must be taken into account the inward extension of the lagoon reefs, a far more rapid increase. To suppose therefore, for the 60 odd years since the survey, a deposit or filling in by coral growth of $2\frac{1}{4}$ inches a year over an area of 22 square miles does not seem to me to be excessive.

To account for this decrease, it should in the first place be pointed out that Addu atoll is markedly different in its topography to all the other banks of the group. From my corrected chart I estimate that five-sevenths of its circumference are protected by land. There are only four narrow passages—two extremely small—with an average depth over their whole sections of probably less than 10 fathoms. There is thus not likely to be much circulation of water in the deeper parts of the lagoon. The prevailing winds and currents are east and west; from the latitude being almost that of the equator it is obvious that they vary but little in different seasons of the year, inclining only somewhat to north-east and south-west. Further the ordinary currents and winds never can have the same force as in the more northern atolls, and hurricanes do not occur so far north or south. By a glance at the chart, it will be at once apparent that in no case can the usual currents or winds affect the lagoon, owing to the positions of the passages and the protection afforded by the land. As important factors in Addu, which they certainly are in other atolls, they may accordingly be neglected. The tidal rise and fall is stated to be 4 feet—on the lagoon beaches certain measurements I made averaged 3 feet 8 inches, but it does not follow that the rise within the lagoon would be as great as on the seaward sides of the islands—which is certainly less than in any other part of the group. Lastly, the encircling reef of Addu averages more in breadth than that of any other Maldivan atoll, and the tidal water in crossing it would be more likely to be saturated with lime before ever it got to the lagoon, so that there could be by its means little solution.

The chief agent in this filling in of the lagoon of Addu atoll is coral growth. Its luxuriance is quite without parallel in any of the described regions of the world, similar in the size and closed character of the area. I have unfortunately no definite observations, which serve to explain its cause. The water of the lagoon, owing to its protection from winds and currents, would naturally be considerably clearer than in most basins. The periphery, over which the surface fauna might be supposed to pass to the interior of the lagoon, is only 8 miles, but I would emphasise the fact that *all those kinds of corals that form the reefs feed rather by their commensal algae.* With regard to this it is probable that, from the decaying matter of the lagoon flats and land, an especially abundant supply of carbonic acid gas is provided. This would seem at first sight to be opposed to my argument that the tidal water would be saturated with lime before ever it reached the lagoon. All the carbonic dioxide would, I conceive, on account of the abundant growth of corals be utilised by them, but the sea-water has a solvent action on calcium carbonate, independent of the

presence or absence of this gas. The greater average and the lesser range of the temperature of the sea-water as compared with more northern and southern atolls (comp. Chagos Archipelago) would probably be an additional factor favourable to coral growth in this region. Lastly, destructive organisms of all kinds are relatively scarce in this lagoon. The larger boring animals are rarely found in the coral skeletons. Indeed in our record of dredgings I do not see a single form recorded, although in contrast to most atolls much rubble was obtained. This is further confirmed by a few corals, which we brought home from the area, in some pieces even the minuter boring sponges being absent. Holothurians and Sipunculids, the two most important sand-triturating forms in such an area, were singularly scarce both on the reefs and in the lagoon, so that there would be in the sea-water a lesser quantity of finely-suspended matter to be removed by the outgoing currents.

On the whole Addu undoubtedly owes the shoaling of its lagoon rather to want of solution than to the luxuriant growth of organisms, but, the greater the latter, the smaller are the solvent surfaces on which the sea-water can act. That Addu really had a considerably greater depth when Moresby's survey was made, and possibly still greater at a previous period, admits of no doubt. The reason of the relatively sudden filling in of its lagoon can only, I think, be ascribed to increase of land and decrease of depth in the passages, both tending to hinder the free circulation of the sea-water. Against this must be set the possible decrease of the area, from which sediment is supplied for filling in the lagoon. It appears to me doubtful, though, whether this would actually be the case or whether the effective source of sediment would not rather be enlarged with increase of land. The factor, however, is of small importance compared to the prevention of circulation in the water and hence of solution.

Finally, I may venture to remark that the physical conditions at this latitude are such that it is not unreasonable to suppose that the encircling reef of Addu atoll might have grown up from a greater depth than would be possible in the more northern parts of the Maldive group. The area of the shoal being small, the rim too might have been perfect from the first, and the lagoon would consequently have had a greater depth. In any case there is nothing in the existing conditions against the supposition that the lagoon may have been at one time greatly deepened by solution, while at present it is decidedly being filled in by coral growth and deposition of sediment.

Everywhere else in the Maldives such change as there has been in the lagoons has been one rather of loss than gain. In the first place the soundings show in the larger atolls an increase rather than a decrease. In dredging, a hard smooth bottom, free from rubble, was constantly found. The lagoon shoals generally fall almost perpendicularly to 20 and sometimes even to 30 fathoms, depths at which they could scarcely have originated in a lagoon. Great falls of rock from their sides are not infrequently found, while the amount of rubble around them is relatively small and forms but a very narrow circle. Boring organisms—so scarce in Addu atoll—are present in extraordinary abundance in other lagoons, and of great importance in destroying corals. The presence of much dead and decaying coral would perhaps provide an abundant supply of carbonic acid gas for solution on the lagoon floor, a position where much could not be absorbed by the corals.

The circulation of water in all the other atolls of the group is much greater than at Addu owing to their relatively much more extended, peripheral reefs, to which must be added the lesser percentage of their surface covered with land. The passages into their lagoons are generally both far more numerous and deeper, consequently producing a greater amount

of change in the sea-water. The currents of the two monsoons are important as well as the tidal current over the whole bank. With the banks close together and having deep passages these largely pass directly through the atoll basins. They thus sweep out small particles in suspension as well as frequently renew the water, so that the total amount of lime removed is greatly increased. The want of protection by land is important, for, whereas Addu lagoon with a westerly gale was quite calm and the water clear to 10 or 12 fathoms, Goifurfehendu and Bodu-faro (N. Mahlos) basins—both as completely enclosed by surface reefs—with not heavier winds were so churned up that the bottom was scarcely visible at 6 fathoms. The sea in rough weather was noticed to be quite milky even some miles off Suvadiva, Haddumati and North Male, while immediately off Addu it was comparatively clear. Even in calm weather the meshes of our tow-nets tended in passages to get blocked up with dead organic matter and fine mud in suspension, showing what enormous effect this sweeping out might have with a moderately rough sea. This movement of organic matter has another, an indirect effect in the formation of lagoons of infinitely more importance than its direct effect, *i.e.* in driving mud against the living reefs and corals, causing the extinction of small coral colonies and larvae, and enormously hampering the growth of larger masses. This effect of mud I have already drawn attention to in the Pacific. In the Maldives I had abundant opportunity of confirming my observations, and I would only here emphasise what I then wrote[1].

Important as the outwash of detritus really is, I cannot for a moment consider that it approaches solution in its effects in deepening lagoons after the reefs on a bank have assumed the definite atoll condition. On banks such as Suvadiva, Felidu, Kolumadulu and Haddumati considerable areas of the bottom must—owing to the perfection of these atoll-forms—be affected to an insufficient degree to greatly stir up their deposits, while probably the currents and winds would give an ample circulation for solution by the sea-water. That this is the case is clearly shown by the presence in protected situations of deposits of soft mud. Any deposit of the lagoons, however clean it may appear, has always a distinct amount of organic matter in the process of decay, this providing carbonic acid gas for the solution. The absence generally of deposition of calcium carbonate in dead coral masses in the larger lagoons—common in many of the smaller atolls and faro—would go to prove that there is no supersaturation by the lime, and hence that there is free circulation of the water.

Some of the muds are being examined by Sir John Murray, and will form the subject of a separate report. I however made a series of analyses to ascertain the silica (SiO_2) in a number of samples[2]. The analyses of 14 surface sands and rocks gave an average percentage of ·047 of silica, while three samples of mud from 40—50 fathoms from Suvadiva lagoon gave 2·441, the latter thus having about 50 times as much silica as is found in the surface rock. To put the matter in another way—admitting solution—about 50 volumes of the sand and rock from the reef and land would have to be dissolved to give the amount of silica found in 1 volume of the Suvadiva mud. No doubt some of the excess of silica in the latter may be explained by special causes, influencing its formation. Nevertheless I fail to see that any complete explanation can be afforded that does not take into consideration the solvent action of the sea.

[1] *Loc. cit.* p. 484, *et seq.*

[2] I am indebted to Mr M. M. Pattison Muir for placing the Chemical Laboratory of Gonville and Caius College at my disposal during the Easter vacation for these analyses, and

In conclusion, it is a fair deduction that the increase both in depth and extent in the lagoons of the Maldive atolls is mainly due to solution, an important additional factor being the outwash of fine matter by the tidal and oceanic currents. It is obvious, though, that there are two nicely balanced sets of conditions, causing the filling in or increase in size of any lagoon. A quantitative estimation of these, a comparison of the factors—analyses of the water at different states of the tide and from several parts of each lagoon, estimation of the amount of water entering or leaving each lagoon, areas of coral growth, etc.—would be useful, and could not fail to throw much desirable light on this most complicated question[1].

Section III. The Bathymetrical Limits of Coral-Reef Builders.

While the dredgings in the Maldive Archipelago were mainly taken to ascertain the general characters of the bottom and its fauna and flora in different positions, the situations were—by particular requests of various authorities on the formation of coral reefs—largely chosen with the view of ascertaining the depth to which the reef corals extend. Dredges of Naples and Plymouth designs and hempen swabs, 3 to 9 feet long, were largely used in addition to the Otter trawl and beam trawls of various patterns. The effectiveness of all these in procuring corals from shallow water, where the bottom could be seen, was carefully ascertained, and the trawls were additionally weighted with 2 or 4 old fire-bars for deeper work. During the time I had the steamer for dredging I chose some of the roughest, and hence most likely ground, between 30 and 50 fathoms, ultimately breaking or leaving most of my apparatus on the bottom. Much dead coral rock was brought up, some of it

also for giving me the assistance of trained attendants. Three to ten grams were taken of each sample after it had been well mixed, the whole carefully washed with distilled water and dried, and the organic matter burnt off. The amount of silica (SiO_2) was then estimated. The only metals found were Calcium, Magnesium, Aluminium and Iron.

	Material	Locality	Position	Percentage of Silica	Remarks
1.	Sand	Minikoi	Middle of Island, 6 feet deep	·028	
2.	Sand	Minikoi	Sea beach	·023	
3.	Sand	Minikoi	S. of lagoon, 1 fathom	·029	
4.	Sand	Minikoi	Centre of lagoon, 8 fathoms	·193	
5.	Sand	Minikoi	Reef flat	·026	
6.	Sandstone	Minikoi	Lagoon cliff at Honi-kodi	·071	Elevated rock
7.	Sandstone	Minikoi	Kodi point	·058	Elevated rock
8.	Sandstone	Minikoi	Seaward reef	·060	Elevated rock
9.	Coral-rock	Minikoi	Seaward reef	·076	Elevated rock; the sand infiltration between the corals
10.	Coral-rock	Minikoi	Seaward reef	·230	Elevated rock; consolidated mud between corals
11.	Coral-rock	Minikoi	Wiringili island	·044	Elevated rock; mixed corals and mud
12.	Sand	Hulule	Centre of island	·024	From a freshwater pool
13.	Sand	Suvadiva	Lagoon beach, Gadu	·006	
14.	Sand	Suvadiva	Lagoon beach, Havaru-Tinadu	·0013	
15.	Sandstone	Suvadiva	Lagoon beach, Wiringili	·0087	A recent rock
16.	Sandstone	Suvadiva	Sea beach	·0023	A recent rock
17.	Mud	Suvadiva	Lagoon, 40—50 fathoms, south	2·203	Two analyses
18.	Mud	Suvadiva	Lagoon, 40—50 fathoms, west	1·992	Two analyses
19.	Mud	Suvadiva	Lagoon, 40—50 fathoms, north	3·127	Two analyses

[1] Mr J. Lomas in a paper at the Brit. Ass. (Sept. 12, 1902) pointed out that the deposits in Palk Bay, Ceylon, are of ancient formation and prove a very extensive solution for that region.

consisting of blocks evidently free and some of masses showing fractures, where they had been broken off the bottom or still larger lumps.

The results were mainly negative, but the apparatus being thoroughly reliable and the dredgings fairly numerous, they may be relied upon. Series of dredgings in the same locality and habitat are repeatedly counted as single dredgings.

On the opposite page is a table showing the number of times *living* specimens of each of the different genera were obtained at various depths beyond 15 fathoms down to which the reef genera extend in great luxuriance.

The forms of growth are as follows:—*B.* branching: *C.B.* coarsely branching: *F.B.* finely branching: *S.B.* spreading branches: *F.* foliate: *I.* incrusting: *M.* massive: *S.M.* spreading massive: *S.* spreading.

A plain cross after the name, thus †, indicates that more than one species was represented.

The genera marked with a star * are to some extent doubtful, but serve sufficiently to show the facies and alliances of the species. *Domoseris* is almost certainly a synonym of some other genus, but I have been unable to examine any specimens of the allied genera.

The following genera of reef-building corals, characteristic of the Maldives, are not found in the collection:—*Coeloria, Leptoria, Prionastraea, Mussa* and *Symphyllia. Goniastraea* was only once obtained, and the *Orbicella* belong to species with small calicles, not found on reefs. The species of *Montipora* and *Hydnophora* and to some extent of *Astraea* and *Galaxea* belong to forms of growth widely differing from the large, characteristic, massive colonies, more generally found on reefs. *Madrepora* with increase of depth breaks up into thinner and finer branches and twigs; its stems ramify almost horizontally, and its calicles are widely separated from one another. *Pocillopora* alone varies but little, its colonies presenting the same two common, finely and coarsely branching, facies of growth, usually seen on reefs.

A few genera, not found at the surface, are evidently of great importance as builders between 20 and 40 fathoms. Of these *Dendrophyllia,* of which there is only one species, *D. ramea,* where found, appears generally to form great groves, immense quantities being obtained; some of its main branches were of large size, even 2 yards in length by 3 to 5 inches in diameter. An allied genus or a sub-genus, *Coenopsammia,* grows commonly on the under, shaded sides of stones on the reef, but was not dredged. *Gonipora* was found either as fixed, large masses, of which chips only were usually broken off, or free in mud or sand in a form allied to *G. stokesi. Alveopora* grew in large masses, usually much crushed when brought up, or in branches, the tips of which alone were alive. *Seriatopora* gave colonies either of extremely fine branches, or of finger-like stems. *Stylophora* was only secured on two occasions, both outside atolls, but the quantity of massive branches then brought up points to its being of no inconsiderable importance in this position. That the same genus should not be found on the reefs is peculiar, as it was one of the most numerous on Funafuti and other Pacific reefs. The specimens, placed under the genus *Trachypora,* represent modified incrusting *Pavonia,* which have taken to a deeper habitat.

The false corals, *Millepora* and *Heliopora,* have already been to some degree considered (pp. 314—317). In the accompanying table they supply 7 out of the 14 times surface-reef genera were dredged between 36 and 40 fathoms, and 3 out of 4—the genus of the fourth being doubtful—between 41 and 50 fathoms. I have never observed either of these genera on a

Table showing the number of times living specimens of the different coral genera were obtained at various depths.

	Forms of Growth. 1st	Forms of Growth. 2nd	16—20	21—25	26—30	31—35	36—40	41—50	Found on Surface Reefs
Depth in Fathoms			16—20	21—25	26—30	31—35	36—40	41—50	
Total Dredgings			29	65	55	33	31	23	R = Rare G = General C = Common
Dredgings having Corals...			11	34	17	11	9	5	
1. *Stylophora* †	C.B.	—	1	3	—	—	—	—	—
2. *Seriatopora* †.....	F.B.	—	3	8	3	2	—	—	—
3. *Pocillopora* †.....	C.B.	F.B.	8	5	2	2	1	—	C.
4. *Madracis*	F.B.	—	—	1	—	—	—	—	—
5. *Euphyllia*	B.	—	4	—	—	—	1	—	G.
6. **Tridacophyllia* ...	S.	—	—	—	1	—	—	—	—
7. **Trachyphyllia* ...	F.	—	1	—	1	—	—	—	—
8. **Echinophyllia* ...	F.	—	—	1	—	—	—	—	—
9. *Echinopora* †	F.	—	—	1	—	1	—	—	—
10. *Merulina*	F.	—	—	1	1	—	—	—	R.
11. *Galaxea* †	M.	—	—	4	—	—	1	—	G.
12. *Goniastraea*	M.	—	1	—	—	—	—	—	C.
13. *Cyphastraea*	M.	S.	1	2	1	2	—	—	R.
14. *Hydnophora* † ...	M.	S.M.	—	2	1	—	—	—	G.
15. *Orbicella*	M.	—	—	1	1	—	—	—	C.
16. *Astraea* †	M.	S.M.	1	4	2	—	1	—	C.
17. *Siderastrea*	M.	—	1	—	—	—	—	—	R.
18. *Pavonia*.....	M.	B.	—	2	—	—	—	—	C.
19. *Sandalolitha*.....	—	—	—	1	—	—	—	—	—
20. **Trachypora* †.....	I.	F.	1	4	1	—	—	1	—
21. *Pachyseris*	S.	F.	1	—	1	—	—	—	—
22. **Domoseris* †	F.	I.	3	5	8	2	3	—	—
23. *Psammocora*	M.	—	1	2	—	—	—	—	C.
24. *Dendrophyllia* ...	B.	—	7	17	5	3	5	2	—
25. *Astraeopora*	M.	—	—	—	1	—	—	—	G.
26. *Turbinaria*	F.	—	2	—	—	—	—	1 (?)	R.
27. *Madrepora* †	C.B.	F.B.	7	11	3	2	2	—	C.
28. *Montipora* †	I.	B.	2	2	1	1	1	—	C.
29. *Alveopora* †	M.	C.B.	1	4	2	1	4	—	—
30. *Porites* †.....	I.	M.	1	2	—	—	—	—	C.
31. *Goniopora* †	M.	—	1	5	3	4	4	1	—
32. *Millepora*	B.	—	—	3	2	—	3	1	G.
33. *Heliopora*	B.	—	—	3	1	—	4	2	G.
SUMMARY: Total			45	94	41	20	30	8 (1 ?)	
SUMMARY: Reef Genera only			26	44	16	7	14	4 (1 ?)	
SUMMARY: Genera not reef...			19	50	26	13	16	4	

true reef flat or in the fissure zone of any Maldivan reef, freely exposed to the sea. They are not important—if at all—builders on the outer slope down to 15 fathoms either against the open ocean or the Great Maldive Sea. On the other hand they are found in great clumps, up to 2 or 3 yards across, in boat channels and on sand flats as at Rotuma, usually the colonies having more or less lamellate facies. The recorded dredgings, where the two genera were obtained, were all in passages or outside atolls, and both were generally found living together. *Heliopora* had previously been obtained by Basset-Smith off the Macclesfield bank between 25 and 35 fathoms[1] and by the writer off Funafuti between 35 and 45 fathoms[2], and *Millepora* at about 25 fathoms, likewise off Funafuti[2]. Otherwise the genera were formerly regarded as essentially reef or surface forms. It is interesting to observe that absolutely no specimens of either were procured in the Maldives from between the surface and 20 fathoms, although *Millepora* at any rate was very abundant in all the passages into Funafuti lagoon, to 10 fathoms in depth. The specimens of both forms were mostly in the form of wide plate-like branches, although one incrusting specimen of *Millepora* was also secured. The quantity usually obtained, when either of these forms was dredged, shows that they are not improbably the most or among the most important of the reef-builders below a depth of 25 fathoms.

Among the other builders requiring consideration the most important is *Polytrema*, the significance of which lies in its power of binding together sand and rock. In the Maldives growths were obtained in practically every dredging, in which corals or fragments of rock were secured. In the passages *Polytrema* forms concentric incrustations round small pieces of coral or rock. Outside the atolls in soundings and dredgings it was obtained down to 125 fathoms, and its importance is probably very great. *Lithothamnion* was constantly present in dredgings outside reefs or in passages down to 45 fathoms, protecting dead coral or rock below 25 fathoms. Indeed the dredgings show that it is chiefly in this last quality that both this form and *Polytrema* are important, neither below 25 fathoms providing any considerable bulk of the material of which the reefs are built. *Halimeda* leaves, serving to fill in the hollows and the interstices of the other organisms, were constantly procured living down to 35 fathoms, beyond which its growth appeared to gradually die out. In Mahlos great beds of young oysters (apparently *Meleagrina margetifera*) were found at 25 fathoms, the shells of which would be of assistance.

Solitary corals have in the list been completely neglected, most genera having only a minute value in the formation of reefs. *Fungia* is sometimes found in great abundance on surface reefs, but was only once dredged, *i.e.* between 16 and 20 fathoms. An allied genus, *Diaseris* (probably synonymous with *Cycloseris*), was obtained living on nine occasions between 25 and 40 fathoms. In five of these dredgings the quantity of coralla—principally dead but also living—was very large, and in a tenth haul only dead specimens were secured. In the north passage into Suvadiva lagoon, 36 to 40 fathoms, in one haul of a 4½ feet beam trawl about 2 cwt. of dead masses of rock were brought up, mainly composed of the dead coralla of this genus, cemented together by sand and deposited carbonate of lime. A second dredging of the same passage, where it opens into the lagoon, gave great quantities of dead *Heteropsammia* in addition to a number of live specimens. In the same position the Snapper lead three times in succession brought up specimens of the dead coralla of this genus, the whole bottom appearing to be almost coated by them.

[1] *Ann. Mag. Nat. Hist.*, Nov. 1890, p. 353 *et seq.*

[2] *Loc. cit.* pp. 478—9.

In conclusion, I may at once remark that the above table absolutely negatives my previously-expressed view[1] that the reef corals probably live down to 40—50 fathoms in great luxuriance. Darwin in placing the extreme depth of flourishing banks of surface-reef corals at 25 fathoms was entirely correct. The specimens of these corals procured from beyond this depth show clearly in their growth that the increased depth is deleterious to them. At the same time the presence of a series of other genera of corals, which evidently flourish just beyond where the surface forms cease to exist, although with a considerable range in depth, is for the first time clearly demonstrated.

Section IV. The Rate of Growth of Corals and Reefs.

The formation of a reef is an exceedingly complex problem, in which a large variety of organisms all play their parts. The rate of growth of many reefs is doubtless infinitesimal. Our scientific interest lies mainly in considering the *probable* rate of growth on open banks freely exposed to the great ocean currents, while the practical interests of navigation require as well that the rate of growth within the lagoons of atolls should be accurately ascertained. Our practical interests demand the consideration of the *possible*, maximum rate of growth, while for the theory we require rather the knowledge of the *probable*, average rates of growth.

Freely exposed ocean banks and lagoons differ so profoundly in the structure of those reefs that have grown up actually on or in them, that any comparison is at first sight impossible. The lagoon reefs are more or less spongy structures, formed mainly of corals filled in with sand, while to build up formations outside an atoll requires a far greater complexity of organisms. The possible maximum rate of growth of a lagoon shoal is obviously the greatest rate of growth of corals in height in that position, the sand, etc., by which the corals are consolidated, not being necessarily formed by the decay of its organisms. These same shoals consist in the first place, until they reach the low tide limit, of mere coral heads, and their probable rate of growth up to this stage is not unlikely to be nearly equal to their possible rate. In addition the possible rate of lateral growth of such shoals is required for practical purposes. The tendency to and possibility of such kind of growth has already been sufficiently discussed in previous chapters, and need not detain us here. It is, peradventure, sufficient to point out that for navigation the accurate fixation of the central point of an ordinary shoal is all that is usually required with a rough contour and, of course, the soundings.

The rate of growth outside atolls is another matter. The general contour of the bottom is smooth, though hollows and pits occur. All its corals grow at about the same rate and so preserve its general contour. This doubtless is due to the strong outward current from the reef above, and is absolutely comparable to the level top of a plantation of firs, on a smooth, exposed hill-side. Rarely does any coral succeed in raising its head above the general level, and, when one does so, it is improbable that it is able to remain as a permanent structure. The loose material, that serves to fill in the interspace between the coral masses, consists mostly of coral fragments—derived principally from the reef flat above—and of free-living Foraminifera. *Lithothamnion* and *Polytrema* turn the whole into rock, loss being almost an unknown factor here. The rate of growth of the whole reef is, hence, not probably widely different from that of the individual corals that mainly serve to build it up. Once

[1] *Loc. cit.* p. 478, etc.

more it is to the rate of growth of the corals that we must look to get an idea of the possible and probable rates of the reef itself.

An almost insuperable difficulty for the consideration of our problem lies in the necessity of determining the rate of growth of the corals at different depths. There are no fixed laws for different species or even genera, but the rate is mainly affected in every case by the environment. When reef corals have once fairly fixed themselves on a shoal, the task of determining when that shoal will reach the surface, is as nothing compared to the difficulty of ascertaining the time that has been taken by the coral larvae to so secure themselves. The larvae must have a firm support, must in fact build up their houses on rocks, and it is owing to this that the growth of new shoals in lagoons is so rare. Above I only deal with reef corals; the task is many times magnified when we come to consider other forms. The problem, in truth, is one beset with innumerable difficulties, but one of such importance that any results, however small, are of great interest and value.

The facts relating to the growth of corals and reefs up to the year 1890 were ably summarised by Dana[1], whose conclusions are best expressed in his own words:—"Whatever the uncertainties it is evident that a reef increases in height or extent with extreme slowness. If the rate of upward progress is one-sixteenth of an inch a year, it would take for the addition of a single foot to its height, one hundred and ninety years, and *for five feet a thousand years.*" (The italics are Dana's, not mine.) This was published antecedent to the appearance of Murray's full work on the influence of pelagic organisms on the formation of rock[2], and it is evident that the possibilities of the enormous rate of increase of these and other organisms were not understood by Dana. Unfortunately I am unable to admit much of Dana's premiss, as I differ profoundly from him in regard to the structure of coral reefs and the mode of growth they exhibit at the present day.

Little work has been published on the subject since Dana's *resumé*. Agassiz gave a few photographs of the natural sizes of certain corals from a telegraph cable at a depth of 6—7 fathoms[3]. Taking the measurements from the figures of the specimens, these show a maximum upward rate of growth of respectively $3\frac{1}{4}$, 2 and 3 inches, and lateral extensions of $3\frac{1}{4}$, $1\frac{3}{4}$ and $2\frac{1}{4}$ inches, taking the halves of the total breadth of each, in seven years. More recently I discussed the rate of growth of certain specimens from Fiji[4], but with no attempt to deduce general conclusions as to the rate of reefs. Calculated out on Dana's method and remembering that practically the whole surface of a reef is covered with growing corals, the Fijian specimens would give an average rate of upward progress of 5·19 mm. in one year or a thickness of about 17 feet in 1000 years.

Many of the inhabited islands of the Maldives have definite channels for their small fishing and trading boats, excavated through their encircling reefs, even the shallowest usually with at least 4 feet of water at low tide. The boat channels between the land and reef accordingly make safe harbours for small vessels, and slips on the shores serve for repairing the latter. These canals, or *magu*—a naturally formed ship's passage, such as those into any of the lagoons, is termed in Maldivian *kandu*—by the laws and customs of the country are cleared out according to the needs of the different districts once every 2 to 5 years. In Mahlos, Male and atolls more particularly under the sway of the Sultan, the law is that this

[1] *Coral and Coral Islands*, 1890, pp. 123—127, 253—258, and 396—397.

[2] "Deep-Sea Deposits," *Challenger Reports*, 1891.

[3] *Bull. Mus. Comp. Zool.* vol. xx. p. 61 (1890).

[4] *Proc. Camb. Phil. Soc.* vol. xi. pt. iii. pp. 214—219 (1901).

shall be performed once in every 3 years. It is the duty of the *atoluveri*, or provincial governors, to see that this is carried out, and, as the duty fits in with the private interests of their officers, it may safely be assumed that it is properly performed. In Mahlos and Miladumadulu I saw—not at the time appreciating the stringency of this law—every range of living coral growth in these canals from 1 to 3 years of age. The bottoms of some were literally covered with corals, and, it was quite evident, would, if left alone, in the course of a very few years become completely blocked up. At Limbo-Kandu in N. Mahlos and Hurubudu in S. Mahlos, both of which were inhabited less than 20 and 30 years ago, the former canals could only be distinguished by the less consolidated nature and the narrowing of the reef, a growth of at least 4 feet in 20 and 30 years. At Fainu also in N. Mahlos what was originally the main passage, 5 feet deep, was abandoned in 1885, or 14 years before my visit. It was situated opposite the middle of a passage into the lagoon of the atoll, and must have been swept by strong currents, so that it decidedly could not have been in a position at all favourable for coral growth. Yet the whole bottom was so studded with branching and massive corals that the canal was not negotiable at low tide.

Innumerable other instances might be given, but they lack sufficient precision, whereas from the canal at Hulule I brought a number of corals, the maximum possible age of which from the ova is accurately known. Hulule is the most south-easterly island of North Male atoll, and is situated to the south of a large faro. There is a velu of moderate size, about 6 fathoms deep, to the north of the island but no other land, except a single island at the north end and a mere rock to the south. In its west reef, a little north of Hulule, are two small passages, kept open by the scour of the water across the faro and round the north end of this island. Opposite the middle of the land on the west side lies a small pool, where the Sultan moors his private yacht, 4 fathoms deep by about 40 yards across. Leading to this a canal had been cut through the reefs to a mean depth of 4 feet at low springs. This is regularly cleaned out once in every three years[1] under the inspection of officers from Male. The island belongs to the Sultan, and is regularly visited by him for religious purposes, the canal being at the same time examined to see that the work is properly performed. My collection was obtained in February, 1900, of the third year, and I visited the channel a second time at the beginning of the following April to secure additional specimens. However, in the mean time it had been cleaned out so thoroughly that not a single piece of living coral could be found; the whole bottom had been levelled, and the coral all removed. Any living fragments of coral, that possibly were left, could not in any case have continued to exist on account of the mud, with which the bottom was coated. The Sultan's annual visit was to take place in 1900 in the middle of May, so that it is safe to assume that it could not have taken place in 1897 until a month later. The work would in 1897 have been done before May, since later, the channel not being protected from the south-west monsoon, the job would have been attended with considerable difficulty. April would accordingly have been the last suitable month, and it is probable that its low spring tides were utilised for the work. The corals brought home would hence have taken

[1] It was very difficult in the Maldives to accurately ascertain measurements, either of time, length, or weight on account of Arab, or peculiar, in fact indigenous, standards being used. The numeration is in twelves, not tens, and Hindustani, Arab and Maldivan terminologies are all mixed. An isolated, tropical race of low culture is, in addition, not accustomed to think precisely.

I have throughout generally used the Maldivan (Mahommedan) year as equivalent to the European, so as to avoid possible exaggeration. One of the few exceptions is that which immediately follows, where I have allowed for the difference in number of days in calculating the times of the Sultan's visit to Hulule.

some period certainly less than 3 years, and probably not more than 2 years and 10 months, to have grown up from ova to their present size.

The physical conditions in the Hulule canal cannot be said to be especially inimical or favourable to coral growth. Strong currents pass in and out of the atoll between Hulule and Male, so that there is ample change in the neighbouring waters. The coral growth is luxuriant on the reefs to the west of Hulule, and the different corals grow fairly evenly in height, no genera being particularly vigorous. During the north-east monsoon there is a considerable sweeping out of mud, weed and sand from the shores of the island, which must be injurious to coral life. One may deduce from the appearance of the western passages into Minikoi atoll in the south-west monsoon, and from that of many of the artificial canals in the Maldives opening to the east in the north-east monsoon, that in the south-west monsoon the bottom of our canal would be swept bare of all sediment, absolutely down to the rock. The same canal, too, feeds no wide stretch of water so that the currents in it would not be of any great force. The canal, accordingly, in the south-west monsoon should be especially favourably situated for the growth of corals. Coral larvae could scarcely succeed in establishing themselves in the north-east monsoon on account of the mud, whereas the opposite monsoon should be most auspicious for their fixation. Indeed, it is probable that all the specimens would have commenced to grow in the latter monsoon, and that they would hence represent three growth periods of less than 3, 2 and 1 years.

The accompanying Table of the specimens serves to explain itself (p. 331). I have not yet worked out my coral collections, so that the naming of the species must be taken as only approximately correct. The important point is to know the form of growth in the genus—it is very unlikely that the rate of growth in a genus differs materially in closely-related species—and the specific name, or some other indication, is given in each case to show the facies. I have added to the form of my table, as originally published, the approximate horizontal area each coral covers in its position of growth, as far as the latter can be perceived, and also the height of each above its true horizontal base. As the colonies had been drying for two years, I have only given one weighing in this state. They were then soaked in water and weighed in the same until the resulting weight became constant; the volume alone, however, of the broken fragments was measured.

It is important to observe a second time that *the above specimens must all have grown up to their present size within a period of* 3 *years ab ovo. Further, they were all obtained out of an area of* 4 *square yards, or* 33416 *sq. cms.* Their position in the canal, some distance from its outer end but more or less in the centre, would certainly not theoretically have been the most luxuriant for coral growth, and indeed was selected rather as representative of the whole channel. Most of the corals were attached, and must have grown in the position in which they were obtained. The *Fungia* and two other free forms, *Orbicella* (No. 8) and *Montipora saxea* (No. 20), if they did not actually grow within the area, can only have originated in its immediate vicinity; in no case is it possible to suppose that they can have come from the reefs at the sides of the canal.

The rate of growth of the reef as a whole can be calculated for *say* 1000 *years* by several methods:—(1) The specific gravity of fine sand-rock being 2·48 (average of 10 samples), the corals may be estimated in this condition, and will give a deposit over the area of 85 cms. (2) With the specific gravity 1·78 (see Table), the deposit would be 123 cms. (3) Taking merely the area 3986 sq. cms., known to be actually covered by the corals themselves, the growth,

Table showing Rate of Growth of Coral Specimens from Hulule Canal.

			Name of Coral	Weight in grams	Volume in cc.	Specific Gravity	Area covered in sq. cms.	Height in cms.	Thickness as a sheet in cms.
Massive	Astraeidae	1.	*Goniastraea eximia*	81	46	1·76	25	4·2	1·84
		2.	„ „	509	380	1·34	84	7·3	4·52
		3.	„ (*Astraea* ?)	318	212	1·50	71	6·8	3·00
		4.	*Prionastraea abdita*	12	6	2·00	7	2·1	·86
		5.	„ *tenella* (sp. ?)	218	103	2·11	34	7·9	3·03
		6.	*Acanthastraea grandis*	1094	660	1·65	221	5·8	2·98
		7.	*Cyphastraea savignyi*	230	128	1·79	55	6·1	2·33
		8.	*Orbicella* (sp. ?)	147	86	1·71	22	4·8	3·91
		9.	„ „	571	287	1·99	81	8·2	3·54
		10.	*Coeloria daedalea*	325	156	2·08	48	6·2	3·25
		11.	„ „	245	199	1·23	68	7·8	2·92
		12.	„ „	321	203	1·58	72	7·3	2·82
		13.	*Hydnophora microcona*	309	161	1·92	74	7·1	2·17
		14.	*Symphyllia sinuosa*[1]	967	693	(1·39)	170	10·2	4·07
	Fungidae	15.	*Pavonia repens*	303	145	2·09	61	7·4	2·37
		16.	„ „	769	410	1·81	113	10·1	3·63
		17.	*Psammocora* (sp. ?)	453	206	2·19	100	5·4	2·06
		18.	„ „	1485	671	2·21	287	11·8	2·68
	Perforata	19.	*Montipora foveolata*	28	15	1·86	17	2·8	·88
		20.	*Montipora saxea*	590	271	2·17	84	9·6	3·23
		21.	*Astraeopora myriophthalma*	214	103	2·08	42	6·0	2·45
	Free Fungidae	22.	*Fungia* (young)	47	19	2·47	27	2·2	·7
		23.	„ „	25	10	2·5	18	1·7	·55
		24.	„ *dentigera*	151	62	2·44	47	3·7	1·32
		25.	„ „	357	127	2·81	72	4·0	1·76
		26.	„ „	379	142	2·67	97	3·9	1·46
		27.	„ „	452	171	2·64	103	4·3	1·66
Branching	Imperforata	28.	*Pocillopora coespitosa*	154	91	1·69	57	5·4	1·60
		29.	„ *plicata*	228	137	1·66	80	8·3	1·71
		30.	„ „	442	218	2·03	118	8·5	1·84
		31.	„ „	531	248	2·14	126	12·7	1·97
		32.	„ „	478	237	2·02	123	10·7	1·93
		33.	„ „	693	426	1·62	139	15·0	3·06
	Perforata	34.	*Madrepora* (stunted)	68	32	2·13	18	5·2	1·77
		35.	„ „	83	37	2·24	25	5·5	1·48
		36.	„ (semi-massive)	343	173	1·98	33	15·6	5·24
		37.	„ „	911	653	1·39	126	22·0	5·34
		38.	„ (clump)	239	93	2·57	62	13·0	1·50
		39.	„ (spreading)	463	237[2]	1·95	336	10·2	·70
		40.	*Porites* (dense clump)	739	544[2]	1·36	216	9·2	2·52
		41.	„ „ „	473	348	1·36	147	8·7	2·37
		42.	„ (open branches)	346	218	1·58	155	9·1	1·42
		43.	*Psammocora contigua*	295	147	2·01	54	8·6	2·72
		44.	*Merulina* (genus ?)	60	37	1·62	38	2·3	·97
		45.	*Euphyllia glabrescens*	134	89	1·51	33	14·1	2·70

[1] A small colony of *Madrepora* of a much stunted growth was attached to the main mass of this coral. The Specific Gravity for the genus is hence quite erroneous.

[2] Calculated from Specific Gravity of fragments.

SUMMARY OF TABLE.

	Weight in grams	Volume in cc.	Specific Gravity	Area covered in sq. cms.	Height in cms.	Thickness as a sheet in cms.
1. Massive Astraeidae	5347	3320	1·61	1032	6·6 [1]	3·22
2. „ Fungidae	3010	1432	2 10	561	8·7 [1]	2·55
3. „ Perforata	832	389	2·14	143	6·1 [1]	2·72
4. Free Fungidae	1411	531	2·66	364	3·3 [1]	1·43
5. Branching Imperforata.....	2426	1357	1·78	643	10·1 [1]	2·11
6. „ Perforata	3665	2335	1·57	1118	10·9 [1]	2·08
7. The rest in List	489	273	1·78	125	8·3 [1]	2·18
	17180	9637	1·78	3986	7·7 [2]	2·42
Add Broken Fragments, etc.[3]	4781	3389	—	—	—	—
	21961	13026				

imagined as solid rock, would be 807 cms. (4) Estimating from the height of the fixed corals and assuming that the interspaces would be filled in by nullipores and material from other areas, the rate of growth would be 2567 cms. or about 14½ fathoms. If the *Fungia*, which lie between and under other corals, be added to the latter, the rate becomes nearly 16 fathoms in 1000 years.

The first two methods are quite erroneous, for, whereas the whole area of a growing reef would be covered with growing corals, only a small part in the area collected was so overgrown. The third gives a possible rate for an extremely poor area, where the corals, before they attain any size, are usually killed off by boring organisms or unfavourable conditions. The last is more useful, but assumes that the rate of increase in height is the same year by year in and throughout the life of any coral or reef. Organisms do not generally obey fixed mathematical laws, but the presumption is that, given the most perfect circumstances, a coral should increase both in the number of its polyps and size according to a regular geometrical progression[4]. The increase in height above is taken in arithmetical progression, which certainly must give too small results when based on the first 3 years of the existence of the corals. The area to the west of Hulule is not a particularly favourable one, but the conclusion that its reefs might grow at the rate of a fathom in about 60 years is certainly not too high.

The main interest of the problem lies in the rate of growth outwards of a reef, where it is freely exposed to the ocean, and the rate of upward growth of a reef on any oceanic bank, arising to within suitable depths from the surface. The inquiry is greatly complicated in such positions by questions of temperature, currents, exposure, depths, etc. The difficulty that the larvae have in affixing themselves could scarcely be much greater than in this canal at Hulule, while the other conditions on an open bank or on the outer slope of a reef would undoubtedly be more favourable. The vigour of the coral growth from 5 to 15 fathoms

[1] Average of all the specimens of the several classes.

[2] Average of the whole forty-five specimens added up separately.

[3] Mostly broken fragments of fine branching *Madrepora*, but also *Psammocora*, *Euphyllia* and *Pocillopora*.

[4] Against this might be set the natural death of corals by senescence—of which there is some evidence—but any vacancies are at once filled in by fresh coral growth.

outside atolls is certainly many times greater than within atolls, and in my opinion does not materially decrease until a depth of over 20 fathoms is attained. Until a surface reef be formed, or until the reef nearly reaches the surface, there is probably no outward sweeping of talus to spread the foundations of the whole. Interstices are filled in largely by nullipores and Foraminifera, or else bridged over. All the corals keep pace in their growth, and the rate of the whole reef would be the average rate of its corals.

Considering all the various factors, and particularly remembering the necessarily slower growth at the initiation of a reef and as it approaches close to the surface, it yet seems to me to be probable that an oceanic shoal at a depth of 25 fathoms might well in 1000 years, or even less, be covered with a perfect surface reef, built up by nullipores and reef corals. In effect, if Falcon Island, erupted to a height of about 250 feet in 1885 and now a mere shoal, be cut down to 25 fathoms by the end of this century—a by no means unlikely proposition—its place might well be marked by surface reefs, perhaps even by a perfect atoll considerably before the year 3000 A.D. Should these deductions be, as I believe, fairly accurate, a natural explanation is at once afforded of the rarity of submerged banks of all sorts in coral-reef areas as compared with surface atolls and reefs.

Section V. The Action of Boring and Sand-Feeding Organisms.

1. *General.*

The skeletons of the corals and other organisms of a reef are either built up into a coral limestone by the animals themselves, or are worn down into mud and sand. A third fate may, however, at any time befall them in being dissolved by the sea-water. It is obvious that as a rule the smaller the skeleton the greater must be the amount of surface that will be exposed to solution. Hence sand should be more acted upon, and should suffer more loss in weight, than corals, shells or nullipores. Now the ground-down skeletons of these organisms form the greater part of the sand, and it is most necessary to examine the means by which their massive skeletons are broken up.

The main destructive agents of reefs are, undoubtedly, marine animals and to a lesser degree plants, aided to some extent by the solvent action of the water and erosion by the currents. The destructive organisms have two modes of procedure. First they bore into corals and other skeletons, and so weaken them that they break either by their own weight or the motion of the sea. Indirectly they probably by their organic matter attract other animals to ingest the fragments and further break them down. The latter or second action, that of sand trituration, is of no small significance.

In actual number, the animals that depend on sand for their food in any atoll are probably more numerous than the boring or free-living forms, as undoubtedly they are the most difficult to get any adequate knowledge of. Besides breaking down the fragments of rock into sand, they are the main factors in the creation of mud. The deeper layers of the sand of a flat pass through their bodies again and again, being in all cases ejected in a still finer state on the surface of the bottom. With the ebb and flow of the tide, with storms, etc. much of the finest matter must pass into suspension in the sea-water, to be, perhaps, deposited outside the atoll. The influence of this outwash on the character of the bottom deposits outside reefs has been thoroughly established by the Challenger expedition, and there is no call for further comment here.

To quote Sir John Murray's Summary of his Report on Deep-Sea Deposits, "Coral Muds and Sands cover a large area in all coral-reef regions, estimated at about 2,700,000 square miles, including those from shallow water and also the area of the islands and of the lagoons and lagoon-channels. The coral-reef region of the Pacific is by far the most extensive, and there Coral Muds and Sands attain their maximum development, being estimated to occupy about 1,500,000 square miles; in the Atlantic they cover about 800,000 square miles, and in the Indian Ocean about 400,000 square miles[1]." The area in the slightest degree covered or enclosed by actual surface reefs in the Indian Ocean is certainly less than 25,000 square miles, so that the space actually covered by deposits, mainly formed from the same, is at least sixteen times as great. As to the rate of formation of the deposit Sir John Murray remarked:—"Around some coral reefs the accumulation must be rapid, for, although pelagic species with calcareous shells may be numerous in the surface waters, it is often impossible to detect more than an occasional pelagic shell among the other calcareous *débris* of the deposits[2]."

The main cause of the formation of lagoons is, assuredly, the solution of the calcium carbonate by the water, but the outwash of mud is an important and direct subsidiary cause. At the same time the mud has an indirect action as well, *i.e.* by preventing the growth of coral and other sedentary organisms on the floor of the atolls, and by constantly checking and restricting all such growth. This was an action repeatedly observed by us, but from its nature one almost incapable of direct estimation. I am here, however, more expressly concerned with the organisms which are the cause in their individual capacity, rather than the effect which they ultimately produce.

Although it is scarcely necessary, one is here impelled to refer to Darwin's work on "Vegetable Mould and Earthworms" in which he estimates that 10 tons of earth per acre annually pass through the bodies of earthworms, and are brought to the surface. The action of the reef organisms takes in not only the deeper sand but the surface material as well. It is independent of summer and winter, drought and frost, and in the smallest estimate could not be placed at less than 50 times as much as that of earthworms, with an erosive action by the average marine animal on the sand many times as strong.

The phenomena, however, are not confined to reefs, and have been demonstrated by Buchanan in the deposits of the ocean[3]:—"As the result I was led to believe that the principal agent in the comminution of the mineral matter found at the bottom of both deep and shallow seas and oceans is the ground fauna of the sea, which depends for its subsistence on the organic matter which it can extract from the mud." With this conclusion I cordially agree, but I do not think that the sand-feeding organisms of coral reefs have any considerable chemical action on the sand. The latter is always free from smell, even on mud flats, as off Huludu, Addu atoll, and, whether dry or wet, sulphuretted hydrogen (H_2S) is not given off, when acted upon by acid. The sand consists of almost pure carbonate of lime, and, although I sought carefully for any digestive action on the sand—the reaction of the contents of the gut was usually neutral, rarely alkaline—I failed to find any trace of such in the true, sand-feeding organisms[4]. The action of these forms, then, is purely one of trituration.

[1] p. 247.

[2] p. 411.

[3] "On the Occurrence of Sulphur in Marine Muds and Nodules, and its bearing on their Mode of Formation." *Proc. R. S. Edin.* vol. XVIII. pp. 17—39 (1890).

[4] I proved experimentally that *Lobophytum* and massive Astraeid corals will dissolve sand grains that may be taken into their coelentera. I have also found *Operculina* in *Flabellum* and other Foraminifera in *Coenopsammia*, with their shells completely or largely dissolved.

2. *Boring Organisms.*

Nearly all the skeletons of the living reef corals in the Maldives are riddled with boring sponges and algae. The algae all belong to one genus, probably *Achyla*, and seemingly to a single species. The sponges are of two kinds, those which form large spaces in the coral skeletons, which they themselves fill, and those whose presence is more or less imperceptible. The latter belong to the genus *Cliona* and probably like the algae to a single species. *Achyla* and *Cliona* resemble one another in their mode of growth. Their ramifications are most delicate, imperceptible to the unaided eye, and wander all over the coral skeleton. In *Pocillopora* their terminal filaments extend so close to the ends of the branches that only the very thinnest layer of corallum separates the polyp tissues from them. When a branch of this genus is decalcified and the polyp layer carefully stripped off, either of these boring organisms will be seen to have formed a close-meshed network, showing accurately the shape of the original branch with all its twigs.

The two genera do not in the Funafuti or other Pacific Ocean corals occur together, but whether they do so in those from the Maldives I cannot as yet say. To separate the two organisms a minute microscopic examination is required, but the presence of one or other in most reef corals is assured. The importance of these forms lies in the fact that they riddle the coral skeleton as soon as ever it is laid down. In the dead or decaying portions of coral masses they are not found; indeed, they seem generally themselves to die with the coral they inhabit. Of themselves they do not, so far as I have seen, directly cause decay, but presumably they show the way to other boring organisms, which certainly are not slow to follow. Their importance, indeed, is not improbably extremely great, but as yet little or nothing is known of their life histories, or modes of growth.

A second kind of sponge—apparently a Myxospongid—is of some importance for its action on corals, particularly within the lagoons of atolls. It apparently enters such coral colonies as are more or less dead at their attached ends—thus presenting bare surfaces not covered with polyps or epitheca—and hollows out cavities up to a square cm. in size or even larger, which it at once fills up with a mass of yellow or grey sponge. From one space it sends on its growths and excavates other cavities, thus perhaps completely riddling the base of the mass and causing it to fall. No connection with other boring animals was in any case observed or indicated, and the presumption necessarily is that it forms its cavities by the action of some acid secretion. The corals most affected by its growth were perforate forms, particularly *Madrepora*, but I also found it in many Astraeidae as well. An interesting point lies in the fact that this sponge seems to become more prevalent with increase of depth down to 50 fathoms, beyond which I do not know of its occurrence.

Of Mollusca *Lithodomus* (Mytilidae) is often very destructive, as it bores large, perfectly rounded holes up to 12 or 13 mm. in diameter through the coral masses. These often extend for several inches or even a foot or more straight through a colony, and, where one is found, there are usually a great number. The various holes seldom or never communicate with one another, and seem for the most part to run almost parallel. There is always a communication with the exterior through some dead part of the corallum, by which the animal entered in the first place, and the polyp tissues are sometimes broken through as well, the original hole then perhaps being plugged up by sponge or other growth. The animal has no preference for one kind of coral, but all are equally affected, the base of a Madrepore colony, the skeletons of massive *Porites* or Astraeidae, or even a thick branch of *Pocillopora*. *Lithodomus* was extremely

abundant in the velu of Hulule, while in Minikoi it was only once secured. Generally it was local in the Maldives, but, where present at all, it usually was found in considerable numbers. It never occurs in coral in an advanced state of decay nor in rock masses.

A second Mollusc, a small spiral Gastropod, is also in places abundant in corals, but whether it makes its own holes or not is uncertain. It may be as is *Vermetus* enclosed by the growth of the coral. In any case it is only local, mainly affecting *Leptoria* and other reef-loving Astraeidae.

Sipunculoidea are prominent forms in breaking up almost any large block of coral from any position on the reefs or from any depth found on them, but only the bases of branching colonies are affected. These borers are perhaps more numerous in lagoon masses than in blocks from seaward reefs. This may be due to the former generally being larger, and it may be that equally large colonies from say 10 fathoms outside and inside an atoll would be similarly affected. While not quite absent from dead coral-rock—of the reef flat or an upheaved pinnacle, etc.—the boring Sipunculids undoubtedly prefer a coral which is to some degree living. Their holes are perfectly round and smooth, and ramify in every direction through the coralla. In size they seldom exceed the half or third of the diameter the animal assumes when freed. How the holes are made is not in most genera quite clear. When in the living state, the bodies of none have any acid secretion, so that their holes are presumably made by friction. The body is slightly swollen out, and, the skin being rough, forms a firm support from which the animal can act. The genera represented were *Physcosoma*, *Phascolosoma*, *Aspidosiphon*, *Cloeosiphon*, and *Lithacrosiphon*, and an account of the species obtained with further notes will be found in Mr Shipley's Report on the Group (pp. 131—140).

Polychaeta are perhaps really the most important boring animals in coral rock, although the actual forms are inconspicuous and of small diameter. In coral reefs at least some specimens can be obtained from every rock below and between tide marks. All large coral masses are bored into and penetrated by their tubes, which bend and twist in every direction. The surface at the edge of the reef is made rotten for some inches by their borings, and the section of the broken base of a coral often appears as a regular sieve from their holes. The finer-textured corals are principally affected, but all corals and rocks are attacked, so long as they have a fixed base of support. Forms with calcareous or other tubes that grow with the corals are also bad, as they make them peculiarly brittle, and their holes form a lodgment for other organisms, whose subsequent destructive work is greater. From their prevalence in every rock be it of coral, sand or nullipore, the total effect of the Polychaeta must be enormous, and they must certainly be regarded as the prime and most effective agents in the breaking down of coral rocks.

Of the families of Polychaeta, found as borers in the corals and rocks of the Maldives, by far the most numerous and important are the Eunicidae, which in large numbers burrow into every rock and coral, extending in the latter up to and often penetrating the polyp tissues. They are the chief cause of the rotting of the rock of the reef flat, and are abundant in the lagoons as well, coral masses obtained from upwards of 40 fathoms being riddled by their holes. The Lumbriconereidae are less numerous, principally affecting recently formed coral, especially of the seaward reefs and passages. The Scoleciformia may bore into any rock, but are not common except in such as are already in a state of decay. The same remark applies also to the Phyllodocidae, but this family was far scarcer in the Maldives than at Funafuti. The Nereidae and Amphionomidae are not properly borers, but isolated forms may sometimes be found in tubes in the rock, which, if they have not made, they have certainly enlarged.

Their importance lies rather in the destruction of the slabs of beach-sandstone, in the soft sand under which they burrow causing them to split off. Of more markedly tubicolous forms Serpulidae and Sabellidae are common, but as to how far they are destructive I have no evidence.

Prof. M'Intosh[1], the great authority on the Polychaeta, whose opinion on this subject I requested, has been kind enough to give me the following note:—"I have not specially worked at the boring of Polychaeta in tropical waters, but from casual observations think that their action is not less than in European waters—probably more. Their action on calcareous rocks is very conspicuous even on our own shores—especially in the south. They form one of the most destructive agencies in wearing away those rocks—just as they do in the case of dead shells on the bottom of the ocean—ubique."

"Corals form a very suitable material for boring animals. I have not the slightest doubt that in tropical waters the boring Polychaets, such as *Polydora, Sabella, Dodecaria* and others are important agents in leading to the disintegration of rocks (especially calcareous and aluminous) and of shells and of loose calcareous stones."

Lithrotrya, a Cirripede, is a form, numerous on the seaward reefs of both Minikoi and Hulule. It generally inhabits holes in overhanging masses of the raised rock of the outer or seaward reefs. The animals attain a length of about 3 inches, and their holes extend in for about this distance from the under surface of the ledge. In suitable positions thousands may be present, riddling the whole surface of the rock. The regularity of their holes precludes the idea that they can have been made by any other organism. In life they hang downwards with their appendages just projecting out of their tubes, when their entrances are covered by water. No other Crustacea are true borers, but *Cryptochirus* and *Hapalocarcinus*[2] are of

[1] *Vide* "On the Boring of certain Annelids," *Ann. Mag. Nat. Hist.*, ser. 4, 1868, II. p. 276 and also "Notes from the Gatty Marine Laboratory. 5. On the Boring of *Polydora* in Australian Oysters," *Ann. Mag. Nat. Hist.*, ser. 7, 1902, LII. pp. 299—308, both by Prof. M'Intosh.

In the latter paper the author remarks that *Polydora* is a ubiquitous genus and well known as an active borer in shells, rocks and stones. He also quotes Prof. Leon Vaillant's estimate that there would be 250,000—300,000 *Polydora ciliata* in one superficial metre of the calcareous rocks at the mouth of the Somme.

Mr Cyril Crossland, who has recently returned from Zanzibar and Pemba, has favoured me with a note on the Polychaeta, the group on which he has been more particularly working. I do not, however, agree with some of his conclusions, and accordingly quote him at length:—

"The inner part and main mass of the reefs, which are formed of crystallised limestone, are too hard for any boring organism to touch, the only effect I have seen produced on this rock by any organism being the impression of the foot and shell of a *Patella*. The surface of the reef-edge to the depth of a few inches is soft, and this is much bored into by Eunicidae, the mud and sand they produce being matted together in this same position by filamentous algae. This in spite of its softness forms to some extent a protection to the reef edge, so that it effectively resists the action of the sea. The recently formed rock of the boat channel is also much bored, but not sufficiently to make any great difference to its cohesion.

"Polychaeta bore more especially in living coral, one or two specimens being found in most coral blocks when broken open. I do not think their effects are of much importance in Zanzibar in comparison to those of parasitic and aulophytic sponges. However weakened the coral may be at its base, it will in general remain in its position of growth.

"The bulk of my collection of Polychaeta was found in sand, or among weed and sponge. Their most important effects lie in the transformation of moderately coarse sand into fine mud. They are rare in very fine sand or in thin mud, seeming rather to require, to be present in any abundance, a fairly stiff mud or a sand coarse enough to cohere somewhat. In such positions their numbers are enormous (though their size is in general very small), and the amount of fine mud produced by them every year must be considerable. Wherever the sand is broken by the spade one sees innumerable, fine, red threads stretching across the crack, these being the bodies of small Lumbriconereidae and Capitellidae. Small tubeless Terebellidae also occur, but larger forms, Eunicidae and Scoleciformia, are not so abundant.

"The principal boring family in live coral is the Eunicidae, the commonest species attaining a length of about a foot and making an intricately twisted boring of corresponding length. Sabellidae make short, straight holes. Serpulidae render branches of Madrepores brittle by their tubes, which hollow them out, sometimes every branch of a clump containing a tube."

[2] *Vide* "Marine Crustaceans. III. Xanthidae and some other Crabs," in the same Part of this Publication.

assistance as maintaining open holes in the living corals, which frequently become later centres of decay.

Of other animals some Echinids and Patellids wear out holes in the rock, where they normally take up their positions in daylight. Ophiurids creep into any holes, however small, preventing them from being filled in with sand. *Bonellia* lives in cavities of the reef, often 1 to 2 feet below the surface, but is a rare form, and many Nemertines retire during the day to holes. None of these animals, however, are so far as I am aware actual borers.

3. *Sand-feeding Organisms.*

There are on reefs a very large number of animals that swallow sand, living presumably on the extremely small percentage of organic matter that it contains. It seems quite certain that the majority of these forms play some considerable part in the grinding up of the sand, but in most cases the process, by which they do so, is not quite clear. It will be seen later that all such sand-consuming forms have peculiar modifications of the gut, which adapt them in a singularly efficient manner for the consumption of such food as the sand contains.

It should here be pointed out that none of these sand-swallowing animals feed directly on living corals, breaking off branches, etc. The polyps are thoroughly well able to protect themselves against most free-living organisms. Indeed, so far as I have seen, a few Gastropods alone *make a practice* of consuming the polyps, leaving dead tracks over the otherwise living colonies. I do not know what author is responsible for the now common text-book statement that Holothurians browse on corals[1]. Even considering the anatomy of these animals, it is obvious that the statement cannot be accepted. Holothurians might, possibly, be able to suck off parts of the polyp layer, but that they could regularly break off coral branches, etc., is clearly impossible. Bits of recently dead corals may occasionally be found in their intestines, but I found by experiment that small living solitary corals and fragments of living coral were always rejected by the ordinary Holothurians of the reef at Minikoi. The actual animals that conceivably could feed on the reef corals of the Indian and Pacific oceans are extremely few, and certainly Holothurians are not among their number.

Holothurians are, however, from their great abundance on reefs the most important animals engaged in sand-consumption. The sand, wherever it is present under the stones of the boulder zone at Minikoi, commonly has living on its surface two or three species of brown and white forms, while in the sand itself a few small, transparent Synaptids are sure to be caught. A form, resembling *Synapta ooplax*, is common on lagoon beaches, often in enormous numbers. Holothurids, related to *Stichopus chloronotus* and *Holothuria atra*, are abundant on every reef. The former generally affects the seaward reef-flats and the encircling reef of the atoll, while the latter is found on all sand-flats and reefs within the lagoons. The two species, though, may sometimes be observed on the same area. Other forms of every conceivable colour up to 2 feet or more in length are also to be seen on the surface of the sand, many covered by its grains so as to be scarcely distinguishable. Large Synaptids, further, come out from overhanging coral masses every night, retiring during the heat of the day.

Most of the above are surface animals, but in addition to these there are numbers of species that live in and bore into the sand. A relatively thin, white species with dark brown spots,

[1] *Vide* "Coral Reefs," by Chas. Darwin, 3rd ed., p. 20. The statement, surely, does not rest on this one observation.

Holothuria maculata, was most conspicuous everywhere on the sand flats, attaining a length of 3 feet when extended. It makes burrows, up to 6 feet in depth, sometimes bent with two or more openings. At Minikoi, where the sand flat of the lagoon near the light-house was at low spring tides uncovered for some distance, the drying up appeared to stimulate these Holothurians to actively extrude their sand, and the whole flat every yard or so was studded with little masses of their pellets, which at once on the tide rising broke down into sand-heaps. 20 out of 52 of these castings from an especially rich area were scraped up and measured, giving an average of 37 c.c. for each animal. This, if spread out evenly, would cover the whole area to a depth of ·11 mm., or a layer of sand of over 40 mm. in thickness might be supposed in this area annually to pass through the bodies of this one species. In addition in every sieve full of sand from this same area large numbers of pink Synaptids, about 2 inches long, were obtained, which, if less conspicuous, probably passed still more sand through their bodies than the larger form just mentioned.

Holothurians are especially adapted to sand-feeding, in that they possess a conspicuous, ciliated groove to the gut. Besides extruding pellets many species also, or perhaps always, pass the sand through their bodies in a stream. The surface forms, mentioned above, feed during the night, remaining during the day more or less dormant. Of 63 specimens of *Stichopus chloronotus,* obtained at dawn between the large island at Minikoi and Wiringili, 59 had sand in the mouth part of the gut. This was absolutely the same as that covering the bottom, mostly clean sand with a little fine washings. The output of these forms seemed almost continuous during the day, and consisted of fine sand only. Of 31 specimens obtained about mid-day all had the fore part of the gut free and the mid part choked with coarse sand. A few, kept in a barrel and not allowed to feed, extruded some of their sand in pellets, but most retained it for 3 or 4 days, only getting rid of the finest particles. In ten specimens, kept in a sunken barrel and allowed to feed on fine sifted sand only, the mid part of the gut was found after 5 days to be still filled with coarser particles than any, which the animals had been given.

A Holothurian dredged from 43 fathoms, E.N.E. of Havaru-Tinadu, Suvadiva, was singularly interesting. It came from an area of the finest mud, which extended for 1½ miles in all directions from the spot where it was dredged. The mid-gut was, nevertheless, full of relatively large fragments of coral, *Halimeda* leaves, etc., the coarseness of the contents approaching such sand as ordinarily covers the bottom at 20 fathoms under a relatively strong current.

The sand of the mid-gut of all reef Holothurians, that I have examined, is always seen to be clean and the particles more or less rounded. In addition there is little loss on washing, while the sand in the first 3 inches of the gut commonly loses 2—8 per cent. of its weight in this process. Indeed, there is no doubt but that the coarser particles are detained in the gut for a considerable time—and probably worn down—while the sand and mud is by some means —presumably the ciliated groove—passed onwards. The extrusion of the whole gut and its subsequent regeneration is a process which commonly occurs in nature. It, not improbably, is for the purpose of getting rid of the very coarse sand, the exertions of the animal not being able to force it out in the form of pellets.

Of course different kinds of Holothurians may behave in diverse ways, but the total effect even of the two surface forms mentioned above must be enormous. The weight of sand, when dried, from 4 average specimens of *Holothuria atra,* taken in the early morning, was 297·3 grams. Of this 44·3 grams were extruded as fine particles into the bucket in 5 hours,

32·5 grams were found in the mouth or first part of the gut, there remaining for the rest of the intestine 220·5 grams of very coarse sand and fragments. A single, rather larger specimen, taken while evidently still feeding, had 190·7 grams of sand. Five other specimens, also taken in the early morning, extruded in the first 12 hours 47·9 grams of mostly fine matter. In the following night the coarse sand began to be got rid of, 49·4 grams being weighed making 97·3 grams for the first day. In the second day 121·4 grams were extruded, in the third 99·3 grams, in the fourth 67 grams and in the fifth 22·5 grams. The experiment was then concluded, 31·7 grams being weighed from the guts of the specimens, making a total weight of sand of 439·2 grams.

The specimens, recorded above, were obtained in fine weather in August, but of 55 specimens examined on July 6, 1899, after bad weather of some days duration, 19 had no sand in the gut at all, and only 18 of the remainder in the anterior part, showing that they had been feeding. The experiments required an accurate means of dividing the sand into its differently sized constituents. As it is, they merely show that the coarser particles are retained in the gut—being necessarily to some extent reduced in size—and also that there is in certain species a continuous passage of fine matter down the gut, presumably along its ciliated fold or groove. The latter or some similar organ is characteristic of most true sand-feeding animals, and probably in all cases functions in the same way.

Of other Echinoderms the Echinids[1] are also true sand-feeders, the gut in most forms being generally choked up with sand or small rock fragments. These animals, however, are of no great importance on coral reefs, the most numerous forms living on the reef flat, boulder zone or between branches of corals. *Echinomus cyclostomus* was found in some quantity in the sand of the flat at Hulule. The adaptation of the sub-order to this mode of feeding is seen in the animals possessing a furrow to the intestine or one or two siphons, which undoubtedly subserve the same function as the groove in Holothurians.

Ptychodera is also of great importance as a sand-feeder, though how far it actively triturates the sand—considering its feeble musculature—is dubious. The presence of ciliated grooves in the hepatic and abdominal regions of the gut indicates that the sand may be for some time retained, when some breaking down would be sure to be accomplished. The ejection of the sand is a rapid process, only taking a few minutes—all the species live in the sand, some having burrows of poor construction—and occurs at the surface, the animal at least in *P. carnosa*[2] slightly extruding its cloaca. No autotomy—so far as I have seen from the examination of several hundred castings—takes place in nature. The animal after ejecting its sand retreats again, but in *P. flava* and in *P. carnosa* still carries with it more than two-thirds of its original amount of sand. Further *P. flava*, if not irritated, retains its sand for a long time, attempts to keep the animal, until it had cleaned itself naturally, being quite futile for 4 days.

The importance of *Ptychodera*, where found at all, lies in its great abundance. The surfaces of sand flats throughout the Maldives are studded with the castings of *P. carnosa*, often 100 c.c. or more of sand. As Dr Willey said of them in the S. Pacific, "they form an important feature of the landscape at low tide[3]." Even more abundant in the sand of the lagoon at Minikoi was *P. flava*, but its distribution in the Maldives was local. Where it occurred, however, a single handful of sand was often found to contain 4 or 5 specimens.

[1] See Prof. Jeffrey Bell's Report on the Actinogonidiate Echinoderms in the same Part of this Publication.

[2] I am indebted to Mr R. C. Punnett, who is working out the collection, for the names of these species.

[3] "Enteropneusta," Willey's *Zoological Results*, p. 256 (1899).

Apparently the same species often lives under beach sandstone masses, at Maduwari in S. Mahlos being present in enormous numbers in this position. *Spengelia* was also obtained, but, although a sand-feeder, was nowhere found in sufficient abundance for it to have any appreciable effect on the sand.

Next in importance come the species of the genus *Sipunculus*, which likewise possesses a ciliated groove to the gut. Mr A. E. Shipley, who has had considerable experience of tropical forms, in considering the Gephyrea (*Camb. Nat. Hist.*, vol. II. p. 422) remarks, "The food of Sipunculids seems to consist almost entirely of sand and their only nourishment must be such small microscopic organisms or particles of animal or vegetable *débris* as are to be found mixed with the sand. The alimentary canal is as a rule quite full of sand, and yet in spite of the tenuity of its walls they never seem to be ruptured. If the contents of the digestive tube be washed out with a pipette, it will be found that it requires considerable force to dislodge many of the sand-particles lying next the wall. These are more or less imbedded in crypts or pockets of the wall, and, as the sand passes along the intestine, they probably serve as more or less fixed hard points, against which the sharp edges of the sand particles are worn off. Amongst the sand are usually to be found pieces of shell, sometimes with a diameter equal to that of the alimentary canal; these are usually rounded but their angles may have been removed by attrition before they entered the mouth of the Sipunculid."

The animals of the genus (*Sipunculus*) are extraordinarily abundant on all coral reefs in certain positions, such as under dead corals or masses of rock. The quantity of sand that passes through their guts must be considerable, but much of it seems to be retained for a long period. It is too almost impossible by anaesthetisation to get the gut free from sand. The castings are relatively both small and fine in texture. The quantity of sand passing through the gut does not appear to be great, but what passes is much triturated. Perhaps therefore the total action of these animals may be of more importance than that of any other group. The species of our collection have already been reported on by Mr Shipley, under each its distribution being noted. I may, however, remark that *S. indicus* is found in large numbers on practically every sand flat in the Maldives.

Of other sand-feeders *Thalassema* may be mentioned, of the contents of the gut of which Shipley has given a list (p. 129). The genus is, however, rare on reefs. Polychaeta commonly swallow as they burrow in the sand, but I have no reason to suppose that the sand forms —although often very numerous—triturate the sand to any notable extent. This does not quite agree with Mr Crossland's view (p. 337), but against this may be mentioned M'Intosh's observation that the deep-sea Challenger forms often had Foraminifera and Radiolaria in their guts in an almost perfect state[1]. Much material, especially on the more muddy flats, must nevertheless pass through their bodies, and cannot but be to some slight degree affected.

Section VI. Beach Sandstone.

Large, linear masses of a friable sandstone, extending sometimes for great distances along the shores of the islands, are characteristic of coral atolls in whatever part of the world they may be found. So far as I have seen in the Maldives and elsewhere, these masses only occur in their typical condition (1) where there is a fringing reef or a sand flat of greater or lesser breadth extending out from the shore, or where the beach is by other

[1] "Annelida Polychaeta," *Challenger Reports*, p. ix. (1885).

means protected from the direct force of the waves; (2) where the beach is made up practically entirely of carbonate of lime formations; (3) where the beach is formed principally of sand and not of masses of rock; and (4) where the beach is at rest so far as growth outwards is concerned or washing away.

In respect to the first of the above conditions it is necessary that the beach for a sandstone formation to be found should be to a large extent protected from the heavy ocean rollers or the smaller but perhaps more persistent influences of the waves within large atolls. At Maduwari (Fig. 30) a little sandstone is found to the north of the island at the south side of an incipient lagoon. The beach is, however, protected by the north-east horn of the island, and the velu is as yet both shallow and small.

Each island, while forming land of a faro or atoll, has generally its own circumscribing or fringing reefs. If the island be situated on a faro as Hulule, Male atoll, or most of the islands to the west of North Mahlos, the reefs may be on one or all sides far distant and connected rather with the encircling reef of the faro. In all cases such an island lies on the reef, or is joined to the growing part of the reef on one or more sides by a shallow flat, no velu in the Maldives having even a single isolated island arising within it. The island indeed may have beach sandstone on any of its shores, but on the side towards the velu, unless there is a considerable sand-flat, beach rock is absent.

Isolated islands, which cover the greater part of their reef, such as most of those in Miladumadulu and to the east of North Mahlos, may, where other conditions are favourable, have sandstone on any side. That there should be a definite protecting flat or reef of some sort is, nevertheless, clearly necessary. On the seaward and lagoon ends of most of the encircling islands of Miladumadulu and Mahlos there is generally no sandstone. Sometimes to seaward the shore is rocky, but very generally sand is found of not greater coarseness than that which forms the rock of many of the lagoon islands. A comparison shows that the explanation is to be sought in the extent of the protection, *i.e.* in the breadth of the fringing reef. Thus on the east or seaward side of the three neighbouring islands of Kenurus, Fainu and Inguradu the reef is respectively about 30, 200 and 60 yards broad, and sandstone is only found on the corresponding shore of the second island.

The reason that there is no beach rock on the lagoon shores of so many of the encircling islands is very largely the same, particularly in the atolls mentioned above. The fringing reef is generally narrow or almost non-existent, and the sand washes to and fro on the beach with every tide. The whole beach, too, is never at rest nor in one condition for any length of time. The currents on each side of the island in the one monsoon form an eddy behind it, piling up sand, which the other monsoon, sweeping across the atoll lagoon, removes so that the beach is restored almost to its former state. For the same among other reasons the corals of the shore, alternately nearly killed by the sand and growing vigorously, are off many islands unable to form a definite fringing reef. The conditions are best seen on the east and west sides of the atolls, through the passages in which the currents attain their greatest force. Even to the north and south in the more open atolls sandstone is rarely found on the beaches of the islands towards the lagoons. To the south of Mahlosmadulu, however, between Hitadu and Defuri the rock is found just as frequently on the lagoon sides of the islands as towards the passages between them.

The beach in the Maldives is in most places formed almost entirely of carbonate of lime formations. Near villages, where much organic matter is present—from the soaking of coconut husks for coir on the reef-flat, etc.—and in the more enclosed parts of Addu lagoon no rock

occurs on the beaches. In Ceylon, where silica is always met with to a very considerable extent in some form or other in the beaches, my examination—extending round more than the half of the coast-line of that island—failed to find any typical formation of beach sandstone or indeed any trace of formation at all, except where the land above was of coral origin. In many parts the other conditions were perhaps not favourable, but in others looked eminently so. In any case the presence of even 5 per cent. of silica seemed to prevent any extensive building up of the sand of the beach into layers and terraces, typical of the appearance of the beach rock on coral islands. At Rotuma off Noatau, Oinafa and Pepji[1], where a typical formation exists, the beach was built up of almost entirely the same constituents as those which form the shores in the Maldives, the land in Rotuma for some distance behind the beach being in the above positions of coral formation.

Even the finest textured specimens of the sandstone show their constitution to the unaided eye. Of the very numerous pieces, which I broke off, none were in any way homogeneous, but all could be clearly seen to have been formed of sand grains of varying size. Where the sand was of extreme fineness, no rock was ever found. Minikoi has near the village on the lagoon side, where the conditions appear in many places exceedingly favourable for the formation of the rock, such a sand on its beach, but there is no trace of any consolidation into rock. Along the west side of Hulule, the sand is perhaps a trifle coarser but there is no sandstone except near the south point, round which coarser material is swept up on to the beach. Of coarseness there is no limit, the rock sometimes consisting of pebbles with the interstices filled in by sand. Indeed, it is only essential that there shall be such an amount of the latter that the surface of the beach is smooth, all the interspaces being filled in by the sand. The coarsest material on a beach is naturally found at its base, and in correspondence the sandstone usually increases in fineness, the higher it lies above the low tide level.

The beach sandstone is everywhere in the Maldives perfectly distinct from the raised rock of the islands, which is a submarine formation differing radically in its constitution. Both rocks, if in the same position, *i.e.* on the beach, would be affected by the same conditions, and might hence in external appearance resemble one another. The structure of the raised rocks has already been dealt with (pp. 35, 162, etc.), but it cannot be too strongly emphasised that the formation of this sandstone can only take place on the beach and between tide-marks. Its constituents show all the characteristics of such a formation, being much broken, angles rounded and surfaces pitted. Among them may be recognised pieces of coral of all the kinds found on the reefs or in the raised rock, but branching species especially of the genus *Pocillopora* are by far the most abundant. Small Molluscan shells and fragments of shell are common. Bits of nullipore, leaves of *Halimeda* and similar algae, spines and ossifications of Echinoderms, Crustacean remains and shells of Foraminifera make up the residue. The only constituents, not of lime formation, sometimes found are more or less decomposed fragments of pumice and sponge spicules and remains, but all these are relatively scarce, and do not in the Maldives form together more than ·1 per cent. of the total analysis. For the constitution of the rock, however, its mode of formation and its method of occurrence may best be considered.

The sand rock presents in its typical development on any beach a series of sloping terraces, separated from one another by steps. These terraces slope at the angle of the dip of the beach or slightly less, and the step from one to the other is about 5 inches and extends

[1] *Vide* "The Geology of Rotuma," *Q. J. Geo. Soc.* vol. LIV. pp. 1—11 (1898) and "The Coral Reefs of Funafuti, Rotuma, etc." *loc. cit.* pp. 438—44 (1898).

at right angles to the slope. The appearance would hence be that of immense stone slabs, all duly squared and laid on one another against a sloping bank. Sometimes there is as it were a single slab, sometimes 9 or 10 apparently on top of one another. Often there are two or more lines of such masses in a beach, each of one or more terraces, separated by hollowed out sandy areas, and yet perhaps more often a single line at the base of the beach from the half tide to the low water mark. Where the beach is steep or ends in a cliff, there may perchance be as at Boni-Kodi, Minikoi (p. 32) an induration of the sand of that cliff, but marked areas are only found on the shore, where the slope does not exceed 10°, and the beach consequently is of considerable breadth.

The varying conditions can of course best be seen by definite instances in different atolls, which will be found in Appendix B. to this paper. The greater part of the evidence also that any beach, where such formation is going on, is being washed away rather than growing outwards on its reef must likewise be sought in the same place. It is, however, clear from the consideration of the mode of formation of the sandstone that such must really be the case.

The first appearance of the rock on different beaches varies considerably. It commonly commences as a single broad line at the base of the beach, where it passes into the sand or reef flat. Such a layer merges into the sand of the beach above and into that of the flat below. Usually its rock is very soft, and can be easily dug out by a hammer or crowbar. It does not, however, remain long in this condition. If the beach is growing outwards on the reef, it becomes covered up with sand, and can only be traced as a slightly more consolidated layer in the sand of the island. More often the waves overtop the layer, and the sand above it is washed out, or the sand above may be removed by the wind. The layer on the face of the beach has now become a definite terrace.

When the sand above the layer has been removed to a depth of about 5 or 6 inches from the face of the beach, the first layer more or less protects the beach from further encroachment, and a fresh layer commences to form. By this means 3 or 4 layers may be found on a beach, the lowest merging gradually into the sand of the flat and the highest almost reaching the high water mark. The water after every wave, that runs up the shore, has somehow to reach the sea again. It naturally is hindered by each layer, along the top of which it flows to make its escape at the lowest point. Its action here is twofold, firstly in wearing away—partially by friction and partially by solution—the top of any layer, thus reducing it greatly in breadth, and secondly in undermining the layer, forming natural crevices by which the water joins the sea again. By this means more and more layers may be formed, in one place on the beach at Duravandu, South Mahlos (Fig. 75), seven having been thus fashioned. The water in its escape off the beach consolidates the sand under the top layer of stone, and the second layer accordingly may be traced under the first. In a section owing to this action all or most of the layers may be perceived, each layer being less consolidated than the one above it, until about the third or fourth merges into the sand of the island.

The natives are thoroughly well aware of the second or undermining action of the sea, and use it largely for obtaining their building material. A firmly consolidated layer is chosen, and, where it immediately overlies the layer beneath, its top is hollowed out so that the water may find a resting-place. When in a year or two the layer has become more or less undermined, a series of cross-cuts is made with the result that in another year the whole of the top layer can be wedged off in a series of slabs. In one of the beaches of the island of Male this action even on coral rock was clearly seen in a square about 4½ feet across, cut

Fig. 1. Beach Sandstone to NE. of Turadu Island, S. Mahlos Atoll.

Fig. 2. Quarrying coral rock at Male Island.

Fig. 1. Sandy Beach to SE. of Hulule Island, Male Atoll.

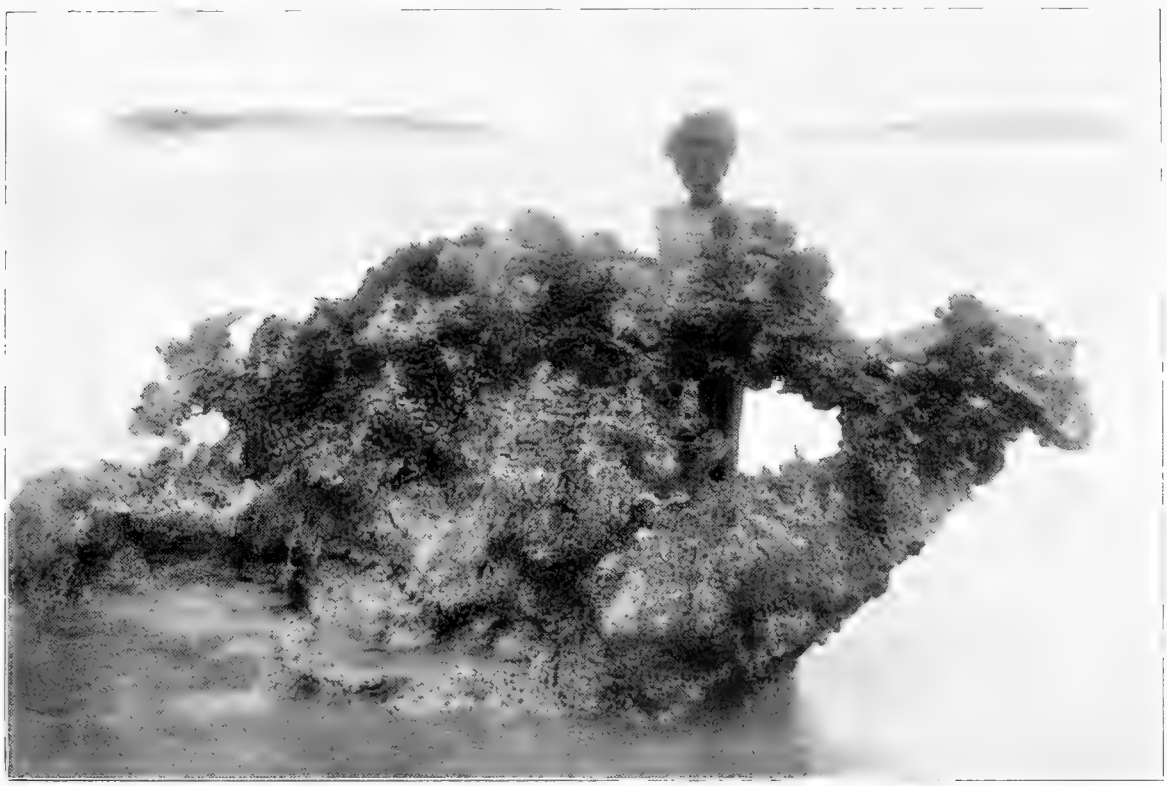

Fig. 2. Elevated mass of coral rock on the sand flat to east of Hulule Island, Male Atoll.

To face p. 344.

in the beach, 5 to 6 inches deep, with a gutter for the water to escape (Plate XVI.). Whether the rock was in this instance part of a raised reef or of other formation was uncertain. It was of great hardness, largely formed of coral masses, worn quite smooth by the waves. According to the workmen's account, 4 to 5 years would be required in this case for the freeing of the slab. If this be so, the undermining action on sandstone masses, that constantly occurs in nature, must be a very rapid one.

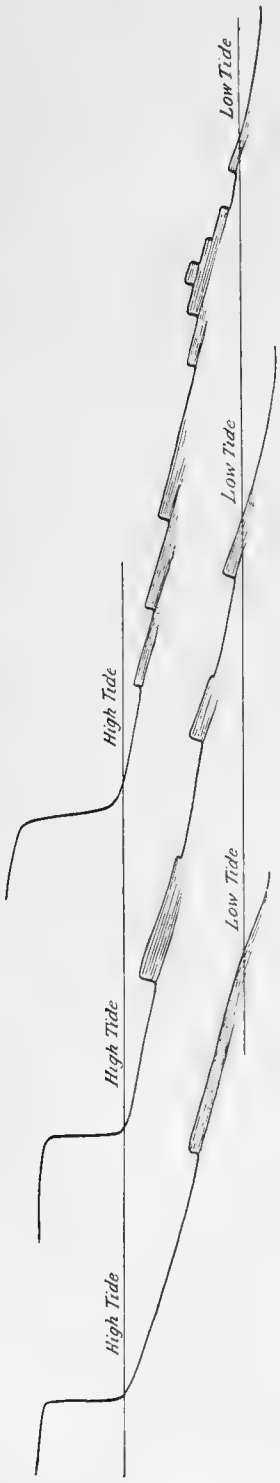

Fig. 75. Three sections of the beach to the south and south-west of Duravandu, S. Mahlos, showing the existing formations of beach sandstone (shaded). (*The vertical scale is double the horizontal.*)

When 4 or 5 terraces, extending from the low to the high water mark, have been formed, the further action by the sea may make no change in the surface appearance of the beach. The lowest and hence outermost line of slabs may be undermined and gradually broken off, but at the same time all the terraces are slowly being eroded away at their upper ends. A fresh terrace will accordingly always be forming just below the high tide mark. Should a cyclone resulting in an especially high sea arise, a considerable quantity of sand might be removed from the beach even above the top terrace. When the sea has thus once made a lodgement, its action tends to go on, resulting in a considerable hollowing out. So long as the washing away by the sea is extensive, no fresh sandstone can form on the beach. Nevertheless, a state almost of equilibrium is bound sooner or later to be reached, and will in most places then result in a fresh formation of rock.

The same conditions may repeat themselves, and the beach may hence come to have not one but a series of terraced masses with sand or water between each. In one part of the shore of Duravandu (Fig. 75), already alluded to in this connection, there are three such series on the beach. The lowest is 18 inches high above the low tide limit by 7 feet broad, and lies almost on the reef-flat; it has the remains of three terraces, and above steps down almost to the low water level again. The top of the second is 37 inches and that of the third 53 inches above the same mark. Above the latter the beach has, where it passes into the land, a distinct cliff, showing that it is still evidently washing away. A fresh series of terraces will probably sooner or later result in this manner. The differences in the height of the three series of masses above the low water level are evidently due to the action of the sea in tearing off and eroding the rock. A further complication is seen to the north-east of Turadu, S. Mahlos (Plate XVI.), where there are close together on the sand flat the remains of four lines of the rock, while at the base of the beach behind a fifth is now forming on the shore. To the south of the same island the washing away of the beach has been more rapid, resulting in two lines running out from the shore for about 140 and

300 feet on to the reef, as well as the remains of two series almost parallel to the beach at distances of 270 and 530 feet from the same.

The action, which forms the rock, is quite clear and requires little comment or explanation. The sea twice in the 24 hours covers and recedes from the beach. In a tropical region the sand may be said to be twice wetted and dried. In the latter process the salts in the sea-water are deposited on the sand grains. Some are at once redissolved on the tide again covering the beach, but the carbonates and the sulphate of calcium largely remain, in course of time filling up the interstices between the sand grains and binding them together. The sulphate of calcium later becomes largely replaced by the less soluble carbonate, a rock being ultimately formed of almost pure carbonate of lime. The rock is naturally built from the surface downwards, the drying up and fresh wetting by the sea being mainly superficial. The thickness of the layers, 5 or 6 inches in the Maldives, probably represents the mean depth to which the drying up of the surface is effective at low tide. That the sand must be formed necessarily in the first place of almost pure carbonate of lime remains is probably due to the more powerful attraction that bodies of the same or like constitution have on one another together with the restriction of the variety of the crystalline forms that would occur in the beach[1].

From the consideration of the foregoing account of the beach sandstone it will be obvious that almost any conceivable complication may arise in its appearance and distribution off any island that may be washing away. In nearly all cases the slope of any mass is that of the beach, of which it originally formed a part. The masses in course of time become more and more indurated with carbonate of lime and of great density and hardness. Where the beach is washed away and they lie on the flat, the terrace arrangement may disappear, and they will then become separate, long, irregular blocks, more or less rounded at the top. In this state they resist the action of the sea even more than the coral conglomerate, and where all remains of the latter may be lost these masses often are left. It is obvious then that from the study of such masses off any island or on any reef the former extent and contour of the land may be deduced with considerable certainty. The erosion of land in the Maldives, the formation of flats at about the low tide level by the washing away of the land and the hollowing out of such flats to form first pools, then velu or definite lagoons, may absolutely be traced. The facts speak for themselves, and—if my views as to the formation of this rock be correct, of which I can have no doubt—I claim to give indubitable proof that the conceptions of Murray as to the formation of lagoons and my own opinions, enunciated in Chapter VII. of this paper, rest on a firm and correct basis.

[1] The skeletons of the organisms that form the sand are generally of calcite or arragonite. Most of the deposit of calcium carbonate is in the first place in the amorphous state, subsequently metamorphosing to the crystalline form of the remains of the organism nearest to it. This deposition of amorphous material may be due to the constant presence of a small trace of organic matter, hindering crystallisation.

The reason why a relatively small amount of organic matter should prevent the formation of beach sandstone, as in the instances mentioned above (p. 343), is not however quite clear.

It is interesting to notice that the natives of Suvadiva make use of this indurating action of the tidal waters to harden the corals of which they make gravestones. The coral—generally a mass of *Porites arenosa*—is roughly squared and then deposited for a year on the beach between tide marks so that the pores may be filled up, the whole then wearing much better when placed in position.

(*To be continued.*)