CIRRIPEDES ASSOCIATED WITH INDIAN CORALS OF THE FAMILIES ASTRAEIDAE AND FUNGIDAE.

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Plate XII.

At Professor Matthai's request I have worked out the Cirripedes associated with the corals discussed by him in the preceding report. These do not include the whole of the collection of Madreporaria preserved in the Indian Museum, for several important genera have been reserved for future consideration. The chief are *Turbinaria*, *Acropora* (*Madrepora*) and *Porites*, on all of which other barnacles may yet be found. I have included a reference to those cirripedes already known to be associated with *Turbinaria* in my key on p. 61.

No attempt has been made since Darwin's time, so far as I am aware, to discover definitely what cirripedes are associated with what corals, or whether the association is in any case specific or even generic. To investigate this point was my chief motive in examining the collection. The results have been disappointing. They are summarized in the table on pp. 67-68. Discussion may be postponed until further material is rendered available by authoritative determination of the corals and the acquisition of well preserved specimens.

Key to the Species of Cirripedes known to be associated with Corals in the Bay of Bengal.

1. Shell with six compartments visible externally, conical or globose.
   - A. Shell conical, with the orifice apical or near (*Balanus*).
     - (*i*) Basis cup-shaped, forming a simple suture with the shell. (Orifice moderately large, distinctly rhomboidal) ... *B. arcuatus.*
     - (*ii*) Basis flat; basal margin of shell produced into processes.
       - (*a*) Basis solid; basal processes of shell simple; orifice pore-like ... ... *B. fujiyama.*
       - (*b*) Basis pierced by numerous perforations, very thin; basal processes of shell (in var. *radicifer*) branched; orifice moderately small ... ... *B. terebratus.*
   - B. Shell globose, with the aperture eccentric in the rostro-carinal line (*Acasta*).
     (Basis flat, solid; shell with basal processes) ... ... *A. funiculorum.*
2. Shell with four compartments visible externally, flat (*Creusia*).
   (Basis cup-shaped; orifice moderately small, rhomboidal; shell decorated with numerous radiating ribs) ... ... *C. spinulosa.*
3. Shell forming a uniform disk without external sutures (*Pyrgoma*).
   - A. Shell with four compartments distinct internally; tergum and scutum fused together ... ... *P. indicum.*

B. Internal sheath of shell uniform, without sutures; tergum and scutum fused or distinct.

(*i*) Shell star-shaped or lobate, with a minute orifice ... ***P. monticulariæ.***

(*ii*) Shell oval or ovate, with a moderately large orifice.

(*a*) Shell smooth, conical, projecting; main axis of orifice forming an angle with that of base of shell; tergum and scutum fused, forming a broad subtriangular plate ... ... ***P. grande.***

(*b*) Shell with radiating ribs, flat or nearly so; main axis of orifice parallel to base; tergum and scutum distinct, the former separated into an upper and a lower region by a transverse ridge, the latter very broad and low ... ... ***P. crenatum.***

Balanus arcuatus Hoek.

1913. *Balanus arcuatus*, Hoek, *Siboga-Exp.* XXXI b, p. 210, pl. xxi, figs. 4-14.

Hoek distinguished his *B. arcuatus* from Darwin's *B. allium* by the structure of the operculum and particularly on the fact that the apex of tergum was distinctly beaked. In the large series of specimens I have examined I find much variation in the opercular valves and especially in the form of the apex of the tergum, which seems to be liable to be worn away into a fine process or beak. I am, therefore, doubtful whether the two forms are specifically distinct, but leave them so provisionally as my specimens agree on the whole rather with Hoek's than with Darwin's figures.

B. arcuatus is by far the most indiscriminate of the cirripedes examined so far as the choice of host is concerned. It is the only species found associated with *Fungia* or its allies. I have rarely observed it, however, on parts of a coral-colony in which growth was very active. On *Fungia* it occurs either on the lower surface or, more rarely, wedged in between the transverse plates on the upper surface. In the latter position the barnacle must have been almost completely enveloped in the soft tenues. On compound coralla its cup-shaped basis is usually overgrown with coral, but in some way it usually succeeds in keeping its shell free or almost free from overgrowth. Occasionally, however, the whole shell is covered by a thin layer of coral.

B. arcuatus was described from the Malay Archipelago.

Balanus fujiyama, sp. nov.

1903. (?) *Balanus terebratus*, Borradaile "Marine Crustaceans VII" in Gardiner's *Faun. Geogr. Maldive and Laccadive Arch.* I, p. 442.

1906. *Balanus terebratus*, Annandale (*nec* Darwin), in Herdman's *Ceylon Pearl Fish.* V, p. 148.

This species has hitherto been confused with Darwin's ***B. terebratus,*** from which the absence of perforations in its basis will at once distinguish it. The structure of the operculum is also different.[1] The nearest ally of the species is probably ***B. quadrivittatus*** Darwin, but the aperture is much smaller and the valves are narrower.

[1] See Hoek, *op. cit.*, p. 207, pl. xx, figs. 17-21; pl. xxi, figs. 1-3.

The shell is very sharply conical, with a very small, indeed almost pore-like orifice, white, sometimes tinged with rose-pink, thin and rather fragile. The compartments are difficult to distinguish in old specimens and the alae and radii are always narrow. The external surface is sculptured with numerous stout irregular vertical ribs, which are prolonged beyond the edge of the basis in the form of simple horizontal root-like processes. These tend to disappear in old shells. No part of the shell or basis is porous. The internal sheath is not very stout and the transverse striation of the parietes is not strong on this surface, but the lower part of the shell is deeply grooved vertically.

The basis is flat, thin, devoid of perforations, somewhat translucent but permeated by numerous radiating threads of more opaque substance.

The type-specimen is 10 mm. high, with a transverse diameter at the base of 13 mm. The orifice is about 1 mm. in diameter.

The operculum closely resembles that of *B. quadrivittatus* Darwin as figured by Hoek, but the outer articular border of the scutum is much narrower on the internal surface and the inner border both of this valve and of the tergum straighter. The tergal spur is also less differentiated.

Type-specimen (C. $\frac{664}{1}$ Z. S. I.) from lower surface of *Pachyseris speciosa* (Dana) from Pilai I, Mergui Archipelago.

The species occurs on the lower surface of *Turbinaria crater* in the Gulf of Manaar as well as on the corals indicated on p. 67.

Balanus terebratus Darwin, var. **radicifer,** nov.

The shell and basis of this barnacle so closely resemble those of *B. terebratus* Darwin that I do not feel justified, in the absence of opercular valves and internal organs, in describing it as a distinct species.

There are, however, constant differences in the seven shells I have examined, not only from Darwin's specimen but also from those recently described and figured by Hoek (*Siboga-Exp.* XXXI b, p. 207, pl. xx, figs. 17-21 ; 1913).

The shell forms a low and fairly regular cone with a small terminal rhomboidal or star-shaped orifice. It is white and fragile. The parietes are rather more distinct than in *B. terebratus typicus.* Their apices are pointed and minutely serrate, their alae poorly developed. Internally the upper part is strongly striated transversely, but externally only obscure traces of transverse striation can be detected. Strong, irregularly serrated ribs arise on the parietes a short distance from the tip and running down the shell are produced horizontally over its support in the form of slightly flattened processes, which in large specimens bifurcate or branch freely at their extremity. There are about 5 or 6 such ribs on each compartment. Their processes extend outwards from the shell for a varying distance but never for much more than half its height. The basis is flat and very thin. It is strengthened below by numerous ribs like those of the parietes, with which they often alternate. Their external terminal processes are similar and extend outwards for the same distance. These ribs converge towards the centre of the basis but leave a circular space bare round it. Between and within them the base is pierced by numerous perforations of varying shape and size but mostly somewhat elongate in a transverse direction. They have no

definite arrangement. On the bare central space the perforations are often partially or completely obliterated by the growth of a very thin calcareous membrane. The upper surface of the basis is smooth.

The shell is small, my largest specimen, without the processes, being about 8 mm. in maximum transverse diameter and 5 mm. high. The maximum diameter of the orifice is about 2·5 mm., but it is smaller in other specimens.

The variety is easily distinguished from *B. terebratus typicus* by its branching processes and by the structure of its basis, which is smooth on its upper surface and strengthened on the lower surface by ribs, which are not in continuity with those of the parietes.

The method by which *B. radicifer* anchors itself to the coral is different from that adopted by *B. fujiyama*, but like that species it is found not on the polyp-bearing surface but on the comparatively inactive lower part of the colony and avoids regions of active growth. It possesses no power of elongating its shell or basis but is attached so lightly to the surface by means of its branching processes that the whole shell can be removed intact without difficulty. In some respects the method of attachment is analogous to that of my *Acasta funiculorum*[1], but the structure is much more complex and differs in that the retaining cables spread out over the surface of the coral instead of penetrating into it.

Type-specimen (C. $\frac{6}{1}\frac{5}{}\frac{9}{}$ Z. S. I.), from the lower surface of a large specimen of the coral *Pachyseris speciosa* (Dana) from Pilai I., Mergui Archipelago. The form occurs also on the basal part of colonies of *Pavona crassa* (Dana) of unknown provenance.

Creusia spinulosa Leach.

1854. *Creusia spinulosa*, Darwin, *op. cit.*, p. 376, pl. xiii, fig. 6; pl. xiv, fig. 6.

Large typical specimens occur on both the upper and the lower surface of a fine specimen of *Pachyseris speciosa* (Dana) from Pilai I. in the Mergui Archipelago. They are completely buried in the coral, except for the orifice, in most instances and the wart-like projection formed over them is often stained of a brownish colour. Some have been entirely overwhelmed and buried. The operculum of one of these specimens has the tergum and scutum of each side fused and agrees with Darwin's fig. 6 *d* on his plate xiii except that the scutal region is a little broader.

I also attribute to the species a number of small specimens in *Pavona praetorta* Dana from the Andamans, but these have lost their opercula.

Pyrgoma indicum, sp. nov.

The species seems to be by far the commonest of its genus in the Bay of Bengal, at any rate on the genera of corals considered. The corals in which it has been found are indicated in my list (p. 68).

P. indicum resembles *P. conjugatum* Darwin in certain characters and cannot always be distinguished with certainty from *P. crenatum* Sowerby by an external examination only. It differs from both in the internal structure of the shell and in the form of the fused tergum and scutum, in both respects showing an interesting approach to the genus *Creusia.*

[1] Annandale, *op. cit.*, p. 145, figs. 5-9 (1906).

The disc is oval or ovate, usually small but sometimes as much as 15 mm. long and 11 mm. broad. It is moderately thin and nearly flat and as a rule white but sometimes irregularly stained with rose-pink. In some specimens it is slightly raised round the orifice, which is ovate and of moderate size, though variable in the latter respect. The external surface exhibits no trace of sutures and bears a comparatively small but variable number of radiating ribs, which take the form of sharp, more or less strongly serrated keels and usually project outwards beyond the margin of the disc. Sometimes the surface is completely overgrown by the coral host. The internal structure of the shell is characteristic in that the compartments and even the radii remain distinct in spite of the complete fusion of the outer sheath, thus resembling those of *Creusia*, in which, however, the sutures remain on the external surface. The internal surface of the parietes is coarsely striated transversely and as a rule stained with purple. There are no pores in any part of the shell. The basis forms a long and narrow cylinder more or less contracted below and often somewhat sinuous. The shell and the basis articulate in a characteristic fashion. From the margin of the former numerous long, pointed processes are given off vertically downwards. These interdigitate with similar processes directed upwards from the edge of the basis. The external surface of the basis bears numerous strong vertical ridges, which are represented by deep grooves on the internal surface.

The fused tergum and scutum resemble those of *P. conjugatum* as figured by Darwin, but differ in that (*a*) the tergal spur is shorter and blunter and is followed externally by a distinct excavation, that (*b*) the external margin of the tergum slopes directly downwards from the apex to the lower margin, that (*c*) the basal part of the valve is nearly square and that (*d*) the scutum is broader and much blunter and not at all retroverted at the tip. The structure of the plate is remarkably constant throughout the species, the only variation observed being in the relative breadth of the scutum, and this is not great.

The *forma typica* is found on corals with star-shaped corallites and of massive form or with stout quadrate branches. It is particularly common on certain species of *Favia*, such as *F. abdita* (Ell. & Sol.).

Type-specimen (C. $\frac{668}{1}$ Z. S. I.) form *Favia valenciennesii* (M. Edw. & H.), Padaw B., King I., Mergui Archipelago.

Phase **merulinae,** nov.

The disc differs from that of the typical form in being much thinner and in that the ribs are more finely and regularly serrate and produced into long horizontal spines, which are finely serrate on their lower margin. The external surface is dull white. The internal structure of the shell and that of the basis and operculum are identical.

I have seen this form only in *Merulina laxa* Dana, a delicately branching coral, from the Mergui Archipelago. It is abundant on colonies of this species from King I. and Pilai I.

Type-specimen (C. $\frac{667}{1}$ Z. S. I.) from Pillai I., Mergui Archipelago.

Phase **symphylliae,** nov.

The structure of the shell is so distinct that I would have regarded the form as a good species but for the identity of the opercular valves. The disc is smooth or nearly so externally, with the ribs obsolete or obsolescent, and of a subconical form. Internally the struc-

ture is similar to that of the *forma typica*, except that the downwardly-directed processes of the disc are fewer and more regular and arise not at the margin but immediately below the internal compartments, which do not extend so far downwards. The external ridges and internal grooves of the basis are also less strongly developed.

This form is scarce. I have seen only two specimens, each in a colony of *Symphyllia agaricia* M. Edw. & H. One of these is from the Mergui Archipelago, the other from the coast of Arracan. The former was growing on a stone side by side with colony of *Favia* in which there were barnacles of the *forma typica* of the species.

Type-specimen (C. $\frac{669}{1}$ Z. S. I.) from Pilai I., Mergui Archipelago.

Pyrgoma crenatum Sowerby.

1854. *Pyrgoma crenatum*, Darwin, *op. cit.*, p. 370, pl. xiii, fig. 4.

After *P. indicum* this is the commonest species of the genus in the corals examined. Most of my specimens agree well with Darwin's description and figures. The shells can usually be distinguished externally from those of *P. indicum* by the shorter, coarser and smoother ridges on the disc and by the narrower and more oval, less ovate form of both disc and orifice, but specimens occur that are difficult to diagnose without an examination of the internal structure of the shell and of the opercular valves. In the former the inner sheath is thin and completely fused into a homogeneous ring, marked internally with fine uninterrupted concentric striae. The tergum shows some variation, the spur being frequently much narrower than the upper part of the valve.

A few specimens from the coral *Tridacophyllia lactuca* (Pallas) seem sufficiently distinct and sufficiently constant to be given a name :—

Phase **tridacophylliae,** nov.

The shell and basis differ only in being much more fragile than those of the *forma typica* and in having the horizontal pores below the outer lamella of the disc exceptionally well developed. The lamella, indeed, is only attached lightly to the partitions between these pores and can be stripped off, leaving the partitions standing up as prominent ribs. The disc is also somewhat concave on the outer surface towards one end.

The spur of the tergum is narrow and spoon-shaped in the specimens examined.

Type-specimen (C. $\frac{677}{4}$ Z. S. I.), probably from the Mergui Archipelago.

Pyrgoma grande Darwin.

1854. *Pyrgoma grande*, Darwin, *op. cit.*, p. 365, pl. xiii, fig. 1.

Darwin's figures of this species are excellent. It is by no means common in Indian seas, in which it is mainly confined to the two genera *Galaxea* and *Euphyllia*, corals which only resemble one another in that the corallites project strongly from the base of the colony. I have, however, seen some dwarfed specimens attached to the edge of a solitary coral. In these the basis was conical and much shorter than usual, but the operculum was normal. Specimens from *Euphyllia* are usually larger than those from *Galaxea*.

I have also found in a colony of *Symphyllia* from the Mergui Archipelago a single barnacle which may represent a much dwarfed and somewhat distorted phase of this species, but the operculum is lost and the shell incomplete, and accurate determination is impossible.

Pyrgoma (Daracia) monticulariae Gray.

1854. *Pyrgoma monticulariae*, Darwin, *op. cit.*, p. 372, pl. xiii, fig. 5.

I have found only one complete specimen of this peculiar barnacle in the collection. It was embedded in a specimen of *Hydnophora exesa* (Pallas) from the coast of Arracan. Other specimens of this coral of unknown provenance, however, contain the characteristic star-shaped cavities formed by the barnacle. The shell of the individual from Arracan is deep pink.

P. monticulariae has been found only on *Hydnophora*, of which *Monticularia* is a synonym.

List of Cirripedes and of Corals with which they are associated.

NAME OF CIRRIPEDE.	NAME OF CORAL	LOCALITY.
Balanus arcuatus Hoek ...	*Fungia danai* Mil. Edw. & H. ...	Pilai Island, Mergui Archipelago
,, ,, ,, ...	,, ,, ,, ...	Macassar Strait, Malaysia.
,, ,, ,, ...	,, ,, ,, ...	?
,, ,, ,, ...	,, *corona* Döderl.	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	,, *patella* (Ell. & Sol.) ..	,, ,, ,,
,, ,, ,, ...	*Pavona lata* Dana	,, ,, ,,
,, ,, ,, ...	,, *crassa* Dana ...	?
,, ,, ,, ...	,, ,, ,, ...	Mergui Archipelago.
,, ,, ,, ...	,, *danai* (Mil. Edw. & H.) ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	,, *decussata* Dana ...	?
,, ,, ,, ...	*Pachyseris speciosa* (Dana) ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	*Favia valenciennesii* (Mil. Edw. & H.)	Mergui.
,, ,, ,, ...	,, ,, ,,	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, *abdita* (Ell. & Sol.) ...	?
,, ,, ,, ...	,, ,, ,, ...	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, *favus* (Forskal) ...	,, ,, ,,
,, ,, ,, ...	,, *doreyensis* Mil. Edw. & H.	,, ,, ,,
,, ,, ,, ...	,, *speciosa* (Dana) ...	?
,, ,, ,, ...	*Leptoseris hawaiiensis* Vaugh. ...	Andamans.
,, ,, ,, ...	,, *fragilis* Mil. Edw. & H.	,,
,, ,, ,, ...	*Cœloria stricta* Mil. Edw. & H. ...	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	*Mycedium okeni* Mil. Edw. & H.	,, ,, ,,
,, ,, ,, ...	*Goniastrea incrustans* Duncan ...	,, ,, ,,
,, ,, ,, ...	,, ,, ,, ...	Mergui.
,, *fujiyama* Annand. ...	*Pachyseris speciosa* (Dana) ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	*Pavona crassa* Dana	?
,, ,, ,, ...	*Mussa brueggemanni* (Quelch) ..	?
,, ,, ,, ...	*Pachyseris speciosa* (Dana) ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,,	,, ,, ,,
,, *terebratus* var *radicifer* Annand.	,, ,, ,,	,, ,, ,,
,, ,, ,,	*Pavona crassa* Dana	?
Creusia spinulosa Leach. ...	*Pachyseris speciosa* (Dana) ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	*Pavona prætorta* Dana ...	?
,, ,, ,, ...	,, ,, ,, ...	Andamans.

List of Cirripedes and of Corals with which they were associated—contd.

NAME OF CIRRIPEDE.	NAME OF CORAL.	LOCALITY.
Pyrgoma grande (Sowerby) ...	*Galaxea musicalis* (Linn.) ...	Mergui.
,, ,, ,, ...	,, *fascicularis* (Linn.) ...	?
,, ,, ,, ...	*Euphyllia fimbriata* (Spengler) ...	Mergui.
,, *crenatum* Sowerby ...	*Favia valenciennesii* (Mil. Edw. & H.)	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,,	?
,, ,, ,, ...	,, *doreyensis* Mil. Edw. & H.	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	*Cœloria dædalea* (Ell. & Sol.) ...	,, ,, ,,
,, ,, ,, ...	,, ,, ,, ...	Kilakarai, Gulf of Manaar.
,, ,, ,, ...	,, *stricta* Mil. Edw. & H. ...	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,, ...	Andamans.
,, ,, ,, ...	,, *astræiformis*, Mil. Edw. & H.	?
,, ,, ,, ...	,, *sinensis* Mil. Edw. & H.	?
,, ,, ,, ...	*Mycedium okeni* Mil. Edw. & H	Mergui.
,, ,, ,, ...	*Merulina ampliata* (Ell. & Sol.) ...	Arracan.
,, ,, ,, ...	,, ,, ,, ...	Singapore.
,, ,, ,, ...	,, ,, ,, ...	?
,, ,, ,, ...	*Goniastrea incrustans* Duncan ...	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,, ...	Mergui.
,, *crenatum* phase *tridacophyllae* Annand.	*Tridacophyllia lactuca* (Pallas) ...	Padaw Bay, King Island, Mergui Archipelago.
,, ,,	,, ,, ,, ...	?
,, *indicum* Annand. ...	*Favia valenciennesii* (Mil. Edw. & H.)	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,,	?
,, ,, ,, ...	,, *abdita* (Ell. & Sol.) ...	Lampee Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,, ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,, ...	?
,, ,, ,, ...	,, *speciosa* (Dana) ...	?
,, ,, ,, ...	,, ,, ,, ...	Pilai Island, Mergui Archipelago.
,, ,, ,, ...	,, ,, ,, ...	?
,, ,, ,, ...	*Favia pentagona* (Esper) ...	Lampee Island, Mergui Archipelago.
,, ,, ,, ...	*Coeloria daedalea* (Ell. & Sol.) ...	Padaw Bay, King Island, Mergui Archipelago.
,, ,, ,, ...	,, *astreiformis* Mil. Edw. & H.	?
,, ,, ,, ...	*Galaxea fascicularis* (Linn.) ...	?
,, ,, ,, ...	,, ,, ,, ...	Padaw Bay, King Island, Mergui Archipelago.
,, *indicum* phase *merulinae* Annand.	*Merulina laxa* Dana ...	,, ,, ,,
,, *indicum* phase *symphyllae* Annand.	*Symphyllia agaricia* Mil. Edw. & H.	Padaw Bay, King Island, Mergui Archipelago.
,, ,,	,, ,, ,,	Pilai Island, Mergui Archipelago.
,, *monticulariae* (Gray) ...	*Hydnophora exesa* (Pallas) ...	Arracan.
,, ,, ,, ...	,, ,, ,, ...	?