Best wishes. Anne Johnson

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The Galatheidea (Crustacea: Decapoda) of Singapore and adjacent Waters

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INTRODUCTION

The Galatheidea of the Indo-Pacific region are a poorly known and little worked group. No recent revision is available which covers the group as a whole. Such partial revisions as do exist are mostly concerned with areas which are rather remote from the Malaysian sub-region. This unsatisfactory situation is of long duration and was already apparent in the latter part of last century. The Porcellanidae in particular have remained badly understood, not merely in the present area. The recent series of papers by Haig (1955, 1956a, 1956b, 1957a, 1957b, 1959, 1960, 1962) has done much to elucidate the taxonomy of this family; but these have not so far been concerned with Indo-Pacific material. Helpful papers for this area include those of Gordon (1931, 1960), Johnson (1958, 1960, 1963), Laurie (1926), Melin (1939), Miyake (1937, 1940, 1942, 1943), and Sankarankutty (1961a, 1961b).

The present paper deals with the results of several years collecting in the Singapore area by myself, my colleagues, and the staff of the former Singapore Regional Fisheries Research Station. I have also been able to examine the Bedford-Lanchester collection in the British Museum (Natural History) and the Archer collection in the Liverpool Free Public Museums. The latter collection was the basis of Walker's (1887) report on the decapod crustacea of Singapore. Though most of the collection is intact the porcellanid and galatheid material has unfortunately been removed at some time in the past. Walker's types, which I formerly reported as lost, were in the collections of the British Museum, though without indication of their type status.

PREVIOUS RECORDS

Prior to the present work there were only 5 species of Galatheidea recorded from the Singapore area. Two of these are in my opinion unidentifiable. The collections which I have examined contain 20 further species bringing the total for the Singapore area to 4 species of the family Galatheidae and 20 species of the family Porcellanidae. Four of these were previously unknown.

Several species have been recorded from Singapore and neighbouring areas in addition to the species listed below. Czerniavsky, in a paper on Black Sea crustacea, described the new genus *Porcellanides* which is synonymous with *Porcellana* and included a new species from Singapore. I have not been able to consult the original paper, but Haig informs me (personal communication) that the species is

unidentifiable. Walker (1887) reported *Petrolisthes dentata* (H. Milne Edwards). At that period the taxonomy of the genus was in a very confused state and it is impossible to be certain as to which species Walker had without re-examination of his specimens. Unfortunately these seem to have been lost, since, with the exception of the type of *Polyonyx cometes* I was not able to find any porcellanid material from the Archer collection in either the Liverpool Museums or the British Museum. De Man (1896) reported *Petrolisthes japonicus* (De Haan) from 'Malacca'. There are no fully authenticated records of this species from the Malaysian area and De Man's specimens most probably belonged to *P. teres* or *P. kranjiensis*. *Petrolisthes ohshimai* (Miyake) might be expected to occur at Singapore, since its host, *Stoichactis*, is not uncommon. However it has not yet been found there despite search and so is certainly rare if present at all.

In Singapore waters the Galatheidae are somewhat poorly represented; but the Porcellanidae are very well represented, as can be seen by comparisons with faunal lists of other areas. Barnard (1950) only records 6 species from the whole of S. Africa. Haig (1955) lists 11 species from Chile, a country noted for its rich anomuran fauna. The total of 20 species found at Singapore compares favourably with the 19 species recorded from the whole Pacific coast of Lower California and the 23 species from the whole of the Gulf of California recorded by Haig (1960). Nonetheless the fauna appears to be less rich than might have been expected for such a centrally situated Indo-West Pacific locality. There are no comparable listings from equally restricted areas in the region (the list given by Macnae and Kalk, 1958: 126, is probably incomplete and Inhaca Island is a fringe locality) so that this impression cannot be quantified. It is dependant on the observed rarity or absence of a number of well known species, some of which are regarded as being very common elsewhere.

Amongst species which are unusually rare at Singapore are *Petrolisthes lamarckii* and *Polyonyx triunguiculatus*. In a period of 10 years we have only collected 2 specimens of the former, though it is usually regarded as a common coral reef species. *P. triunguiculatus* is listed on the basis of a single specimen collected by Lanchester at the end of last century. It has not been collected in recent years.

This depauperization is by no means confined to the Galatheidea. I have previously commented on it in discussing the Hippolytidae and the Caridea in general (Johnson, 1961: 47 and 64). It is also apparent in such unrelated groups as the gastropod molluscs. This impoverishment is probably in part a consequence of the comparatively low salinity of the sea water of the Singapore area. In contrast to the 'oceanic' waters of the South China Sea which have salinities equal to or in excess of 33 parts per thousand the water in the Singapore Straits has salinities of less than 32 parts per thousand (see Tham, 1953; Ommanney, 1961; Hall, 1962). Inshore areas receiving much drainage from land and subject to dilution by rainwater often have much lower salinities. In the terminology of the Venice system no Singapore waters are truly euhaline. The most saline areas can be regarded as mixoeuhaline but the water at most inshore stations is only polyhaline.

In addition local marine conditions have deteriorated considerably during the last fifty years, and are still deteriorating as a consequence of the growth of the port of Singapore and of various oil installations. One consequence is a great increase in silting. Habitats which fifty years ago bore flourishing coral reefs are now covered with mud or silt. Conditions are thus becoming progressively more unfavourable for clear water species. This could have resulted in a decrease in abundance of such species as *Petrolisthes lamarckii* and *Polyonyx triunguiculatus*.

SYSTEMATIC ACCOUNT

GALATHEIDAE

The only genus of this family represented in Singapore waters is *Galathea* Fabricius. The local species are all of small size. None is really common. *G. elegans* (White) stands somewhat apart from the rest and might well merit separation at sub-generic level when the genus as a whole is revised. It is readily distinguished by its characteristic rostrum and equally distinctive, though variable, colouration. The other species are less easily separated but can be distinguished by the characters given in the key below.

Colour patterns form a useful guide to the identification of the Singapore species of this group. *G. aculeata* Haswell and *G. spinosorostris* Dana are dull species without any striking pattern. *G. longimanoides* is dark reddish or purplish with a median, pale-coloured lingitudinal stripe. *G. elegans* is usually pale ivory, stone, or pink in life, with a striking pattern of red or pink longitudinal stripes.

KEY TO THE SPECIES

1. Rostrum long and narrow with 7 to 9 small lateral teeth on each margin ..... *G. elegans*
–. Rostrum shorter and broader with only 4 lateral teeth on each margin, these teeth being of large size 2
2. Striations on the gastric region of the carapace broken up into scale like lobes. Cervical groove well defined ..... *G. aculeata*
–. Striations on the gastric region of the carapace continuous. Cervical groove indistinct, at least dorsally 3
3. Spines on gastric region of the carapace very small. Chelipeds very long and slender. Rostrum comparatively long and narrow, with the basal teeth much smaller than the rest ..... *G. longimanoides*
–. Spines on gastric region of the carapace conspicuous. Chelipeds short and stout, with the finger tips blunt and excavated. Rostrum broad with the basal teeth not differing greatly in size from the rest ..... *G. spinosorostris*

Galathea elegans White

Galathea elegans White, in Adams and White, 1848, pl. 12, fig. 7; Haswell, 1882, p. 163; Miers, 1884, p. 278; Walker, 1887, p. 112; Ortmann, 1894, p. 23; De Man, 1902, p. 709; Southwell, 1909, p. 120, pl. fig. 11; Grant and McCulloch, 1906, p. 50, pl. 4, figs. 6 and 6a; Doflein and Balss, 1913, p. 169; Potts, 1915, p. 83, pl. 1; Balss, 1921, p. 22; Laurie, 1926, p. 133; Melin, 1939, p. 77, figs, 48–53; Barnard, 1947, p. 379; Bernard, 1950, p. 487, figs, 91 i-k; Macnae and Kalk, 1958, p. 126; Johnson, 1963.

Galathea longirostris Dana, 1852, p. 482; Dana, 1855, pl. 30, fig. 11; Yokoya, 1936, p. 138.

Galathea deflexifrons Haswell, 1881, p. 76; Haswell, 1882, p. 163.

Galathea grandirostris Henderson, 1888, p. 119, pl. 12, fig. 3; Stimpson, 1858, p. 252; Stimpson, 1907, p. 234.

Local records.—Singapore Regional Fisheries Research Station: B 30, off Ajax Shoal, Singapore, 1♂, C.L. 12 mm.; B 31, east of Sultan Shoal, 9 fms, stony bottom, 1 ovigerous ♀, C.L. 10¼ mm.; B 65, Singapore Straits south of Bedok, about 1° 15′ N, 104° E, 24 fms, clean bottom, 3 ovigerous ♀♀, C.L. 9–11 mm.

This species was previously collected at Singapore by Archer (**Walker**, 1887). I have also obtained a single ovigerous ♀ from a dredge haul off the Sembilan Is., Perak, 25–45 fms, shell-gravel coral-brash grounds.

General notes.—*G. elegans* is readily distinguished from all other members of its genus by its broad, elongate, pointed rostrum, the lateral margins of which are each armed with from 7 to 9 small to vestigial teeth. The colour pattern, though variable, is equally characteristic.

I agree with Grant and McCulloch in synonymizing both *G. longirostris* Dana and *G. deflexifrons* Haswell with *G. elegans*. I also agree with Barnard in considering that *G. grandirostris* Henderson is a further synonym. *G. longirostris* Yokoya is an interesting nomenclatural anomaly. Yokoya thought that his species was new and was evidently unaware of Dana's *G. longirostris*. Yokoya's name is thus invalid as a junior homonym of the latter. In my opinion Yokoya's species cannot be distinguished from *G. elegans*. The only differences apparent from Yokoya's description concern the size and form of the rostral teeth, which are said to be less well developed in *G. longirostris* Yokoya, and the number of teeth on each lateral margin. Yokoya claims that these number 10 but states that posterior teeth are indistinct. Moreover his figure only shows 7 teeth. The number of these teeth is not constant in *G. elegans;* but varies from 7 to 9. Their size is also variable. Thus in both characters Yokoya's species falls within the known or expected range of variation of *G. elegans*. *G. longirostris* Yokoya thus falls as a synonym of *G. elegans*. It is hence a synonym of the homonymous *G. longirostris* Dana.

Colouration.—Singapore specimens of this species are ivory to pale stone in colour with 3 principal pink or red longitudinal stripes, each of which may be double. This pattern is somewhat similar to that described by Southwell. Miers and Laurie both refer to the variability in colour pattern of this species. Barnard (1950) describes a specimen from *Tropiometra* which was brown with 2 pale yellow, longitudinal stripes. Possibly this is to be regarded as an individual in which the width of the dark bands has been greatly exaggerated at the expense of the pale interspaces. Despite such variations the basic pattern seems to be fixed and readily recognizable.

Distribution.—*G. elegans* is widely distributed in the Indo-West Pacific region from Natal and the Seychelles through to S. Japan, the Bonin Is., and northern Australia.

Ecology.—Records in the literature indicate that this species is a crinoid commensal. Crinoids were present in all the Singapore collections. Thus, whilst this commensalism remains putative as far as concerns Singapore, there is no real reason to doubt that it is a commensal there.

Galathea aculeata Haswell Figure 1.

Galathea aculeata Haswell, 1881, p. 761; Haswell, 1882, p. 162; Whitelegge, 1900, p. 190; Grant and McCulloch, 1906, p. 48; Doflein and Balss, 1913, p. 169.

Local records.—Shoal west of Pulau Pawai, Singapore, depth about 5 fms, shell gravel, 1 ovigerous ♀, C.L. 7½ mm.

General notes.—The specimen keys out to *G. aculeata* in Grant and McCulloch's key. It agrees well with Haswell's descriptions and with specimens in the British Museum from the Great Barrier Reef, identified as being of this species.

The striations of the gastric region are broken into scale like lobes. In my specimen the 2 anterior median lobes bear large spines corresponding in position to the gastric spines of *G. australiensis*. There are 2 other fairly large spines on each hepatic region. In specimens which I have examined the 2nd striation bears smaller spines which may be assymetrical in arrangement. Commonly, as in the type, there are 2 such spines on each side, one on each of the lobes into which this striation is subdivided. There may, however, be only 1 such spine on one or both sides. The cervical groove is clearly defined throughout. The region posterior to this groove bears 4 complete transverse striations which are not divided into lobes.

The triangular rostrum is rather broad. All the lateral teeth are large and acutely pointed; but the basal tooth is smaller than the rest.

The 3rd maxillipedes resemble those of *G. australiensis;* but the ischium bears a well developed distal ventral spine. In the Australian specimens the ischial ridge bears about 26 denticles in contrast to the 21 denticles of *G. australiensis.* However my Singapore specimen has only 22 denticles on this ridge. The character is thus not sufficiently constant to be of use in separating these two species.

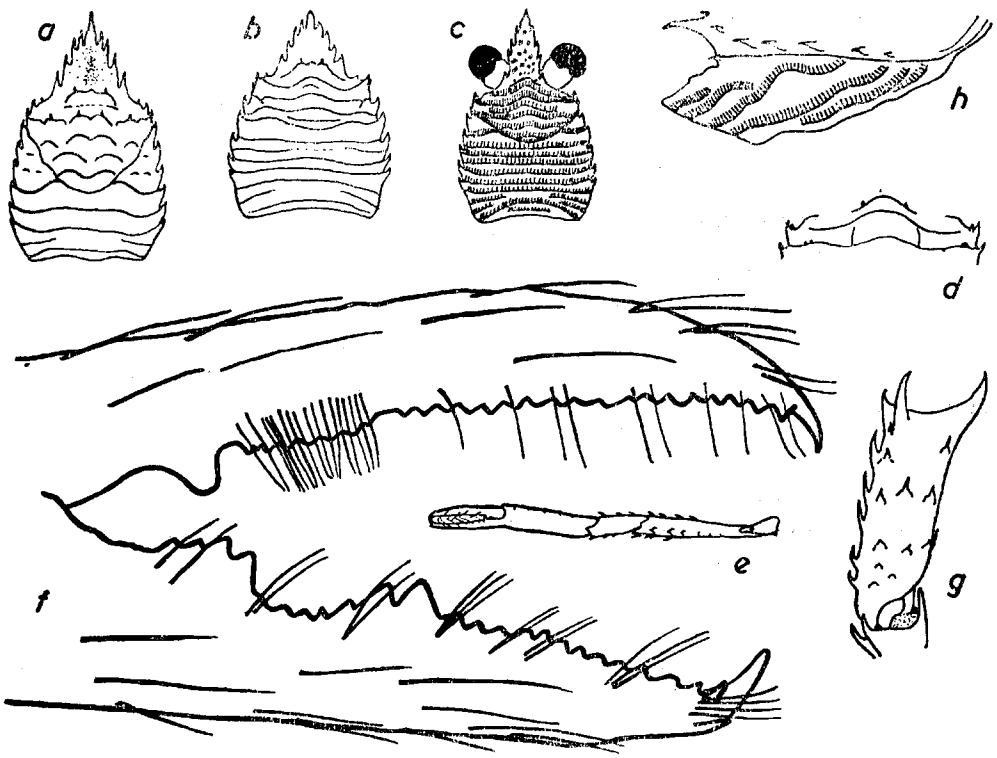

Figure 1. *a Galathea aculeata* Haswell, ovigerous ♀, Singapore, dorsal view of carapace. *b. Galathea spinosorostris* Dana, ♀, Singapore, dorsal view of carapace. *c-h Galathea longimanoides* sp. nov., type ♂, Singapore; *c* dorsal view of carapace; *d* detail of gastro-hepatic region, general setation omitted; *e* larger cheliped, internal view, finer sculptural details omitted; *f* fingers of larger cheliped; *g* detail of spination of carpus of larger cheliped; *h* semi-oblique view of pterygostomial region.

The chelipeds are long and narrow. The fingers are longer than the palm. There is a conspicuous and very distinctive row of close set spines along the outer border of the hand and fixed finger. The cutting edges of the fingers are minutely serrated.

Colouration.—In life *G. aculeata* is a mottled, sandy brown.

Distribution.—This species was previously known from northern Australian waters and also from the Philippines (Miers, 1884: 278). The present specimen thus represents a considerable extension to its known range.

Ecology.—Beyond the fact that it is not a commensal little is known of the ecology of this species. It appears to be a shallow water form occurring below the tidal zone.

Galathea spinosorostris Dana Figure 1.

Galathea spinosorostris Dana, 1852, p. 480; Dana, 1855, pl. 30, fig. 9; Lenz., H., 1910, p. 566, Laurie, 1926, p. 124; Melin, 1939, p. 63; Johnson, 1963.

? *Galathea spinosirostris* Miers, 1884, p. 560.

Galathea spinulifera Southwell, 1909, fig. 12.

Local records.—Bedford-Lanchester collection: Raffles Light, low tide; also Cape Rachado, Malacca. Other collections: coral-gorgonian ground, fringing reef west of Pulau Pawai, 1 to 2 fms, 2 damaged individuals; Sultan Shoal, Singapore, on coral-head on piers, just below low water spring tide level, 1 damaged ♀; Pulau Sudong, Singapore, on large head of *Pavona frondifera,* 1 to 2 ms, 1 'sacculinized' individual, C.L. 4 mm.

General notes.—G. spinosorostris is very closely related to *G. australiensis* Stimpson (1858: 251; 1907: 351). The most clear cut distinction between the two is provided by the armature of the hepatic region. In *G. australiensis* each hepatic region bears a large spine; there are no such spines in *G. spinosorostris.* Another distinction is provided by the form of the rostrum. In *G. spinosorostris* this is comparatively narrow and the basal teeth are comparatively small, the form being intermediate between that found in *G. australiensis* and that found in *G. orientalis.* Melin gives as an additional character the presence of a spine in the middle of the outer margin of the 3rd maxillipede in *G. spinosorostris;* but I cannot find this spine in Malayan specimens.

G. spinosorostris can be distinguished from the remaining species of *Galathea* by the broad rostrum with 4 large teeth on each margin, of which the basal teeth are somewhat smaller than the rest. The cervical groove is poorly defined. The carapace bears 8 major transverse striations which are uninterrupted. There are 2 large and closely set gastric spines. The chelipeds are comparatively short and broad. The fingers are blunt and are hollowed at the tip. In Malayan specimens the ischial ridge of the 3rd maxillipede bears about 23 teeth. The ischium has a distal dorsal spine. The inner margin of the merus of this limb bears 2 large spines. In Malayan specimens there is no spine in the middle of the outer margin; but such a spine may be present in specimens from other areas. The dorsal margin of the merus of the 3rd walking leg bears a row of 7 to 8 spines.

Colouration.—This dull species has no striking colour pattern.

Distribution.—G. spinosorostris is widely distributed in the Indo-West Pacific region. It is known from Ceylon; Malaya; northern Australia; and possibly islands in the western Indian Ocean (Miers, 1884).

Ecology.—This is the only Singapore species which occurs in the littoral zone. In the Singapore area it appears to be confined to the lowest part of the littoral zone and the immediate infra-littoral. It is apparently commensal with living corals.

Galathea longimanoides sp. nov. Figure 1.

Type.—♂ C.L. 4½ mm., crinoid ground, Johore Shoals, Singapore, 10 fms, deposited in the British Museum (Natural History).

Other material.—An ovigerous ♀, C.L. 4.8 mm. from the same locality in the collections of the University of Singapore (other specimens have also been examined from the same locality but these were lost in transit during a changeover of departmental accommodation).

Diagnosis.—A species belonging to the *G. orientalis* complex and closely related to *G. longimana* Paulson from which it differs in the features cited in the discussion below.

Description.—These specimens clearly belong to the group of forms centering around *G. orientalis* Stimpson (1858: 252; 1907: 231); but they cannot be ascribed to any described species.

In general build the carapace resemble that of *G. orientalis*. The cervical groove is indistinct dorsally. The transverse striations are not interrupted. There are about 10 striations running right across the carapace and several others which do not cross the whole carapace. Each lateral margin of the carapace bears 7 teeth of which the 2nd is distinctly small compared to the rest. The spines on the gastric region are very small and inconspicuous. There may be 2 such spines set at some distance apart as in *G. orientalis* or each of these may be replaced by a group of 2 to 3 spines. Each hepatic region bears 2 very small spines.

The rostrum resembles that of *G. orientalis;* but it is longer and more slender, being about 2.5 times as long as broad. The basal teeth are small. Their terminal portion is long and acutely pointed.

The pterygostominal region bears numerous close set striations and has no spine.

The ischium of the 3rd maxillipedes bears a conspicuous distal ventral spine. The ischial ridge bears about 25 to 27 teeth. The outer margin of the merus has 2 non-spiniform serrations. The inner margin bears 2 spines. The outer margin of the carpus has no spines.

The chelipeds closely resemble those of *G. longimana* Paulson. They are very long and slender. The merus is about 1.75 times as long as the carapace (including the rostrum). The fingers are about 0.6 times as long as the palm. They are pointed and are not excavated at the tip. On both fingers there is on each side of the cutting edge a row of tubercles terminating just before the tip. These tubercles increase in size distally. The more distal ones are sharply pointed and sub-spiniform. The ventral margin of the fixed finger bears a procumbent, short, blunt spine, near its tip.

Comparison with related species: *G. longimanoides* differs from *G. orientalis* principally in the absence of spines from the outer margin of the carpus and merus of the 3rd maxillipede and from the pterygostomial region. The rostrum is longer and more slender. The gastric spines are smaller. The distal ventral spine of the ischium of the 3rd maxillipede is stronger. The striations of the pterygostomial region are more numerous and more closely set.

It differs from *G. ternatensis* Melin in details of the armature of the 3rd maxillipede, in the narrower rostrum, and in having only 7 not 8 lateral carapace teeth. In *G. ternatensis* the ischium of the 3rd maxillipede has no large ventral spine, the outer margin of the merus of this limb is not serrated, and the inner margin bears more than 2 spines.

G. longimanoides differs from *G. amboinensis* De Man in the much narrower rostrum, the very much longer and more slender chelipeds and the presence of gastric spines. The general resemblance between these two forms is nonetheless very close.

G. longimanoides differs from *G. consobrina* De Man in its longer and narrower rostrum, its very much longer and more slender chelipeds, the conspicuous distal ventral spine of the ischium of the 3rd maxillipede and the much more numerous teeth of the ischial ridge.

It differs from *G. affinis* Ortmann in the longer and much narrower rostrum, the very much longer and more slender chelipeds, the much weaker gastric spines, and the presence of 2 spines on the inner margin of the merus of the 3rd maxillipede.

From *G. longimana* Paulson it differs in the absence of a tooth on the sub-hepatic region of the carapace, in the absence of spines on the external margin of the merus of the 3rd maxillipede, and in the presence of only 2 instead of 3 spines on each hepatic region. If Paulson's figure is correct *G. longimana* differs

further from the present species in having the transverse ridges of the anterior portion of the carapace somewhat broken up. In *G. longimanoides* the rostrum is even longer and more slender than in *G. longimana* where it is only twice as long as broad.

Colouration.—G. longimanoides is strikingly coloured in life. The ground colour is deep red or purple red. There is a conspicuous median, pale stripe, and there may be narrower lateral, longitudinal stripes. The colour pattern thus resembles a negative of the usual colour pattern of *G. elegans;* but the median stripe is relatively more prominent than it is in that species. De Man has noted that the colour pattern of *G. amboinensis* resembles that of *G. elegans* thus providing a further point of resemblance between that species and the present species.

Distribution.—G. longimanoides is at present only known from the type locality.

Ecology.—From the circumstances of its capture and from the nature of its colouration it appears probable that *G. longimanoides* is a crinoid commensal, though this cannot be considered to be fully established as yet.

PORCELLANIDAE

The Porcellanidae are much better represented in Singapore waters than are the Galatheidae. Several species are commonly encountered in the littoral zone. Others are not infrequent in offshore waters.

The genera known from or likely to occur in Singapore waters can be separated by the following key:

1. Dactyli of walking legs long, slender and tapering, with conspicuous hair fringes on both margins and without ventral spines or teeth ..... *Rhaphidopus*
–. Dactyli of walking legs not of this form 2
2. Chelipeds held almost straight when at rest and with short carpus; antennal flagellum very short ..... *Pseudoporcellanella*
–. Chelipeds strongly flexed at rest and with carpus much longer than merus; antennal flagellum long 3
3. First segment of antennal peduncle short and not reaching the upper margin of the carapace so that the flagellum is not excluded from the orbit proper 4
–. This segment much produced to articulate with the upper margin of the carapace and thus exclude the flagellum from the orbit 5
4. Pterygostomial region entire ..... *Petrolisthes.*
–. Pterygostomial region divided by a vertical membraneous suture into a larger anterior and a smaller posterior portion ..... *Pachycheles*
5. Front not very prominent, deflexed, and appearing almost straight in dorsal view; first segment of the antennal peduncle very elongate; carapace usually elevated and commonly broader than long; dactyli of walking legs with 2 large principal claws and usually also 1 or more accessory claws or spinules ..... *Polyonyx*
–. Front more or less prominent, not or not greatly deflexed and as seen in dorsal view cut into broad teeth or lobes or at least with a single, large, denticulate lobe; first segment of the antennal peduncle less elongate; carapace usually depressed, never much broader than long and often longer than broad; dactyli of walking legs various ..... *Porcellana* 6
6. Carapace longer than broad and usually much longer than broad; front very prominent and cut into large, flat teeth or lobes; hand with a conspicuous hair-crest in the middle of the inner face; dactyli of walking legs very short and armed with 4 claws ..... sub-g. *Porcellamella*
–. Carapace less elongate; front not of this form; dactyli of walking legs with only a single claw or at most with a moderate sized accessory claw but often with several small accessory spinules 7
7. Fingers more or less markedly twisted with the inner face more or less excavated and provided with a hair tuft which is often well developed; lateral lobes of front well developed ..... sub-g. *Pisidia*
–. Fingers straight and chelipeds in general *Petrolisthes*-like, the fingers not being excavated on their internal face and lacking any special development of hairs; lateral lobes of front much reduced ..... sub-g. *Enosteoides*

Genus **Petrolisthes** Stimpson

The local members of this genus are small, flat-bodied crabs which dwell under stones, in holes in stiff mud-scarps, or amongst corals. Several species are abundant on suitable local beaches.

As I have previously indicated (Johnson, 1960) I do not consider that Miyake's genus *Neopetrolisthes* is sufficiently distinctive to be worthy of generic separation from *Petrolisthes*. With this exception I have largely followed Miyake's treatment of this genus. I have not quoted full synonymies where these are available in the literature.

The following key is intended to differentiate all the species known from or likely to occur in Singapore waters:

1. Carapace high and convex; eyes somewhat reduced; propodi and dactyli of the walking legs unarmed on their posterior margin ..... *P. ohshimai*
–. Carapace depressed and little if at all convex; eyes of normal size; propodi and dactyli of walking legs with at least some spinules on the posterior margin 2
2. Carapace with supra-orbital and lateral spines; palm of chelipeds with a conspicuous fringe of long hairs which arises from the ventral portion of the outer face ..... *P.* cf. *militaris*
–. Carapace without supra-orbital and lateral spines; palm of chelipeds lacking this hair fringe 3
3. Carapace, except in rare individuals with epibranchial spines; posterior margin of carpus of chelipeds cut into distinct teeth at least distally ..... *P. lamarckii*
–. Carapace lacking epibranchial spines; posterior margin of carpus of chelipeds bounded by an oblique, rugose ridge and ending in a prominent spine, but not otherwise cut into teeth ..... ***P. hastatus***
4. Posterior border of carpus of chelipeds with 2 or 3 spines in addition to the distal spine; inner or mesial margins of fingers not setose ..... *P. japonicus*
–. Posterior border of carpus of chelipeds with only a single spine in addition to the distal spine; inner margins of fingers setose 5
5. Ventral distal spine or merus of first ambulatory leg small or absent; pterygostomial region covered with downy hairs; outer surface of palm of chelipeds with a distinct mesial, longitudinal crest ..... *P. teres*
–. Ventral distal spine of merus of first walking leg prominent; pterygostomial region lacking this setation; outer surface of palm of chelipeds without this crest or with this crest poorly developed ..... *P. kranjiensis*

The Malayan record of *P. japonicus* is dubious. *P. ohshimai* is included since it may yet be found in Malayan waters.

The species of this genus show well defined habitat preferences which form a good field guide to their specific identity.

Petrolisthes ohshimai (Miyake)

Neopetrolisthes ohshimai Miyake, 1937, p. 34; Miyake, 1942, p. 350, pl. 1, fig. 5; Miyake, 1943, p. 101; McNeill, 1953, p. 90.

Petrolisthes ohshimai Johnson, 1960, p. 164; Gordon, 1960, p. 166; Johnson, 1963.

Miyake also recorded this species in 1940 (fide Gordon 1960) but I have not been able to consult this paper.

General notes.—*P. ohshimai* has not yet been recorded from Malaysian waters. It could be readily recognized by the characters given in the key together with its distinctive colouration. Further information is given in the papers cited.

Petrolisthes cf. **militaris** (Heller) Figure 2.

cf. *Porcellana militaris* Heller, 1862, p. 523; De Man, 1887, p. 410.
cf. *Petrolisthes militaris* Miyake, 1943, p. 56, fig. 1.

Local records.—Crevices in *Heliopora* heads at about low water spring tide level, Raffles Light, Singapore, 6-3-55, 1 ovigerous ♀, C.L. 6 mm.; coral heads at about low water spring tide level, Tanjong Gul, Singapore, 7-1-55, 2 individuals of C.L. 4½ and 7¾ mm.; coral heads in a depth of 1 to 2 fms, coral-gorgonian ground fringing west coast of Pulau Pawai, Singapore, 29-12-51, 3 specimens of C.L. 6–6¾ mm.; coral heads in a depth of 2 to 3 fms on submerged coral reef between Pulau Tembakul and Pulau Sakijang Pelepah, Singapore, 5-1-52, a damaged specimen.

General notes.—This species can be readily distinguished from all other Malayan members of the genus by its habitat and by the presence of supra-orbital and lateral carapace spines. Other distinguishing features include: the hairy carapace; the conspicuous squamous or sub-squamous sculpturing of the outer face of the palm of the chelipeds; and the armature of the carpus of the chelipeds, which has the anterior margin cut into several broad teeth, themselves serrated, and which has a row of small spines along most or all of its posterior margin.

Distinct though this species is in the local fauna its exact identification presents considerable difficulties. These are mainly the result of the confused taxonomy of the forms centering around *P. militaris* Heller. The exact relationships of the three supposed species: *P. militaris* (Heller), *P. annulipes* Miers (1884: 270 & 528), and *P. scabriculus* Dana (1852: 424; 1855: pl. 24, fig. 13) are very poorly understood. Moreover these specimens from Malaya do not correspond exactly with the descriptions given for any of these species. It has been usual to synonymize *P. annulipes* with *P. militaris*, as Miyake does, even though Miers pointed out differences in sculpturing and setation which, if valid, are quite sufficient to establish his form as a distinct species. I have re-examined Miers's types and can confirm that in *P. annulipes* the palm of the cheliped lacks a ventral hair fringe. This fringe was presumably lacking in life since I could not detect any impressions which would mark the site of setae which had been rubbed off. The sculpturing of the chelipeds consists essentially of fine unbroken parallel ridges or raised lines. There is no associated pubescence or this is very feebly developed. In contrast *P. militaris* is stated to possess this ventral hair fringe. There is no adequate description of the detailed sculpturing of the chelipeds in specimens which can be undoubtedly assigned to *P. militaris;* but it seems reasonable to suppose that Miers knew these features when he made his comparison. Pending a re-examination of Heller's type it seems wisest to treat *P. militaris* and *P. annulipes* as distinct species.

There is considerable difficulty in separating *P. militaris* auct. from *P. scabriculus*. Both forms are apparently variable in those characters which are commonly used to separate species in this genus. They are usually separated on the basis of the spinulation of the front. In *P. scabriculus* the lateral frontal lobes are said to be denticulate. In contrast the lateral frontal lobes of *P. militaris* are said to be smooth. This character is really one of degree. Moreover such denticulation is known to be variable in other species of the family Porcellanidae. Thus it seems a very unreliable character on which to base a specific distinction. *P. scabriculus* is also supposed to differ from *P. militaris* in the sculpturing of the chelipeds. In *P. militaris* this is supposed to consist essentially of parallel ridges, coarser than those of *P. annulipes*. In *P. scabriculus* there is a strongly developed squamous sculpturing. This difference is probably of more importance than the denticulation of the front. Unfortunately the two characters do not vary together. The validity of these two forms and the true distinctions between them could only be fully determined after the examination of much more extensive series than are at present available, drawn from the full geographical ranges of both supposed species.

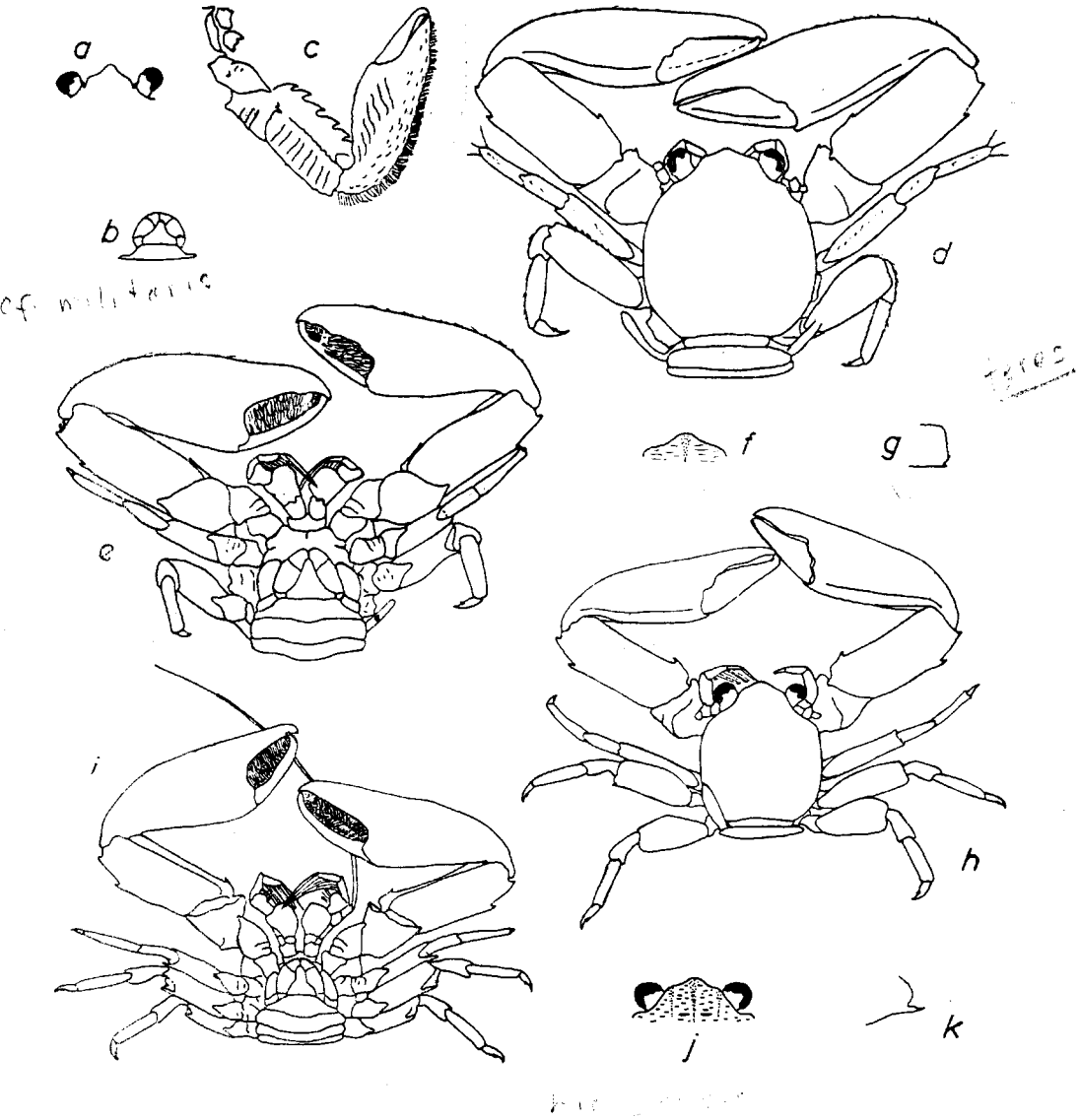

Figure 2. *a-c Petrolisthes* cf. *militaris* (Heller), ♂, Singapore; *a* frontal region, carapace sculpturing omitted; *b* telson and last abdominal segment; *c* ventral view of larger cheliped and base of 3rd maxillipedes. *d-g Petrolisthes teres* Melin, ♂, Singapore; *d* dorsal view, fine sculpturing omitted; *e* ventral view, finer details of sculpturing and spination omitted; *f* frontal region, dorsal view; *g* end of merus of 1st walking leg. *h-k Petrolisthes kranjiensis* sp. nov., ♂, Singapore; *h* dorsal view, fine sculpturing omitted; *i* ventral view, finer details of sculpturing and spination omitted; *j* frontal region; *k* end of merus of 1st walking leg.

My specimens from Singapore show very little variation among themselves; but they combine characters of previously described forms in an eclectic fashion. It is thus not possible to assign them to any of these forms. It is equally impossible to be certain that they do not in fact belong to one or other of them. They can only be assigned to the *P. militaris* complex without further restriction.

In details of the form and armature of the front and carapace they agree most closely with *P. annulipes* Miers; but they differ strikingly from that form in the presence of a ventral hair fringe on the palm of the chelipeds and in the sculpturing of the chelipeds. In the first of these features they agree with both *P. militaris* and *P. scabriculus*. The squamous sculpturing and highly pubescent nature of the chelipeds agrees best with *P. scabriculus;* but the lateral frontal lobes are as in *P. militaris*. The principle feature separating these Singapore specimens from *P. militaris* s.s. is thus the squamous sculpturing of the chelipeds.

There are, however, a number of detailed differences between these Singapore specimens and the form described by Miyake. In Miyake's form, as in *P. annulipes*, there is a mesial, longitudinal ridge on the outer face of the palm, which is absent in these Singapore specimens. In the Singapore specimens the meri of the 1st and 2nd walking legs are armed with a small terminal spine in addition to the large sub-terminal spine. In the 1st walking legs the merus has in addition a small sub-terminal spine on the ventral margin. In the Singapore specimens the propodus of the 3rd walking leg bears a row of 3 spinules in addition to the distal margin, In Miyake's specimens this row only contains 2 spinules. The dactyli of walking legs 1 to 3 are armed with 4 ventral spinules in Singapore specimens, whereas in Miyake's specimens there are only 3 such spinules. The anterior margin of the merus of the 3rd maxillipede is not crenulate in Singapore specimens. The merus lobe of the chelipeds bears a small nipple-like projection which is neither noted nor figured by Miyake. These Singapore specimens also differ from *P. militaris* auct. in details of the antennulary peduncle. In the Singapore specimens the 1st segment is broader and less spinous, whilst the crest of the 2nd segment is not constricted at its base and bears a single large projection, proximally, together with some much smaller, more distal projections.

Colouration.—This species is strikingly coloured in life. The carapace is dark green dorsally. The inner face of the chelipeds is a brilliant purple. The outer face may be similarly coloured or duller and more or less green. The hair fringe is pale brown and forms a striking contrast to the purple of the chelipeds.

Distribution.—Owing to the taxonomic confusions discussed above it is not possible to give precise distributional data for members of this complex. The complex as a whole is distributed from the western Indian Ocean through to northern Australia, the Philippines, and the Ryu Kyu islands. Representatives have been reported from Nicobar islands and from Java. No described forms correspond exactly with the Singapore population.

Ecology.—In contrast to other Malayan species of *Petrolisthes* the present species appears to be an obligate commensal of living corals. It is found in shallow water up to about low water spring tide level. It appears to be less common than other coral dwelling procellanids in the Singapore area.

Petrolisthes lamarckii (Leach)

Borradaille, 1898, p. 464, pl. 36, figs. 1a & 1b & 2; Miyake, 1942, p. 342, figs. 7 & 8; 1943, p. 98, fig. 29; Barnard, 1950, p. 477; Kalk, 1958, p. 73, fig. 18a.

Local records.—Raffles Light, Singapore, 30-11-59–4-12-59, 1 juv. C.L. 5 mm. and 1 ovigerous ♀, C.L. 7 mm., on corals.

It is possible, but not certain that Walker's record of *P. dentata*, mentioned above, refers to this species. Since Walker's specimens appear to be lost the doubt cannot be resolved.

General notes.—These are the only certainly identified specimens from Singapore. Elsewhere it is believed to be a common species and has been adequately described. My specimens, which possess epibranchial spines, do not differ in any significant features from published descriptions. The only Malayan species with which *P. lamarckii* could easily be confused is *P. hastatus* Stimpson. The two species differ in colouration and can also easily be separated by the characters given in the key and their very different habitats.

It is now generally agreed that *Porcellana dentata* H. M. Edwards, 1837; *P. speciosa* Dana, 1852; *P. bellis* Heller, 1865; *Petrolisthes Haswelli* Miers, 1884; and *Petrolisthes obtusifrons* Miyake, 1937, are all synonyms of the present species. Barnard further considers that *P. rufescens* of Hilgendorf, 1878, and *P. politus* Stebbing, 1920, are further synonyms; but the former, at least, may prove to be distinct. Miyake (1942, p. 345, figs. 9 & 10) treats *P. rufescens* of Heller as a variety of *P. lamarckii*. Individuals of *P. lamarckii* do occur in which the epibranchial spines are lacking; but the true *P. rufescens* appears to be a distinct species.

The specimens recorded by Kalk as *P. lamarckii* probably do not belong here. The figure shows no epibranchial spines. The habitat 'at a high tidal level under large flat stones or rocks' is suggestive of *P. hastatus*.

Colouration.—In life this species has a characteristic, mottled, reddish colour.

Distribution.—*P. lamarckii* is distinctly rare at Singapore. Elsewhere in Malaya it is recorded from P. Bidang near Penang (Lanchester, 1902: 363 as *P. speciosus*). It ranges from S. Africa and the western Indian Ocean through to S. Japan, Polynesia, and Australia (see e.g. Doflein and Balss: 162). The nearest recorded localities to Malaya are the Mergui Archipelago, the Nicobars, and Java. It is generally considered to be one of the most abundant Indo-West Pacific species; but it is strikingly rare in central Sundaland, possibly as a reflection of the non-oceanic conditions of the area.

Ecology.—An inhabitant of coral reefs, *P. lamarckii* is not confined to living coral.

Petrolisthes boscii Audouin

De Man, 1888, p. 217; Lanchester, 1902, p. 364.

General notes.—This species can readily be separated from *P. lamarckii* by the features given in the footnote to the key.

Distribution.—*P. boscii* has not so far been found in southern Malayan waters. Lanchester recorded a single male from P. Bidang, near Penang. Elsewhere it is known from the Red Sea and the Mergui Archipelago.

Petrolisthes hastatus Stimpson

See Miyake, 1943, p. 62, figs. 5 & 6; 1956, p. 309.

Local records.—Labrador beach, Singapore, September 1959, crevices in a scree of large stones and boulders in a narrow zone at and about high water neap tide level, numerous specimens including ovigerous ♀♀ of C.L. up to 9 mm. and ♂♂ of C.L. up to 10¼ mm.

General notes.—In the past *P. hastatus* has been confused with *P. lamarckii* despite the considerable differences between them. *Porcellana inermis* Heller, 1865 and *P. lamarckii* of H. Milne Edwards, 1837 are both synonyms of *P. hastatus*.

P. hastatus is readily distinguished from *P. lamarckii* by its lack of epibranchial spines and by the details of the armature of the chelipeds. Its affinities seem to be rather with the *P. japonicus* group. Ecologically it resembles members of the *P. japonicus* group.

The characters given in the key will serve to distinguish *P. hastatus* from other Malayan species. The carapace is almost smooth with the exception of some very feebly indicated, short, fine, transverse, protogastric ridges. The frontal area is shaped much as in *P. lamarckii*. It is bounded posteriorly by a pair of strong, transverse, protogastric ridges. The frontal region has a well marked, median longitudinal groove which extends between and posterior to these ridges. The cervical groove is almost obsolete dorsally.

The anterior margin of the carpus of the chelipeds is armed with 3 large, regularly spaced teeth, the most distal of which is placed at about 0.7 to 0.75 of the length of the carpus from its proximal end. The ventral border of the palm is bounded by a granulated keel. There is a feebly marked longitudinal keel running just dorsal to the middle of the outer face of the palm. The mesial faces of the fingers bear a rather feebly developed short pubescence. The chelipeds are distinctly granulated on their inner face.

The dorsal margins of the meri of the walking legs are armed with several spines and bear a fringe of moderately long setae. The ventral margins of the meri of legs 1 and 2 end in a pronounced spine; the ventral margin of the merus of leg 3 is unarmed.

Colouration.—Preserved specimens are dark, mottled, reddish-brown; but living individuals are dark green in colour. In life there is a minute vermilion spot at the base of the dactylus of the chelipeds. The extreme tip of this joint is also vermilion in colour.

Distribution.—*P. hastatus* is known from the Nicobars; Java, Sumatra and P. Satang in Indonesia; the Ryu Kyu islands and south Japan. Though not definitely known from the western part of the Indian Ocean it may occur there since Kalk's specimen of '*P. lamarckii*' may be this species.

Ecology.—Miyake states that *P. hastatus* is usually found under rocks between tidemarks. My observations confirm this statement; but it is possible to be more precise in connection with the Singapore population. At Singapore it is an inhabitant of the upper beach and does not occur at any appreciable distance below mid tide mark. Equally it does not extend for any great distance above high water neap tide level. Within this narrow zone it may be very abundant. These habitat requirements are rather similar to those of *P. teres;* but the latter species is found on more muddy beaches, where the stones are much silted, whilst *P. hastatus* inhabits areas where the stones are relatively clean. I have not found the two species together.

Kalk (see above) recorded *P. lamarckii* from Inhaca Island and gave its habitat. The morphological details indicate that she more probably had specimens of *P. hastatus* or a closely allied form. The habitat given corresponds with that in which *P. hastatus* is found in Singapore.

Petrolisthes japonicus (De Haan)

Miyake, 1943, p. 7; 1956, p. 309.

General notes.—This species was recorded from 'Malacca' by De Man (1896). The specimens recorded by De Man from Elphinstone island in the Mergui Archipelago (1888: 215) are certainly not *P. japonicus;* they may be *P. teres* or an allied form. There are not any other records of *P. japonicus* from Malayan waters.

Thus it seems probably that De Man's record was a misidentification. Malacca, at this period was used by non-British authors as synonymous with Malaya. Thus all that is established by De Man's record is that some member of the *P. japonicus* group occurs in the Malayan area. *P. japonicus* itself cannot be maintained on the Malayan list.

P. japonicus is closely related to both *P. teres* and *P. kranjiensis*. All three agree in the general form of the carapace and the chelipeds; in the presence of a sub-basally situated, small, acute tooth on the anterior margin of the carpus of the chelipeds; and in the presence of a distal terminal spine and at least one other spine on the posterior margin of this joint. Distinctive features of the present species include: the presence of 2 or 3 spines in addition to the distal spine on the posterior margin of this joint; the presence of a slight but distinct longitudinal ridge on the outer face of the palm; the absence of pubescence on the mesial margins of the fingers and on the pterygostomial regions; the absence of pronounced grooves on the dorsal surface of the frontal region; the decidely convex lateral carapace margins; the decidely concave posterior carapace margin; the presence of well developed, acute, distal ventral teeth on the meri of the first two pairs of walking legs; the presence of a dorsal spinule on the carpus of the 1st walking leg; and the presence of 3 well developed distal spines on the 1st segment of the antennulary peduncle.

Distribution.—*P. japonicus* is only known with certainty from a limited area of the Indo-West Pacific. Established localities are: southern Japan; the Ryu Kyu islands; the Bonin islands; and Hong Kong. De Man's records from the Mergui archipelago, Malacca, and Borneo cannot be accepted as referring to this species.

Petrolisthes teres Melin Figure 2.

Petrolisthes inermis Haswell, 1881, p. 757; 1882, p. 146; Miyake, 1943, p. 80, figs. 16 & 17.

non *Porcellana inermis* Heller, 1865, p. 76, pl. 6, fig. 5.

Petrolisthes japonicus var *inermis* Miers, 1884, p. 268.

Petrolisthes teres Melin, 1939, p. 105.

Local records.—Tanjong Kranji, Singapore, slipway, under silted stones, various occasions, not very numerous; Siglap, Singapore, under silted stones and boulders at and above mid tide level, several occasions, very numerous, specimens of C.L. up to 6½ mm. (♀) and 8½ mm. (♂); Lim Chu Kang, Singapore, under silted stones, several occasions, not numerous. I have also examined several specimens from under slightly silted stones, at and above mid tide level at Mersing, eastern Johore.

General notes.—*P. inermis* Haswell is pre-occupied by *P. inermis* (Heller). Thus the present species must be called *P. teres* Melin.

P. teres is very closely related to *P. kranjiensis;* but the two species differ strikingly in habitat and colouration. *P. teres* shows certain other morphological differences from *P. kranjiensis*. The central lobe of the front is usually distinctly narrower and more produced. It is often distinctly denticulated. The median dorsal groove of the front is well developed; there are no lateral dorsal grooves. The lateral carapace margins are more convex. The sculpturing, which consists of fine granulated lines, is more distinctly developed. On the chelipeds these lines are somewhat broken up so as to give rise to a finely squamous appearance. There is always a longitudinal keel on the outer surface of the palm, though this keel is sometimes poorly developed on the large cheliped. The inner lobe of the merus is normally armed with a small spine. The ventral surface of this joint terminates in a distinct angulation or a definite tooth. The ventral distal tooth of the merus of the 1st walking leg is small, vestigial or absent. The sternum of the segment of

the 3rd maxillipedes is deeper antero-posteriorly and its lateral points are less pronounced. The anterior border of the 1st segment of the antennular peduncle bears two large, broad, inner spines and a number of smaller denticles. Distally it terminates in a distinct outer spine. The pterygostomial regions, the dorsal margins of the ambulatory legs, and the ventral margin of the palm of the cheliped are all distinctly setose. The hair tuft between the fingers is better developed than in *P. kranjiensis.*

Colouration.—Colouration in life provides the easiest distinction between this species and *P. kranjiensis.* In *P. teres* the dorsum and the dorsal surfaces of the walking legs and the outer face of the chelipeds are all dark green, somewhat mottled with a slightly paler green. There may be a faint, poorly defined, median, longitudinal, pale stripe on the carapace. This colouration is essentially cryptic and differs little from that of allied species. The distinctive specific colours are borne by the anterior appendages. They are best seen in anterior view — the view most likely to be revealed to another porcellanid. They can be regarded as species specific apodeictic colours. A small orange spot is present at the base of the outer face of the dactylus of the cheliped. The tip of of joint has no special colouration. The inner faces of the chelipeds are ivory to ochraceous without any trace of blue. The antennules, the antennae, and all except the 2 terminal joints of the 3rd maxillipedes are green. These 2 joints are pale blue and are provided with orange-red setae. The whole effect is much duller than the colouration of the corresponding region of *P. kranjiensis.*

Distribution.—*P. teres* is only certainly known from the Bonin islands and north-eastern Australia. Its occurrence at Singapore represents a considerable extension to its known range. The specimens recorded by De Man (1888: 215) from Elphinstone Island in the Mergui Archipelago as *P. japonicus* are either the present species or *P. kranjiensis.*

Ecology.—Like *P. japonicus, P. teres* lives under silted stones at and above mid tide level on sandy, muddy-sandy, and mixed beaches. In Singapore it occurs on muddier beaches than *P. hastatus,* where the silting is more severe.

Petrolisthes kranjiensis sp. nov. Figure 2.

Type.—A female of C.L. 9 mm. deposited in the British Museum (Natural History). Type locality: Tanjong Kranji, Singapore. Inhabits *Upogebia* burrows in stiff, black, oil-impregnated mud, forming a scarp bounding the seaward edge of a mangrove swamp, above mid tide level. Type collected 15.5.55.

Other material.—Numerous other individuals from the same locality at various dates of which 7 ♂♂ C.L. $5\frac{3}{4}$ to $8\frac{3}{4}$ mm., 6 ovigerous ♀♀, C.L. 6 to $8\frac{1}{2}$ mm., and 2 non-ovigerous ♀♀, C.L. $4\frac{1}{2}$ and $6\frac{3}{4}$ mm., are preserved in the collections of the Department of Zoology, University of Singapore. Slipway at Tanjong Kranji, under silted stones, 17.2.54, 1 ♂, C.L. 6 mm., and 1 ovigerous ♀, C.L. $5\frac{1}{2}$ mm.; beach just east of Lim Chu Kang, Singapore, no date, in burrows in stiff mud, above mid tide level, 2 ♂♂, both C.L. $7\frac{1}{2}$ mm.

Description.—This medium sized species is clearly a member of the *P. japonicus* group. It cannot be identified with any described species of that group, though it resembles *P. teres* in most features.

The animal is smooth and not hairy. The carapace is marked by a fine sculpturing of broken, transverse lines, which is usually not visible without high magnification. The chelipeds have a similar lineolation. The pterygostomial regions are not pubescent. The carapace is approximately rectangular in shape; but there

is a sudden outbulging of the lateral margins just posterior to the cervical groove. The lateral carapace margins posterior to this groove are sub-parallel and almost straight. The carapace is about 1.1 times as long as broad. The front is from about 0.3 to about 0.38 times the maximum carapace breadth. It is rounded but has a well marked median longitudinal groove on the dorsal surface. The frontal region also possesses, somewhat less well developed, lateral grooves.

The chelipeds are large, much flattened, and subequal. In large males the chela is about 1.6 times as long as the carapace. In large females it is about 1.45 times as long. The inner distal corner of the meral lobe is rounded off and not denticulate. The ventral border of the merus ends distally in a slight angulation; but there is no spine or tooth. The carpus is a little more than twice as long as broad. Its anterior and posterior borders are straight and parallel. The anterior border bears a single, small, acute, sub-basally situated tooth. The posterior border terminates in a prominent distal spine. There is a similar spine set at about 0.67 of the length from the proximal end. The dorsal surface is flat and bears no trace of a longitudinal ridge.

The chelae are triangular in outline and much flattened. They are about 2.7 times as long as broad. The ventral carina of the palm and fixed finger is not denticulate. There is usually no longitudinal ridge on the outer surface of the palm. In exceptional specimens such a ridge may be present but is feebly developed. The fingers are about 0.67 times as long as the palm. They are almost straight but the dactylus ends in a hooked tip. The inner margin of the fingers is densely setose, though this setation is less well developed than it is in *P. teres*.

The sternum of the segment of the 3rd maxillipedes is very narrow in the antero-posterior direction and is produced into pronounced, forwardly curved, lateral angles.

The 1st segment of the antennular peduncle has the distal margin armed with 2 very small internal teeth. The outer corner is produced, rounded, and devoid of teeth. There is a spine on the lateral, outer margin, which does not over-reach the tip. The 3rd segment of this limb is armed with a single spinule as in *P. teres*.

The 1st pair of walking legs bears a large tooth at the distal end of its lower margin. The meri of the other walking legs are unarmed. The carpus of the 1st walking leg bears a single spinule dorsally. The propodi of the walking legs bear only 3 or 4 ventral spinules.

The male has a pair of well developed spinules. The telson has 7 plates.

Colouration.—In life the colour scheme of this species is very distinctive. The general colouration varies from a dull, slaty green to almost black or slaty brown. Only this cryptic colouration is visible in dorsal view. The anterior view of the animal in defensive pose reveals the brightly coloured inner surfaces of the chelipeds and neighbouring structures. The tip of the dactylus of the cheliped and a small spot at the base of this joint are bright vermilion, as is also the whole of the lower border of the inner face. The inner faces of the chelipeds are buff or fawn; but are often tinged with blue. There is a conspicuous blue-grey or grey-blue spot at the distal end of the inner face of the carpus. The distal segments of the antennulary peduncles and the 3rd maxillipedes are a brilliant cobalt blue, whilst the setae of the 3rd maxillipedes are pale orange. The walking legs are banded with pale lime green or greenish-fawn bands.

Comparison with other species.—*P. kranjiensis* can be distinguished from *P. leptocheles* (Heller), *P. tenkatei* De Man, and the insufficiently described *P. wolfi* Sendler, by the presence of a spine on the posterior border of the carpus of the cheliped in addition to the distal spine; by the absence of the small, rounded,

distal protuberance on the anterior margin of the carpus which characterizes those species; by the form of the front; and by the almost straight posterior margin of the carapace. It can be distinguished from *P. unilobatus* Henderson, by the presence of a spine on the posterior border of the carpus of the chelipeds in addition to the distal spine; by the fact that the anterior margin of the carpus is normally armed with an acute spine rather than a blunt lobe; by the relatively larger size of the chelipeds; by the less distinctly marked cervical groove; and by the straight posterior margin of the carapace.

P. kranjiensis is closely related to *P. elongatus* (H. Milne Edwards), *P. japonicus* (de Haan), and *P. teres* Melin. It agrees with these species in general form; in the general form and armament and size of the chelipeds; in the type of carapace sculpture; in the presence of a small, acute, sub-basal tooth on the anterior margin of the carpus of the chelipeds; and in the presence of at least one spine on the posterior margin of this joint in addition to the distal spine.

P. kranjiensis can be distinguished from both *P. japonicus* and *P. elongatus* by: the detailed form of the lateral margins of the carapace which are convex in those two species; by the almost straight posterior border of the carapace; by the armament of the 3rd segment of the antennular peduncle; by the narrower carapace, which is distinctly longer than broad; by the absence of the small spine situated at about the mid-point of the anterior margin of the carpus of the chelipeds; by the presence of only one spine in addition to the distal spine on the posterior margin of this joint; by the well developed pubescence of the mesial margins of the fingers; by the absence of rows of spines and of a hair fringe on the dorsal surfaces of the meri of the walking legs; by the absence or vestigial development of the distal ventral spine of the merus of the 2nd walking leg; and by a number of more minor characters.

P. kranjiensis agrees with *P. teres* in the armament of the carpus of the chelipeds and in having the mesial margins of the fingers setose. It also agrees in the general nature of the armament of the antennulary peduncle and of the propodi of the walking legs. It furthermore closely resembles that species in general body form. It differs from *P. teres* in: the absence of pubescence from the pterygostomial regions and the dorsal margins of the meri of the walking legs; in details of the armament of the 1st segment of the antennulary peduncle; in the non-spinous meral lobe of the chelipeds; in the sculpturing of the palm of the chelipeds, the dorsal border of which is not cristate and not denticulate, and in which the longitudinal ridge of the outer face is either poorly developed or absent; in the detailed form of the sternum of the segment of the 3rd maxillipedes; and in the large distal meral spine of the 1st walking legs. The two species also differ in some more minor characters and differ strikingly in habitat and colouration in life.

Distribution.—*P. kranjiensis* is only certainly known from the cited localities on the Johore Straits coast of Singapore. As I have remarked under *P. teres*, the specimens from Elphinstone island which De Man brought to *P. japonicus* belong either to the present species or to *P. teres*.

Ecology.—This species inhabits holes in stiff mud above mid tide level on the seaward edge of mangrove swamps. Occasional individuals may occur under stones on neighbouring beaches; but this is a marginal habitat. There appear to be other distributional requirements since *P. kranjiensis* has not been found in apparently similar situations in the Jurong area of Singapore, where most of its associates occur.

Pachycheles sculptus (H. Milne Edwards) Figure 3.

Porcellana sculpta H. Milne Edwards, 1837, p. 253.

Porcellana pisum H. Milne Edwards, 1837, p. 254; Heller, 1865, p. 73.

Porcellanapulchella Haswell, 1881, p. 758; 1882, p. 148.

Pachycheles pulchellus Miers, 1884, p. 273, pl. 30, fig. A; Henderson, 1888, p. 114; Ortmann, 1894, p. 30; De Man, 1902, p. 702.

Porcellana (*Pisosoma*) *sculpta* De Man, 1888, p. 218.

Pachycheles pisum Ortmann, 1897, p. 295.

Pisosoma pisum De Man, 1896, p. 380; Miyake, 1943, p. 112, figs. 38 & 39B.

Pachycheles sculptum Johnson, 1963.

Local records.—Singapore Regional Fisheries Research Station: B. 42, south of Singapore, stony bottom, 14 fms, 1 ♂, C.B. 9 mm., and 1 ♀, C.B. 8 mm.; B. 76, Burun Darat, Singapore, 1 ovigerous ♀, C.B. 5½ mm. Other collections: between Pulau Tembakul and Pulau Sakijang Pelepah, Singapore, 5-1-52, submerged coral reef, depth 2 to 3 fms, 2 ♂♂, C.B. 5½ and 6½ mm., 1 ovigerous ♀, C.B. 6¼ mm., and 2 damaged individuals; (these last presented to the British Museum); Pulau Pawai, Singapore, coral heads in depth of 1 to 2 fms on coral-gorgonian ground fringing west coast, 29-12-51, 1 ♂, C.B. 4¾ mm. and 1 non-ovigerous female, C.B. 4¾ mm.; Pulau Sudong, Singapore, 19-2-55, crevices in a large head of *Pavona frondifera*, in a depth of ½ to 1 fm, 2 ♂ ♂, C.B. 4½ and 5½ mm., and 1 ovigerous ♀, C.B. 6¼ mm. I have also seen a single ♀, C.B. 4¼ mm., collected 5-2-54, 'littoral', Penang.

Notes.—Haig (1960: 132) has shown that the genus *Pisosoma* cannot be maintained. Whilst concurring with her decision, I believe that *P. sculptus* and its allies form a natural group within the genus which might well be accorded subgeneric rank. To do this, however, would mean the creation of other subgenera. Since I am not sufficiently familiar with New World species I refrain for the moment from taking this course.

Examination of photographs of the type of *Porcellana sculpta* H. Milne Edwards, kindly loaned to me by J. Haig, has convinced me that this species is identical with *P. pisum* H. Milne Edwards. Since *P. sculpta* has page priority this name should be used. This leaves without a name a second Indo-West Pacific species, which I had formerly believed to be *P. sculpta*, and which corresponds with the *P. sculpta* of Miyake (1943: 110, figs. 37 & 39A) and most other authors. This species, '*Pachycheles* sp. A', appears to be rarer and has not so far been found in Malayan waters.

Examination of the series of *P. pulchellus* reported on by Miers shows that this belongs to the same species as *P. sculptus* H. Milne Edwards. There is sufficient identity with Haswell's description of *Porcellana pulchella* to establish that Miers was really dealing with that species.

Ortmann (1894) identified *Porcellana natalensis* Krauss with *Pachycheles sculptus*. Whilst Krauss's form is a true *Pachycheles*, it does not belong to the *P. sculptus* group, and has nothing to do with that species.

P. sculptus and 'species A' can be readily distinguished by the sculpturing of the chelipeds and the carapace, as I have been able to ascertain by comparisons of series of specimens in the collections of the British Museum (Natural History). In 'species A' the anterior portion of the carapace bears well marked transverse ridges which are absent in *P. sculptus*. This sculpturing does not change with age or size. In 'species A' the longitudinal ridges of the carpus of the chelipeds are broken into numerous small tubercles or squamiform granules. In *P. sculptus* the sculpturing of the chelipeds varies with size. Since the chelipeds are very unequal, especially in large males, the sculpturing is often very different on the two chelipeds. In very large males, the sculpturing is vestigial on the larger

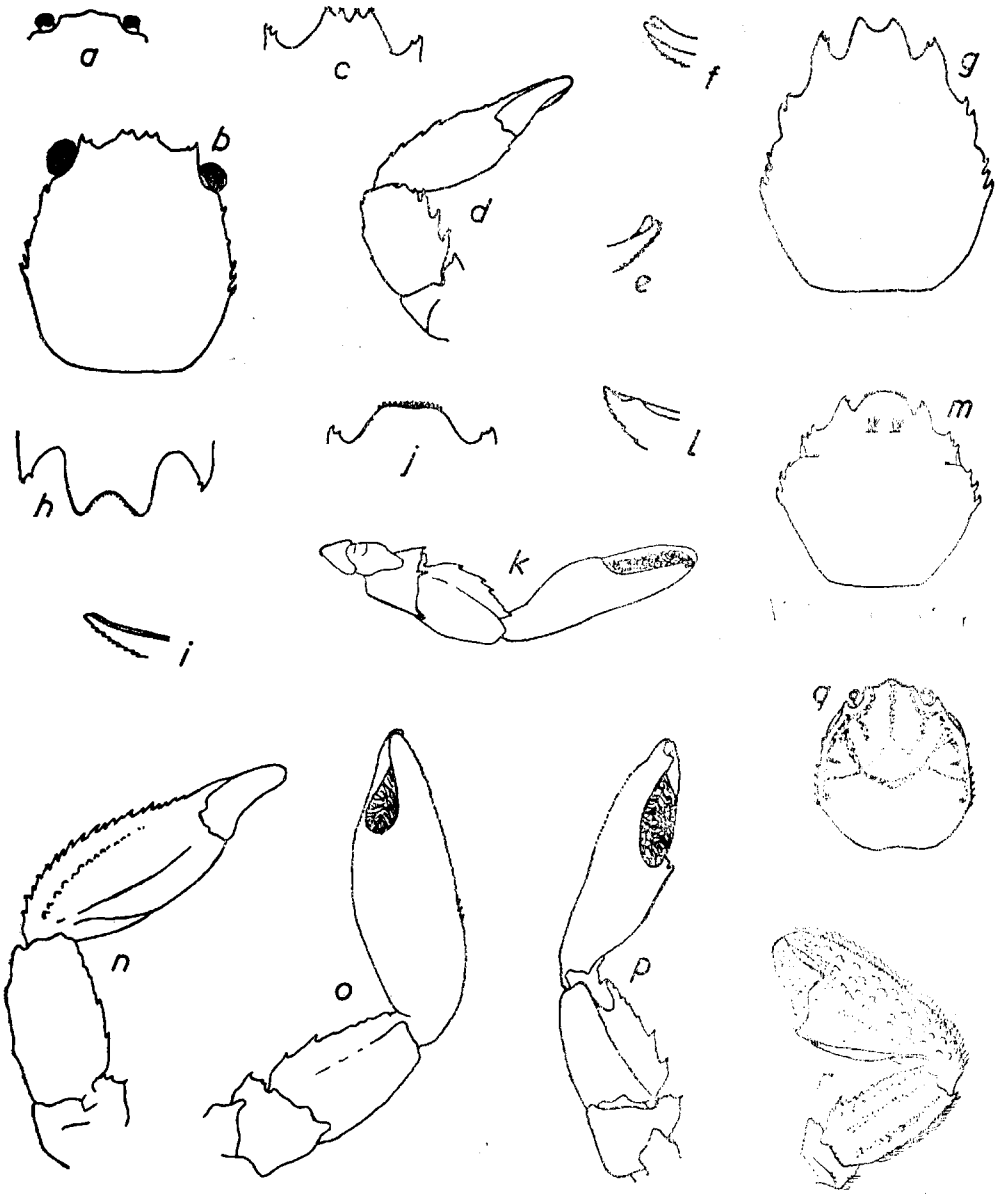

Figure 3. *a* *Pachycheles sculptus* H. Milne Edwards, ♂, Singapore, frontal region. *b-f* *Porcellana* (*Pisidia*) *latifrons* Stimpson, ovigerous ♀, Singapore; *b* outline of carapace; *c* outline of front of another individual; *d* large cheliped; *e* tip of fixed finger of small cheliped, external view; *f* the same, internal view. *g-i* *Porcellana* (*Pisidia*) *quadrilobata* Miers, ovigerous ♀, Singapore; *g* outline of carapace; *h* detail of front; *i* end of fixed finger of small cheliped, external view. *j-l* *Porcellana* (*Pisidia*) *streptochiroides* nom. nov., ovigerous ♀, Singapore; *j* front; *k* ventral view of small cheliped; *l* end of fixed finger of small cheliped, internal view. *m-p* *Porcellana* (*Pisidia*) *gordoni* sp. nov., type ♂, Singapore; *m* outline of carapace; *n* large cheliped, dorsal view; *o* large cheliped, ventral view; *p* small cheliped, ventral view. *q-r* *Porcellana* (*Enosteoides*) *corallicola* Haswell, ♂, Singapore; *g* dorsal view of carapace; *r* dorsal view of larger cheliped.

cheliped and sometimes on both, so that they are smooth. The carpus and the outer face of the palm bear two very low, uninterrupted ridges. In smaller males and in females these ridges are more elevated and are broken into sections by a number of gaps or transverse grooves. In young females they are represented by a series of elongate tubercles. The type specimen is of the intermediate form. Even in the smallest individuals which I have seen the tubercles are less elevated than those of 'species A' and they are always arranged in longitudinal rows.

Colouration.—The colouration of *P. sculptus* is variable but distinctive. It exhibits a pronounced sexual dimorphism, an unusual feature in this group. The general colour of the dorsal surface is some shade of brown, diversified by a median, longitudinal band of ivory or a similar shade, which varies in width. In males the ground colour is darker than in females, varying from nigger brown to ebony. The central band is well defined, irregular in outline, and transversely expanded towards the middle of its length. It is broad and may, exceptionally, occupy most of the dorsal surface. In females the ground colour is some shade of chestnut. The longitudinal band is much narrower and it may be ill defined. The tips of the fingers are pale, varying in colour from ivory to pale pink.

Distribution.—Singapore and Penang are the only Malayan localities. Elsewhere *P. sculptus* is known from: the Nicobar islands; Sumatra; Enoe Island; New Guinea; northern Australia; the China Sea; and the Ryu Kyu islands.

Ecology.—P. sculptus is closely associated with living coral and should probably be classed as a commensal. It extends from about low water spring tide level down to the lowest depths at which living corals are found.

Genus **Porcellana** Lamarck

The taxonomy of this genus is only a little less chaotic than that of *Petrolisthes* was, until recent years. The principal characters used in separating species are the form of the front and the shape and armament of the chelipeds; but many other characters are also of some importance. It is desirable that descriptions should be as complete as possible, thus enabling one to use many characters in conjunction in determining specific limits. In this genus individual and age variations are often very considerable. Failure to appreciate these has, in the past, given rise to erroneous taxonomic conceptions.

Haig (1960: 197 & 207) has suggested that the genus be split into several genera. For one of these she proposes to revive the old name *Pisidia* Leach. As normally understood the genus does indeed comprise several distinct groups of species; but, in my opinion, the presence of aberrant and intermediate forms makes subdivision into genera inadvisable at the present time. The recognizable groups can be treated as subgenera.

In my opinion the genus *Porcellanella* Stimpson cannot be separated from *Porcellana* interpreted in this broad sense. Its distinctive features are approached closely by certain species in both the subgenus *Porcellana* and the subgenus *Pisidia*. *Porcellana corallicola* Haswell does not readily fit into any of the previously recognized groups and I am proposing a new subgenus *Enosteoides* for its reception.

Three subgenera are represented in the Singapore fauna: *Pisidia* Leach; *Enosteoides* subgen. nov.; and *Porcellanella* Stimpson. They can be distinguished by the characters given in the generic key.

Subgenus **Pisidia** Leach

Thus subgenus includes most of the Malayan species. The following key will assist in their identification:

1. Median lobe of front entire, apart from small denticulations ..... 2.
–. Median lobe of front with a well defined median notch ..... 3.

2. Anterior margin of carpus of cheliped cut into several lobes (each of which ends in an acute tooth in young individuals); palm with only one spine row on its outer face ..... *P. streptochiroides*
–. Anterior margin of carpus armed with spines but not cut into lobes; outer face of palm with 2 longitudinal rows of spines ..... *P. gordoni*

3. Front very prominent with the median notch as broad as the middle lobe, deep and denticulated. Posterior margin of the carpus of the cheliped unarmed; propodus of the cheliped lacking any longitudinal row of spines on its outer face ..... *P. quadrilobatus*
–. Front less prominent with the median notch less broad and deep and not denticulated. Posterior margin of carpus of cheliped with several spines; propodus of chelipeds with a longitudinal row of spines on the ventral portion of the outer face, just above the ventral margin ..... *P. latifrons*

Porcellana (Pisidia) latifrons Stimpson Figure 3.

Porcellana latifrons Stimpson, 1858, p. 243; 1907, p. 190, pl. 23, fig. 4.

Local records.—Singapore Regional Fisheries Research Station: B. 76, Burun Darat, Singapore, 1 ovigerous ♀, C.B. 4½ mm. Other collections: Pulau Pawai, Singapore, coral-gorgonian ground in depth of 1 to 2 fms, fringing west coast, on coral heads, 1 ♀, C.L. 5¼ mm.; between P. Tembakul and P. Sakijang Pelepah, Singapore, coral heads on submerged coral reef in depth of 2 to 3 fms, 5-1-52, 1 ovigerous ♀, C.L. 3¾ mm.; P. Sudong, Singapore, crevices in large head of *Pavona frondifera* growing in ½ to 1 fms depth, 19-2-55, 2 ♂♂, C.L. 3¾ to 4¼ mm., 2 non-ovigerous ♀♀, C.L. 3½ & 4 mm., and 2 ovigerous ♀♀, C.L. 3 & 3½ mm.; Raffles Light, Singapore, reef and lower parts of reef flat, various occasions, numerous individuals, the largest an ovigerous ♀ of C.L. 5½ mm.; Sultan Shoal, Singapore coral heads on piers at about low water spring tide level, 7-3-53, 7 ♂♂, C.L. 4 to t mm., and 4 ovigerous ♀♀, C.L. 4 to 5¼ mm.; Labrador, Singapore, crevices in silted coral rock on lower beach, various occasions, several, the largest an ovigerous ♀ of C.L. 5¾ mm.; Tanjong Gul, Singapore, coral-heads at about low water spring tide level, 7-1-55, 2 ♂♂ C.L. 3¾ & 5 mm., 2 non-ovigerous ♀♀, C.L. 2 & 5½ mm., and 1 ovigerous ♀, C.L. 3½ mm.; Kg. Mata Ikan, clinging to washed in sponge on beach 500 yds. N.E. of village, 8-1-55, 1 ovigerous ♀, C.L. 4½ mm.; Singapore Straits, south of Singapore, 27-3-56, mixed shell-gravel and mud bottom, 1 non-ovigerous ♀, C.L. 4½ mm.

Notes.—P. latifrons is readily recognized by its broad front in which the central lobe is 3-notched, and by the form and armament of the chelipeds.

The carapace is slightly longer than broad (about 1.15 times). The lateral margins are convex. The posterior margin is almost straight. The very broad front occupies somewhat more than half of the maximum carapace breadth and considerably more than half of the fronto-orbital breadth. The form of the front is variable; but the basic pattern is constant and characteristic. The frontal region is shallowly concave in a transverse direction. The lateral lobes are well developed and acutely pointed. Their orbital margin is convex. Their inner margin is usually concave. The lateral lobes are separated from the central lobe by deep, open notches. The outer border of these notches bears 1 to 3 teeth or spines, varying in number and size even on the two sides of a single individual. The central lobe is broad. It is subdivided by a small but conspicuous median notch, which is triangular and not denticulated. Each subsidiary lobe is again notched. These notches are usually, though not invariably, smaller than the central notch. Each of the subdivisions may terminate in 1 to several teeth. The lateral margins of the central lobe may be unarmed or variously denticulated. Dorsally the frontal region bears a shallow median groove.

The ventral border of the orbit bears a small spine very near to its posterior corner. There may also be 1 or 2 more anteriorly situated spines. On the carapace margin, just posterior to the posterior corner of the orbit, there is another small spine. There is a single larger spine between this and the cervical groove. Posterior to the cervical groove each lateral margin bears 3 large, procurved spines.

The chelipeds are assymmetrical. They always show some differences in structural details and in large individuals they differ in size. Out of a sample of 14 individuals with both chelipeds attached the left cheliped proved to be the larger in 13. This ratio is unlikely to be a mere chance effect and there is thus reason to believe that left-handedness is favoured in this species.

The merus, carpus, and chela are sculptured with closely set, approximately transverse, more or less interrupted and squamous, finely granular ridges. These ridges are broken up and more irregularly arranged on the chela than on the other joints. The granulations are also more prominent on the chela, where, in small individuals they may be represented by small denticles.

The anterior dorsal margin of the merus is produced into a prominent lamina, which, however, is relatively smaller than that found in *P. quadrilobatus*. Distally this lamina bears a number (usually 3 to 5) of small teeth or spines. The posterior margin of the merus usually bears a single spine; but this spine is sometimes absent. There may also be a small spinule on the distal dorsal margin, just medial to the posterior corner. The ventral distal margin bears a single large spine. This spination of the merus shows considerable individual variation; it is usually better developed in small than in large individuals, and on the small cheliped than it is on the large cheliped.

The carpus is moderately long. It is from 0.7 to 0.9 times as long as broad. Its internal face is deeply excavated. Distally the dorsal, anterior margin is produced in the large cheliped of large individuals into a broad, blunt, distally directed lobe. In large individuals, especially in large males, the remainder of this border is somewhat sinuous but lacks teeth. The posterior margin bears 3 small spines of which the middle one is sometimes vestigial or lacking. In large individuals the carpus of the small cheliped has the dorsal anterior margin ending distally in a rounded triangular projection, which is armed with from 1 to 3 minute teeth. Proximal to this projection there are from 3 to 4 blunt teeth. In smaller individuals these teeth are better developed and acutely pointed. In small males and in all save the very largest females both small and large chelipeds have the dorsal anterior margin of the carpus armed with well developed teeth or spines and possess a single spine in place of the distal lobe. In such individuals the ventral anterior margin is often armed with a small tooth placed at about the middle of its length.

The chela is depressed, rather slender, and somewhat contorted. It has a pronounced ventral keel. This keel is usually denticulated; but in large individuals the keel of the large chela may merely be granulate. On the outer face of the palm, just dorsal to this ventral keel, there is a longitudinal row of from 5 to 9 (usually 7) small spines, associated with some of which are smaller, accessory spines. The dorsal margin of the palm is rounded and not keeled. On the outer face parallel and just ventral to this margin there is a shallow, unsculptured groove, which marks the morphological line of transition between the inner and outer faces. The fingers are rather strongly twisted. The dactylus is strongly curved distally and crosses the fixed finger. Its cutting edge bears a large, triangular, basal projection and a few blunt teeth. Its 'inner' face is slightly excavated and is lined with hairs. The fixed finger is nearly straight, except for the strongly curved tip. Most of its inner face is strongly excavated and lined with a thick bunch of setae continuous with the

setation on the dactylus. In the small cheliped the fingers are slenderer and more strongly twisted. They are somewhat gaping and their cutting edges are not armed with teeth. They are excavated throughout their length, the excavation being filled with closely set, regularly arranged setae which form a fringe externally The fixed finger is bifurcated at the tip forming a notch which accommodates the tip of the dactylus.

The relative lengths of the distal segments of the chelipeds have been determined for a sample of 9 males and 13 females. The results are tabulated in table 1 and in figures 5 and 6. In the males these show a pronounced positive heterogony with an allometric growth coefficient of the order of 1.2 to 1.3. In both segments measured there is a lower value for the small cheliped than for the large cheliped but the difference is very slight and certainly not significant. Nonetheless one might expect that a significant difference could be demonstrated with very large samples. In the females the growth co-efficient is always less than one but no significant difference can be claimed for the large cheliped. The evidence does indicate a strong possibility that the distal segments of the small cheliped are negatively heterogonic with respect to the carapace.

TABLE I

Heterogonic growth of chelipeds in *Porcellana (Pisidia) latifrons* Stimpson (equation log y = log a + K log x)

Sex	Segment	Number of Individuals	k	Probability if k=1.000	a
♂	Large propodus (p)	9	1.245 ± 0.123	.05 – .10	– 0.022
♂	Large carpus (c)	9	1.250 ± 0.098	.02 – .05	– 0.345
♂	Large p+c	9	1.286 ± 0.100	.02 – .05	+ 0.142
♂	Small propodus (p)	8	1.234 ± 0.129	circa .15	– 0.078
♂	Small carpus (c)	8	1.225 ± 0.101	.05 – .10	– 0.383
♂	Small p+c	8	1.230 ± 0.075	.02 – .05	+ 0.098
♀	Large propodus (p)	11	0.911 ± 0.056	.10 – .20	+ 0.103
♀	Large carpus (c)	11	0.976 ± 0.076	.80	– 0.243
♀	Large p+c	11	0.931 ± 0.054	.20 – .30	+ 0.265
♀	Small propodus (p)	12	0.817 ± 0.061	.01 – .02	+ 0.116
♀	Small carpus (c)	12	0.060 ± 0.088	.10 – .20	– 0.223
♀	Small p+c	12	0.831 ± 0.058	.01 – .02	+ 0.280

The meri of the walking legs are unarmed distally. The carpi bear one or two distal dorsal spines. The distal ventral margins of the propodi bear a pair of slender spinules. The dactyli are long and rather slender. They have a moderately large accessory claw. More proximally they bear 2 or 3 smaller spines.

Colouration.—In life the animal is dark green mottled with paler green. In the middle of the carapace there is an indistinct, pale, longitudinal stripe. The legs are indistinctly banded.

Distribution.—This species seems to be confined to the central portion of the Indo-West Pacific; but in the absence of a thorough revision of the genus it is not possible to give its exact distribution.

Ecology.—P. latifrons appears to be a common inhabitant of the lower littoral zone and the immediate infra-littoral fringe in the Singapore area. Because of its small size it is easily overlooked. It is rather uncommon in offshore collections. A crevice dweller, it is commonly found in association with corals; but it is by no means confined to living coral.

Porcellana (Pisidia) quadrilobata Miers Figure 3.

Porcellana quadrilobata Miers, 1884, p. 276, pl. 30, D & d; Barnard, 1950, p. 819.

Porcellana streptochira Miers, 1884, p. 277.

Examination of the types of Miers's species preserved in the collections of the British Museum leaves no doubt as to the identity of these two forms. I comment further on this identity and on the dating of *P. streptochira* to Miers rather than to White in the discussion of *P. streptochiroides*.

Local records.—Singapore Regional Fisheries Research Station: B. 75, south of Singapore, clean bottom, 35 fms, 1 ovigerous ♀, C.L. 6 mm.

Notes.—My specimen shows a few minor differences from Miers's specimen. These are in my view individual and sexual variations; the two specimens being clearly members of the same species.

The carapace is distinctly elongate. Miers gives it as being 1¼ times as long as broad; the Singapore specimen is only 1.2 times as long as broad. The form of the front is very characteristic. It is very broad, occupying about 0.67 of the maximum carapace breadth, and it is also very prominent. The whole frontal region is very flat and not at all deflexed. Anteriorly the front is cut into 3 large lobes. The lateral lobes are well developed and their tips are slightly incurved. In my specimen each is armed with a terminal spine. In addition there are 2 inner spines on one side and 1 inner spine on the other. The notch between the lateral and the central lobe is deeper and narrower than that found in *P. latifrons*. The central lobe is almost twice as long as the lateral lobes. Its anterior broader is almost completely occupied by a broad, deep, V-shaped notch. The margins of this notch are finely denticulated. There is a very shallow, median dorsal groove on the frontal region.

The outer orbital angle bears a strong spine. Just anterior to this the ventral margin bears a minute spine. There is a single large spine between the orbit and the cervical groove. Posterior to the cervical groove there are 3 large, procurved spines on each lateral margin. In my specimen there is a minute epibranchial spine.

The chelipeds are rather slender. The merus is unarmed posteriorly. The merus lobe is a large, cristiform, angular projection, which bears a single large spine at its inner distal corner. There are 1 to 4 spines on the distal ventral margin. The carpus is about as long as the palm. The anterior margin bears 3 large teeth. In my specimen the small cheliped has 4 smaller teeth distal to these, whilst the large cheliped has 2 such teeth. This condition resembles that in *P. gordoni*. Miers neither mentions nor figures these smaller spines and I can confirm that they are absent from his type specimen. This specimen is a large male. Such differences between females and large males are common in this genus. In both chelipeds there is a prominent tooth in the middle of the inner ventral margin of the carpus. The ventral margin of the palm and fixed finger bears a denticulate keel in both chelipeds. On the outer surface of the palm, just dorsal to this keel, there is a short spine row. In my specimen this contains 2 spines on the larger chela and 3 on the smaller. The appearance is very different from the continuous spine rows found in *P. latifrons* and on the small chela of *P. streptochiroides*. The fingers are a little shorter than the palm. They are much less twisted than those of *P. latifrons*. They do not gape in either chela. The finger tips are strongly hooked and cross each other. The fingers of the large chela bear a large tooth on their cutting edges. This tooth is absent in the small chela where the cutting edge is denticulate. The fixed finger of the small chela is not bifid at the tip. The fingers are somewhat excavated on their 'inner' face and are filled with a thick tuft of fine hairs which extends for a short distance onto the palm. This tuft is precisely comparable to that found in *Porcellanella*.

The dactyli of the walking legs bear a large accessory claw; proximal to this there are 1 or 2 small spines.

Miers recognised that this species was closely related to *P. latifrons*. I entirely agree with this opinion. It is easily differentiated from that species by its very characteristic front. The carapace is more elongate than it is in *P. latifrons*. The keel of the 1st antennal segment is slightly more pronounced. The merus lobe is larger and bears only one spine. The posterior borders of the merus and carpus are unarmed. The hair-tuft between the base of the fingers is quite different in appearance. The spination of the chela is different and the fixed finger of the small chela does not have a bifid tip. *P. gordoni* somewhat resembles *P. quadrilobata* in the form of the chelipeds; the two species are readily separated by the very different form of the front and the spinulation of the small cheliped.

P. quadrilobata is well removed from the central type of the sub-genus *Pisidia*. It appears to form an extreme of the series to which *P. latifrons* belongs. In some features it approaches the sub-genus *Porcellanella*. These include: the elongate carapace; the large accessory claw on the dactyli of the walking legs; the form of the front; the form of the chelae; and the hair-tuft between the bases of the fingers. Barnard (1950) has indeed assigned the species to *Porcellanella*. I cannot follow Barnard in this opinion; but I consider that *P. quadrilobata* is sufficiently close to *Porcellanella* to prevent this genus being maintained as such.

Distribution and ecology.—This species appears to be very rare. It is known from S.E. Africa, Queensland, and now Singapore. All records are from offshore localities.

Porcellana (Pisidia) streptochiroides nom. nov. Figure 3.

Porcellana streptochira De Man, 1887, p. 419, pl. 18, fig. 6.

non *Porcellana streptochira* White, 1847, p. 277, nomen nudum; Miers, 1884, p. 277.

Local records.—Singapore Regional Fisheries Research Station: B. 43, Angler Buoy, 5 fms muddy bottom, 1 ♂, C.B. 7½ mm.; B. 50, off Tanjong Rhu, Singapore, 2 fms. muddy bottom, 1 ovigerous ♀, C.L. 6¼ mm., Other collections: E.S.E. of main harbour breakwater, Singapore, 6 ms., coll. P. Wickstead, 7 specimens including ovigerous ♀♀ to C.B. 7 mm.; in much bored, rotten driftwood, Changi beach, Singapore, 11-9-53, 5 specimens of 3¾ to 5¼ mm., of which 3 including the largest are ovigerous ♀♀; Kg. Mata Ikan, Singapore, beach about 500 yds. N.E. of village, on washed in sponge, 8-1-55, 1 ♂, C.L. 5¼ mm.

General notes.—These specimens correspond well with De Man's description of *P. streptochira*. They differ slightly in the form of the merus lobe and in the absence of epibranchial spines. Both these features fall within the expected range of individual and age variation for this species. Thus my specimens can be accepted as belonging to De Man's species.

Unfortunately De Man's species is not the same as that of White and Miers. White's name is a *nomen nudum;* but Miers's notes of 1884 (given in his discussion of *P. quadrilobata*) are sufficient to characterize the species, so that the name is valid as of that date. Miers's notes show clearly that his form is not the same as that of De Man, though they are too brief to permit certain identification. The very different form of the front is alone sufficient to separate the two forms. Miers himself suggested that *P. streptochira* might be a form of *P. quadrilobata*. This synonymy is consistent with Miers's descriptions. I have been able to examine the types of *P. streptochira* in the dry collections of the British Museum (Natural History). I could find no significant differences from *P. quadrilobata* Miers.

Fortunately *P. quadrilobata* has page priority over *P. streptochira* Miers whilst *P. streptochira* White, as a *nomen nudum,* has no nomenclatural standing. The correct name for *P. streptochira* Miers is thus *P. quadrilobata* whilst *P. streptochira* De Man must be renamed. I am therefore proposing *P. streptochiroides* in place of De Man's name.

The front of this species is trilobate as in *P. latifrons;* but it is narrower, being less than 0.5 and usually less than 0.4 of the maximum carapace breadth. The lateral lobes are comparatively blunt and feebly developed. The central lobe is rather prominent. It may be rounded or flat-topped; but it is never notched. This lobe is always denticulate; but the exact arrangement and size of the spinules is very variable. The front as a whole is not deflexed. The frontal region is almost flat; but the lateral margins are very slightly raised and there is a shallow, median longitudinal groove. The lateral carapace margins are very convex. The posterior margin is almost straight.

De Man mentions the presence of epibranchial spines; but there are no such spines in my specimen. There is a large procurved spine anterior to the cervical groove. There are also 1 or 2 smaller teeth between this spine and the orbit. De Man mentions 2 large spines on the lateral margins posterior to the cervical groove. In all my specimens there are 3 such spines. These decrease in size anteriorly. The most anterior may be very minute and can easily be overlooked.

The keel on the 1st segment of the antenna is less acute than in *P. latifrons.* My specimens have a spinule of variable size on the 2nd antennular segment. It may be very minute to very prominent.

The chelipeds differ in size and, to some degree, in form. The differences are most pronounced in adult males. Such measurements as can be made on the available material indicate growth rates which do not differ significantly from those shown by *P. latifrons.* It seems probable that, the relative growth is linear in young individuals and becomes positively heterogonic in the sexually mature male.

In males the merus lobe of the large cheliped is of moderate size. It is provided with a spine on the inner margin, which is usually, but not always, large and conspicuous. There may be up to 5 additional teeth, or the remainder of this margin may be quite smooth. The distal ventral margin bears a single well developed spine. The carpus is about 0.67 times the length of the palm. It is about 1½ times as long as broad. There is an acute, forwardly directed, distal tooth on the posterior margin. This margin is otherwise unarmed. The anterior dorsal margin is produced into a large lamella. The distal corner forms a small, rounded, distally directed lobe. The remainder of this border is sinuous, forming 2 shallowly separated lobes. The ventral margin is not toothed. The anterior face is deeply excavated. In small specimens, especially females, the large cheliped differs from this pattern and approximates to or even resembles the small cheliped.

The chela is little compressed. The dorsal margin is rounded and unkeeled. The outer face bears a low, bluntly rounded keel. The palm is about 1.8 to 2.0 times as long as deep. The ventral margin has a distincty denticulated keel. Just dorsal to this on the outer face there is a prominent, narrow, longitudinal keel, which does not extend on to the fixed finger. In its distal portion this keel is broken up into several portions, each of which is finely denticulate and may end in a larger tooth. There are no large spines. In small individuals, especially females, the form and armament of the palm differs considerably from this pattern (see below). The fingers are stout and they are greatly twisted. The dactylus is between 0.5 and 0.7 times as long as the palm. Distally the fingers are strongly hooked

and cross at their tips. The dactylus passes externally to the fixed finger. The cutting edge of each finger is armed with a large triangular tooth, whose margin is crenulated. That on the dactylus is the more proximally situated. The fingers do not gape in external view. Internally they are deeply excavated and thickly clothed with hairs. There is a prominent, longitudinal groove on the outer face of the dactylus just ventral to the dorsal margin. The ventral margin of the chela is almost devoid of hairs.

The merus of the small cheliped resembles that of the large cheliped. The carpus differs in the form and armament of the anterior dorsal margin. The distal lobe is smaller and may be denticulated. The proximal lobes may each bear a small apical spine. In small individuals the internal margin is somewhat convex and bears two large teeth at about $\frac{1}{4}$ and $\frac{1}{2}$ of its total length. The more distal portion of the margin in such individuals may bear a few minute denticles. There is no distal lobe. The chela is more compressed and more slender than that of the large cheliped. The greater slenderness is in part a consequence of the greater relative length of the fingers. On the outer face there is a shallow, longitudinal depression just ventral to the dorsal margin. The median keel is well developed. The ventral margin of the palm and the whole outer face of the fixed finger are thickly clothed with a fringe of long hairs. The dactylus is about $\frac{3}{4}$ the length of the palm. Both fingers are greatly twisted and possess strongly hooked tips. The tip of the fixed finger is bifid. The hooked tip of the dactylus is accommodated by the notch so formed. The fingers are gaping, the gaps being closed externally by a thick hair fringe. The cutting edges are unarmed. Internally the fingers are excavated and very setose. The dorsal margin of the dactylus bears a pronounced crest, with obsolescent denticulation.

In females and young individuals the form and armament of the large cheliped approximates much more closely to that of the small cheliped than it does in large males. The internal margin of the carpus is armed as in the small cheliped. There is usually no distal lobe; where this lobe is developed it is small and little different from the two large, proximal teeth in form. In these small individuals the large chela is relatively slender. The palm is more than $2\frac{1}{2}$ times as long as deep. The ventral margin is strongly denticulated. The sub-ventral keel is replaced by a spine row of some 7 to 11 spines. This cheliped is not setose. The small cheliped has the palm more than twice as long as broad. The denticulation and spination are usually nore pronounced than in the large cheliped but similar in character. The fingers and the setation are as in the large males.

The meri of the walking legs have no ventral teeth. The carpi terminate distally in a minute spinule. The propodi are armed ventrally with 2 or 3 spinules in a row and a distal pair of spinules.

P. streptochiroides is closely related to *P. latifrons*. It resembles that species in the peculiar form of the fingers of the chelipeds and especially in possessing a bifid tip to the fixed finger of the small cheliped. The general form and growth changes of the chelipeds and the detailed changes in the armament of the distal segments of these with sex and size are similar in the two species; as are also many other features of general body structure. At all ages *P. streptochiroides* can be distinguished from *P. latifrons* by: the narrower front with its un-notched median lobe; the unarmed posterior margins of the meri of the chelipeds; and the absence of spines, other than the distal spine, on the posterior margin of the carpus of the chelipeds. Adult males can be easily recognized by the characteristic armament of the palm; but smaller individuals may be difficult to distinguish from *P. latifrons* on the basis of this character. The form of the anterior margin of the

carpus will serve to distinguish adult males and young individuals of the two species but individuals of intermediate size are not easily distinguished on this character alone.

Young males and females of *P. streptochiroides* might be confused with *P. spinulifrons* and *P. gordoni*, which they resemble in the form of the front and the general character of the armament of the anterior margin of the carpus of the cheliped. *P. streptochiroides* can be recognized by the form of the fixed finger of the small cheliped. It also lacks the median spine row on the palm.

Distribution.—*P. streptochiroides* is known from Indonesia and Singapore. It is probably widely distributed in the central portion of the Indo-West Pacific region.

Ecology.—Little can be said of the ecology of this species. It appears to be essentially a form of muddy to sandy bottoms in shallow, offshore habitats. It is absent from coral reefs.

Porcellana (Pisidia) gordoni sp. nov. Figure 3.

Porcellana spinulifrons Gordon, 1931, p. 530, figs. 4 & 5.
non *Porcellana spinulifrons* Miers, 1879, p. 46.

Type.—A male of C.L. $6\frac{1}{4}$ mm., from barnacle-hydroid growth on fishing stakes in Nanas channel, north of Pulau Ubin, Singapore, 28-3-53.

Other Singapore material.—Singapore Regional Fisheries Research Station: B. 25, outer shoal, 6 fms, bottom of mud, shell, and stone, 1 ♂, C.L. $3\frac{1}{2}$ mm.; B. 50, off Tanjong Rhu, Singapore, 2 fms, mud bottom, 1 ovigerous ♀, C.L. $6\frac{1}{4}$ mm. Other collections: type locality and date, 1 ♂, C.L. 4 mm., 2 ovigerous ♀♀, C.L. 3 & $5\frac{3}{4}$ mm., and 2 young ♀♀, C.L. about 2 mm.; Johore Shoals, Singapore, crinoid ground, about 10 fms, 17-6-54, 1 ♂, C.L. $3\frac{1}{4}$ mm., and 1 ovigerous ♀, C.L. 3 mm.; E.S.E. of main harbour breakwater, Singapore, coll. P. Wickstead, 1 ♂, C.L. $7\frac{1}{2}$ mm., and an isolated large cheliped; P. Sudong, Singapore, reef flat, 1 non-ovigerous ♀, C.L. 5 mm.

Other material.—I have also been able to examine and to compare with the type series of *P. spinulifrons* the series of specimens which Gordon reported on from Hong Kong.

Description.—The present series of specimens from Singapore agree in all essential features with Gordon's series from Hong Kong. Gordon appears to have overlooked the small denticulations distal to the main teeth on the inner margin of the carpus of the chelipeds. These denticulations are present in both series. As there are no other important differences the two series must be accepted as being conspecific. However neither series agrees with Miers's description of *P. spinulifrons* or his type series of that species. I therefore consider that they must be separated as a new species which I am naming *P. gordoni* in honour of Dr. I. Gordon.

The carapace is usually as broad as it is long; but in some specimens it is slightly longer than broad. In the Singapore series the mean carapace length is 1.03 times the mean carapace breadth. The front is prominent and rather narrow. It occupies a little more than 0.4 of the carapace breadth and is always less than 0.5 of this breadth. The frontal region is distinctly concave in a transverse direction. There is a well marked, broad, median frontal groove. The front is not at all deflexed. It is divided into 3 lobes. The lateral lobes are narrow, prominent, and slightly incurved. They terminate in a spine, and there are 1 or 2 spines on their

inner margins. The median lobe is rounded, denticulate, and un-notched. The lateral margins of the carapace are strongly convex. The posterior margin is straight or almost straight. There is usually a conspicuous spine at the outer angle of the orbit. The usual spine in front of the cervical groove is well developed. There may be a smaller spine between it and the orbit. There are from 2 to 5 (usually 3) small, epibranchial spines on each side. Posterior to the cervical groove the lateral margins of the carapace bear 3 or 4 spines which increase in size antero-posteriorly. The last is usually situated at the level of the maximum carapace breadth. The dorsal surface of the carapace is conspicuously sculptured with numerous closely set, short, transverse lines. The protogastric ridges are prominent and minutely denticulate. Each bears a conspicuous tuft of long stiff bristles. There are several scattered tufts of smaller bristles on the remainder of the carapace.

In females and young males the chelipeds are subequal in size and form; but there are always slight differences in the form of the fingers between the two chelipeds. The merus lobe is well developed. It bears a conspicuous spine and from 2 to 7 unequally developed, smaller spines. In the middle of the posterior margin of the merus there is a spine associated with a tuft of stiff bristles. The merus usually has a tuft of bristles at its posterior distal corner. There are one or two spinules on the dorsal distal border near to the posterior margin. The ventral distal border is armed with 1 or 2 spines. The ischium has a prominent ventral spine. The carpus is broadest proximally, tapering distally. The anterior dorsal margin is armed with 2 or more rarely, 3 large teeth, the most distal being situated at 0.5 to 0.7 of the length from the proximal end. Distal to these there are a number of small or minute teeth (2 to 5 on the large cheliped; 3 to 8 on the small). This dentition is best developed on the small cheliped of small individuals. In very large males the 2 large teeth may be reduced to 2 small notches and the distal denticulations may be lacking altogether on the large cheliped. The palm has dorsal and ventral keels, which are both denticulate. The outer surface has well developed median and sub-ventral keels, each of which is armed with a row of spines. The spines of the median keel are usually the smaller and the more irregularly arranged. This spine row contains 18 to 27 spines; but in very small individuals the number is less and may be as low as 11. The sub-ventral spine row contains 15 to 20 spines. In this row also the number may be less in very small individuals. In the large cheliped of very large males the palm is less compressed and its sculpturing is reduced. The spines on the median keel tend to become very small and obsolescent. The denticulation of the dorsal and ventral keels also becomes obsolescent.

The fingers are long and slender. The dactylus is from 0.6 to 0.75 times the length of the palm. They are very slightly twisted. Apart from this twist they are almost straight; but the tips are hooked. They do not gape. In both chelipeds the cutting edge lacks large teeth; but in the large cheliped, and sometimes also in the small one, there are numerous small denticles. The fixed finger of the small cheliped is not bifid at the tip; but it bears a tooth on its internal margin which may, especially in young individuals, be as far as $\frac{1}{4}$ of the length of the finger from the tip. In very large males by contrast this tooth may be as little as 0.15 of the length of the finger from the tip, so that the armament more closely approaches the condition characteristic of *P. latifrons* or *P. streptochiroides*. The inner margins of the fingers are somewhat excavated. They bear some hairs; but they are less hairy than those of *P. latifrons*. The dorsal margin of the dactylus has a denticulate or spinous keel, separated by a groove from a similar keel on its outer face.

The ventral margins of the propodi of the walking legs have a pair of spinules distally and a single spinule proximal to these. The dactyli of these legs have large accessory claw and 2 proximal spinules. The dorsal margins of these legs bear scattered hair tufts.

Comparison with Miers's specimens shows that the present species is closely allied to *P. spinulifrons* but quite distinct from it. The differences are best expressed as follows:—

P. gordoni	*P. spinulifrons.*
Spinules of front smaller with several small epibranchial spines.	Spinules of front much larger No epibranchial spines; at most 1 or 2 vestigial granuliform projections.
Gastric region with a very conspicuous pair of bristle tufts.	Gastric region without bristle tufts.
Chelipeds, carapace and legs more hairy; legs with dorsal bristle tufts.	Chelipeds, carapace and legs less hairy; legs without dorsal bristle tufts.
Sculpture of carapace more pronounced.	Sculpture of carapace less pronounced.
Anterior dorsal margin of carpus with 2 or, more rarely, 3 large teeth in the proximal half to two-thirds of its length and, except in very large males, with a number of much smaller teeth distal to these.	Anterior dorsal margin of carpus with 3 regularly spaced teeth at one-third, two-thirds and the full length of the margin and without accessory teeth.

These differences are constant. They cannot be attributed to the small size of Miers's specimens, since my series includes equally small specimens of *P. gordoni*. The first 5 differences are in themselves minor but, taken together, they add up to two distinct facies. The last difference is more important. Whilst the size and degree of development of teeth on the anterior margin of the carpus of the cheliped is a variable character in this group of species, the relative positions of such teeth, when present, remain constant. The different relative positions of the large teeth in these two species is of fundamental importance. Geographical distribution also supports the conclusion that the two species are distinct. *P. spinulifrons* is a Western North Pacific species found in Korea and Japan. Comparatively few species with this distribution also occur as centrally in the Indo-West Pacific as Singapore. Whilst the 2 forms are undoubtedly related present evidence indicates specific rather than subspecific distinction.

Miyake (1943: 121) synonymizes both of these forms with *P. serratifrons* Stimpson. I do not think that either synonym is valid. *P. spinulifrons* has well marked protogastric ridges, and the fixed finger does not show the deeply bifid form found in *P. serratifrons; P. gordoni* differs from *P. serratifrons* in many features, including: the detailed form and armament of the chelipeds; the well developed sculpturing of the dorsal surface of the carapace; the well developed protogastric ridges; the presence of hair tufts on the gastric region; and the presence of groups of epibranchial spines.

Distribution.—At present *P. gordoni* is only certainly known from Singapore and Hong Kong.

Ecology.—*P. gordoni* seems to be an essentially sub-littoral species though it has, on occasions, been collected in the littoral zone. It is possibly associated with growths of hydroids and similar organisms. It is not a coral frequenter.

Subgenus **Enosteoides** nov.

The name is chosen as being reminiscent of *Enosteus* a synonym of *Porcellana.*

In this subgenus there is a strong, but superficial, resemblance to the genus *Petrolisthes.* As in the subgenus *Porcellana* the fingers are not twisted out of the plane of the palm. In contrast to that subgenus, the lateral margins of the carapace are armed with spines posterior to the epibrancial angle. The front differs strikingly from the pattern found in the subgenera *Porcellana, Pisidia,* and *Porcellanella.* The lateral lobes are obsolescent and the general form approaches that characteristic of the genus *Polyonyx.* The first segment of the antennule is armed anteriorly with spines as in the subgenus *Pisidia.* The chelipeds resemble those of members of the genus *Petrolisthes.* The outer margin of the chela has a well developed hair fringe. The type is *Porcellana corallicola* Haswell, 1881. It is possible that *Polyonyx carinatus* Ortmann and *Porcellana ornata* Stimpson should also be placed here.

Porcellana (Enosteoides) corallicola Haswell Figure 3.

Porcellana corallicola Haswell, 1881, p. 759; 1882, p. 150; De Man, 1888, p. 220.

Petrolisthes ? corallicola Miers, 1884, p. 271, pl. 29, fig. C.

Pisidia corrallicola Johnson, 1963.

Local records.—Pulau Sudong, Singapore, ½ to 1 fm., crevices in large head of *Pavona* frondifera, 19-2-55, 1 ovigerous ♀, C.L. 3¾ mm.; Pulau Hantu, Singapore, crevices in coral heads at about low water spring tide level, 21-11-53, 1 ovigerous ♀, C.L. 5 mm.; Tanjong Gul, Singapore, 7-1-55, 1 ♂, C.L. 4¾ mm.

Notes.—This species bears a superficial resemblance to members of the genus *Petrolisthes,* especially in the form of the front. Miers doubtfully transferred it to that genus. The structure of the antennal region reveals that it is a true *Porcellana.*

The characteristic front is narrow, occupying less than ½ of the maximum carapace breadth. It is slightly depressed and distinctly concave in a transverse direction. It has a deep, median longitudinal groove, and 2 shallower lateral grooves. The lateral lobes are obsolescent. The median lobe is prominent. The whole border is occupied by regularly spaced spinules of somewhat variable size.

The carapace is hairy and the carapace regions are well defined. The protogastric regions are markedly elevated and each bears a prominent bristle tuft. The outer corner of the orbit is angular. There are several small spines between this angle and the spine in front of the cervical groove. There are no epibranchial spines. Posteriorly to the cervical groove the lateral margins are raised into a vertical ridge which bears a number of spines, 5 or 6 of which are of considerable size.

The 3rd joint of the antennal peduncle is armed with a blunt spinule.

The chelipeds differ slightly in size. The larger is somewhat stouter in build and the two differ slightly in the armament of the fingers. Otherwise the two chelipeds are essentially similar in form. The merus has a minutely denticulated, subtriangular, meral lobe. On its dorsal surface it has a transverse ridge bearing about 3 small spinules. The posterior border is hairy but unarmed. The distal dorsal border bears several small spinules. The distal ventral border bears 2 large spines. The carpus is 1.7 to 2.0 times as long as broad. It is rectangular in dorsal view. The posterior border is very hairy. It has a distal spine and about 6 other

small spines. The anterior border bears a considerable number of small, spine like, teeth, 2 or 3 of the most proximal of which are much larger than the rest. The dorsal face bears a flat-topped, longitudinal ridge. In small individuals this may be broken up into transverse squamae. The ventral border is irregular but bears no large spines.

The palm is slightly more than 1.5 times as long as broad. The dorsal margin is strongly keeled. The keel terminates distally in a prominent tooth. Proximal to this it is interrupted and proximal to this interruption there is a second, smaller tooth. The ventral margin is strongly keeled. It is densely clothed with a fringe of long hairs. The outer face bears a prominent, flat-topped, longitudinal keel. Ventral to this the palm is irregularly tuberculate. There is a subventral spine row just dorsal to the ventral margin. The dactylus is about 0.75 times as long as the palm. The fingers are stout and straight, with strongly hooked tips. The dactylus passes internally to the fixed finger. The fingers do not gape. The cutting edges are crenulated. The inner faces of the fingers are scarcely excavated and very sparsely hairy. The dorsal edge of the dactylus has a well developed, denticulate keel. The dactylus of the large chela has a large, triangular, basal tooth, which is absent from the small chela.

The dactyli of the walking legs are armed posteriorly with about 4 slender spinules. There is no accessory claw.

Distribution.—This species has previously been reported from the north-eastern portion of Australia, and from the Mergui archipelago.

Ecology.—This species is a coral commensal. It is the rarest of the coral inhabiting Porcellanidae so far encountered in Singapore waters, with the exception of *Petrolisthes lamarckii.*

Subgenus **Porcellanella** Stimpson

As I have indicated above *P. quadrilobata* Miers is in some respects transitional between the subgenera *Pisidia* and *Porcellanella.* Haig (1960: 197 & 205, pl. 15) has described the species *Porcellana* (*Porcellana*) *corbicola* which also shows some striking resemblances to members of the subgenus *Porcellanella.* In view of these transitions it seems to me to be impossible to maintain *Porcellanella* as a full genus.

The subgenus is characterized by: the very elongate carapace; the prominent front consisting of 3 broad and flat teeth, which are not denticulate; the absence of carapace spines; the long and relatively slender chela; the characteristic longitudinal crest of soft hairs which extends from the base of the fingers for some distance on to the inner face of the palm; and the very short dactyli of the walking legs, each of which is armed with 4 claws. The carapace is smooth, shining and hair free. It is feebly sculptured with short, transverse lines. It is slightly convex in a transverse direction.

The subgenus comprises 2 very closely related species: *P. triloba* White and *P. picta* Stimpson, which have often been considered to be synonymous. I have dealt with these and given Singapore records of the last elsewhere. *P. picta,* which alone occurs in Singapore, is found as a commensal of *Pteroeides* in shallow water.

Genus **Polyonyx** Stimpson

I have previously dealt at some length with this genus (Johnson, 1958). For a key to the species and species description reference should be made to that paper.

Polyonyx suluensis (Dana)

Porcellana suluensis Dana, 1852, p. 414; 1855, pl. 26; Miyake, 1942, p. 354, figs. 15 & 16.

Polyonyx denticulatus Paulson, 1875, p. 89, pl. 11, fig. 6; Johnson, 1958, p. 100, figs. 1A & 1B (synonymy).

Local records.—Singapore Regional Fisheries Research Station: B. 25, outer shoal, 6 fms, mud, shell and stone bottom, 1 ovigerous ♀, C.L. 3¾ mm.; B. 30, off Ajax Shaol, Singapore, about 40 fms, 1 damaged ovigerous ♀, C.L. about 4¼ mm.; B. 76, Burun Darat, Singapore, 1 damaged specimen, C.L. about 3 mm. Other collections: west of Pulau Pawai, Singapore, shell gravel ground, about 5 fms, 1 ovigerous ♀, C.L. 4½ mm.

General notes.—From the description and illustration it seems clear that *Porcellana suluensis* is really a *Polyonyx* and identical with the present species. This synonymy was overlooked in my previous paper. This species *P. suluensis* is closer to the genus *Porcellana* than are other species of *Polyonyx*.

Distribution.—*Polyonyx suluensis* is widely distributed in the Indo-West Pacific region. It ranges from the Suez Canal and Red Sea, and various localities in the western Indian Ocean through to Singapore, the Philippines, and Amboina.

Ecology.—This is a species of hard bottoms in shallow waters. It is known from depths of up to 40 fms. It is not associated with coral and does not appear to be a commensal.

Polyonyx telestophilus Johnson

Polyonyx telestophilus Johnson, 1958, p. 103, figs. 2A-2C.

Local records.—The type series comes from the Johore Shoals, Singapore. The collections of the Singapore Regional Fisheries Research Station contain: B. 45, south of Singapore, 14 fms, stone bottom, 1 ♂, C.L. 3¾ mm.; B. 60, Singapore Straits, 21–22 fms, *Telesto*, etc. present, hard bottom, 2 ♂♂, C.L. of each 3 mm.

General notes.—In form this species resembles *P. obesulus* but it belongs to the *denticulatus* group and so can easily be distinguished from that species. The relatively high body, the pale colouration, and the habitat distinguish it at once from other members of the *denticulatus* group.

Distribution.—At present this species is only known from the above Singapore localities.

Ecology.—An offshore form of shallow waters, *P. telestophilus* is a strict commensal of the alcyonarian *Telesto*. Its very unusual colouration of ivory and pale pink matches that of its host.

Polyonyx biunguiculatus Dana

Porcellana biunguiculata Dana, 1852, p. 411; 1855, pl. 26, fig. 1.

Polyonyx biunguiculatus Nobili, 1901, p. 7; Johnson, 1958, p. 105, figs. 3A–3C.

Local records.—Bedford-Lanchester collection: New Harbour (=Keppel Harbour), 5 to 10 fms, Singapore, 2 very small ♀♀; 'Pelawan' reef, Singapore, 7 to 10 fms, 1 ovigerous ♀ (I have not been able to identify this locality). Singapore Regional Fisheries Research Station: B. 30, off Ajax shoal, Singapore, about 40 fms, 1 ♂, C.L. 4½ mm.

Distribution.—This species is widely distributed but apparently rare in the Indo-West Pacific region. It is known from various localities from the Red Sea and the Seychelles through to Palau, Amboina, and northern Australia. The specimens which Kalk (1958: 73) records as inhabiting the tubes of a sand-dwelling

polychaetes at Inhaca Island were identified by Barnard. This fact and the habitat show that they are representative of *P.* cf. *biunguiculatus* Barnard. This is a member of the *sinensis* group and quite distinct from the present species (Johnson, 1958: 100).

Ecology.—P. biunguiculatus is an offshore form of hard bottoms. There is no evidence of commensalism. It appears to be rare in Singapore waters.

Polyonyx obesulus (White) Figure 4.

Porcellana obesula White, 1847, p. 130 (nomen nudum).

Polyonyx obesulus Miers, 1884, p. 272, pl. 29, fig. D; Johnson, 1958, p. 108, figs. 4A–4C.

Local records.—Bedford-Lanchester collection: New Harbour (Keppel Harbour), 5 to 10 fms, 1 ovigerous ♀; off Pasir Panjang, Singapore, 25-1-99, 6 fms, 1 large ♂; 'Pelawan' reef, Singapore, 1 small ♂ (I have not been able to identify this locality); off Singapore, 'Torfieldia' ground, 2 fms, 2 ovigerous ♀♀. Singapore Regional Fisheries Research Station: B. 31, Ajax/Sultan Shoal, Singapore, 9 fms, stony bottom, 1 ovigerous ♀, C.L. 6 mm.; B. 45, Outer Shoal, Singapore, 6 fms, mud and stone bottom, 1 ovigerous ♀, C.L. 6 mm.; B. 50, off Tanjong Rhu, Singapore, 2 fms, muddy bottom, 1 ovigerous ♀, C.L. 6¾ mm.; B. 54, off Pulau Damar Laut, Singapore, 5 to 8 fms, muddy bottom, 1 ovigerous ♀, C.L. 7½ mm., and 1 non-ovigerous ♀, C.L. 5½ mm.

Other collections.—Selat Sinki, Singapore, off Pulau Bukum, about 5 fms, coral brash bottom, 14-4-52, 1 ♂, C.L. 5 mm., and 1 non-ovigerous ♀, C.L. 4½ mm.; between Singapore and the southern islands, shell gravel bottom, 21-10-53, 1 ♂, C.L. 4 mm., and 1 non-ovigerous ♀, C.L. 3¾ mm.; between Pulau Tembakul and Pulau Tembakul and Pulau Sakijang Pelepah, Singapore, 2 to 3 fms, coral heads on submerged reef, 5-1-52, 1 ovigerous ♀, C.L. 3¾ mm.; Raffles Light, Singapore, coll. Patton, coral heads just below low water spring tide level, 1959, several specimens; P. Sudong, Singapore, various occasions, on reef flat, several specimens; P. Hantu, Singapore, crevices in coral rock at reef edge, 16-7-57, 1 ovigerous ♀, C.L. 4½ mm.; Nanas channel, north of Pulau Ubin, Singapore, amongst hydroid growth on fishing stakes, 28-3-53, 1♀, C.L. 3¼ mm.; Tanjong Gul, Singapore, coll. Patton, crevices in coral heads at about low water spring tide level, 1959, several specimens; up to C.L. 5 mm. (this specimen an ovigerous ♀); Johore Shoals, Singapore, crinoid ground, about 10 fms, in large sponge (*Suberites inconstans*), 1 ♂, C.L. 6¾ mm., and 1 non-ovigerous ♀, C.L. 4 mm.

This species are previously recorded from Singapore by Walker.

Distribution.—P. obesulus is widely distributed in the Indo-West Pacific region, occurring from the Persian Gulf through to the Kadjice-Sima islands, New Guinea, and N.E. Australia. Within this area it is usually more abundant than either of its two closest relatives.

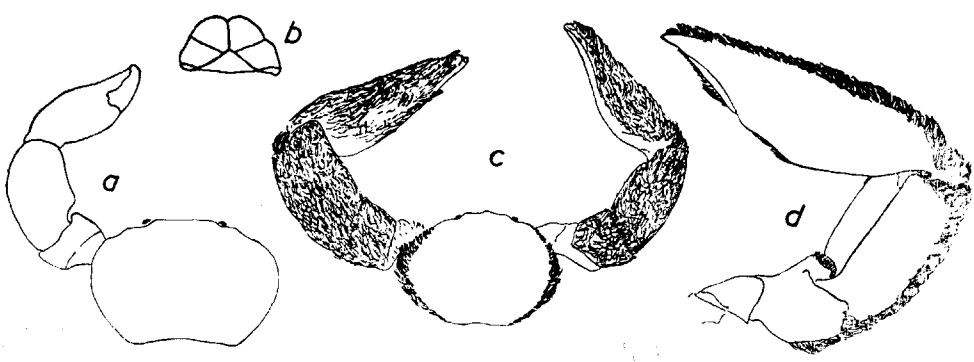

Figure 4. *a-b Polyonyx obesulus* (White), ovigerous ♀, Singapore; *a* dorsal view of carapace and larger cheliped; *b* telson. *c-d Polyonyx cometes* Walker. type ♂, Singapore; *c* dorsal view of carapace and chelipeds; *d* ventral view of large cheliped.

Ecology.—This is by far the commonest member of its genus at Singapore. Though sometimes found on beaches at extreme low water spring tide level, it is essentially an offshore form. There it is probably the commonest of Singapore porcellanids. It appears to be a crevice dwelling form and is likely to be found wherever there are available crevices. It is otherwise a tolerant species which is found on all sorts of bottom. Though not a true commensal it is sometimes found as a facultative commensal of corals and sponges.

Polyonyx triunguiculatus Zehntner

Polyonyx biunguiculatus Miers, 1884, p. 559.
non *Porcellana biunguiculata* Dana, 1852.
Porcellana (Polyonyx) biunguiculatus De Man, 1887, p. 421.
Polyonyx triunguiculatus Zehntner, 1894, p. 185; Johnson, 1958, p. 110 (synonymy).
Polyonyx acutifrons De Man, 1896, p. 385, pl. 32, fig. 49.

Local records.—The only Singapore specimen which I have seen is an ovigerous ♀ from Raffles Light, in the Bedford-Lanchester collection.

Distribution.—*P. triunguiculatus* is widely distributed in the Indo-West Pacific region. Its range extends from the Gulf of Suez and the Western Indian Ocean through to Amboina.

Ecology.—General records indicate that this is essentially an offshore form. It is sometimes found associated with coral, though it is not restricted to living coral. It is by no means a commensal species. It appears to be very rare in the Singapore area.

Polyonyx cometes Walker Figure 4.

Polyonyx cometes Walker, 1887, p. 116, pl. 9, figs. 1–3; Johnson, 1958, p. 114.
Porcellana (Polyonyx) euphrosyne De Man, 1888, p. 221, pl. 15, figs. 1-3.

Local records.—The only Singapore specimen in existence is a single specimen in the dry collections of the British Museum (Natural History). This bears the label 84.3. Singapore. Reference to the museum record books shows that the specimen was collected by Archer. It thus appears to be Walker's type specimen, which I had previously reported as being lost, though there is no entry to this effect in the museum records. This is the specimen shown in figure 4.

Distribution.—*P. cometes* is a very rare species which has only been collected twice, once at Singapore and once in the Mergui archipelago.

Ecology.—It seems probable that the species is a commensal of *Brechites* (= *Aspergillum*) but I have failed to rediscover it in association with the few living specimens of that genus which I have been able to examine.

SIZE AND FORM IN THE PORCELLANIDAE

Singapore porcellanids show a considerable number of parallel trends associated with increase in individual size. The most important of these are: (a) a tendency towards increased relative carapace breadth (females only); (b) increasing assymetry of the chelipeds especially in males, an assymetry which, at least in males, is combined with marked positive heterogonic growth especially of the larger cheliped (figs. 5 and 6); reduction in number and size of the teeth on the inner margin of the carpus of the chelipeds, commonly associated with the development of one or more prominent lobes on this margin; (d) reduction and simplification of the general sculpturing of the chelipeds; (e) reduction of the denticulation of keels on the palm and fingers of the chelipeds; (g) a tendency towards increased gape of the fingers.

Trends (a) and (b) depend on overall size of the individual. The remaining trends depend rather on the size of the individual cheliped.

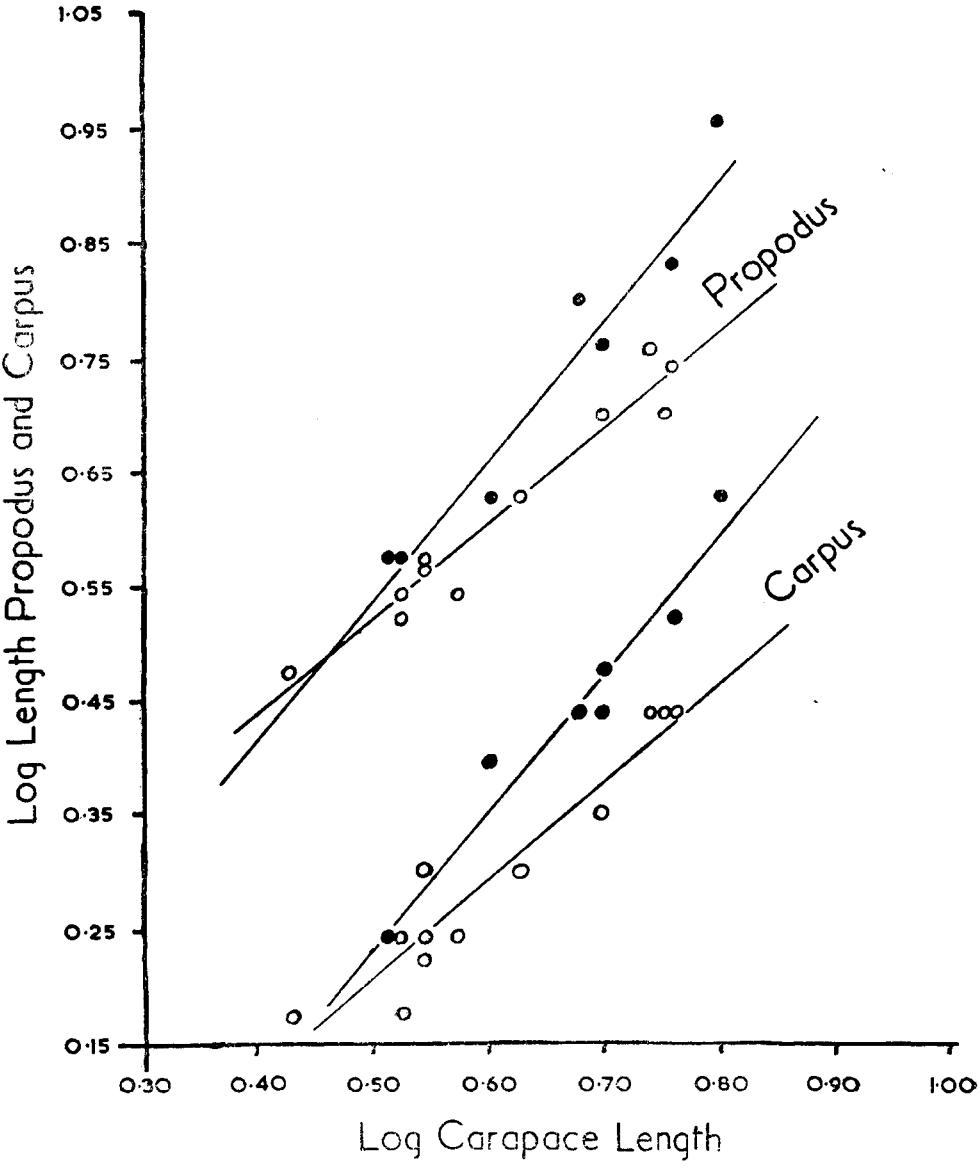

Figure 5. *Porcellana* (*Pisidia*) *latifrons*, relative growth of small cheliped in individuals from Singapore.

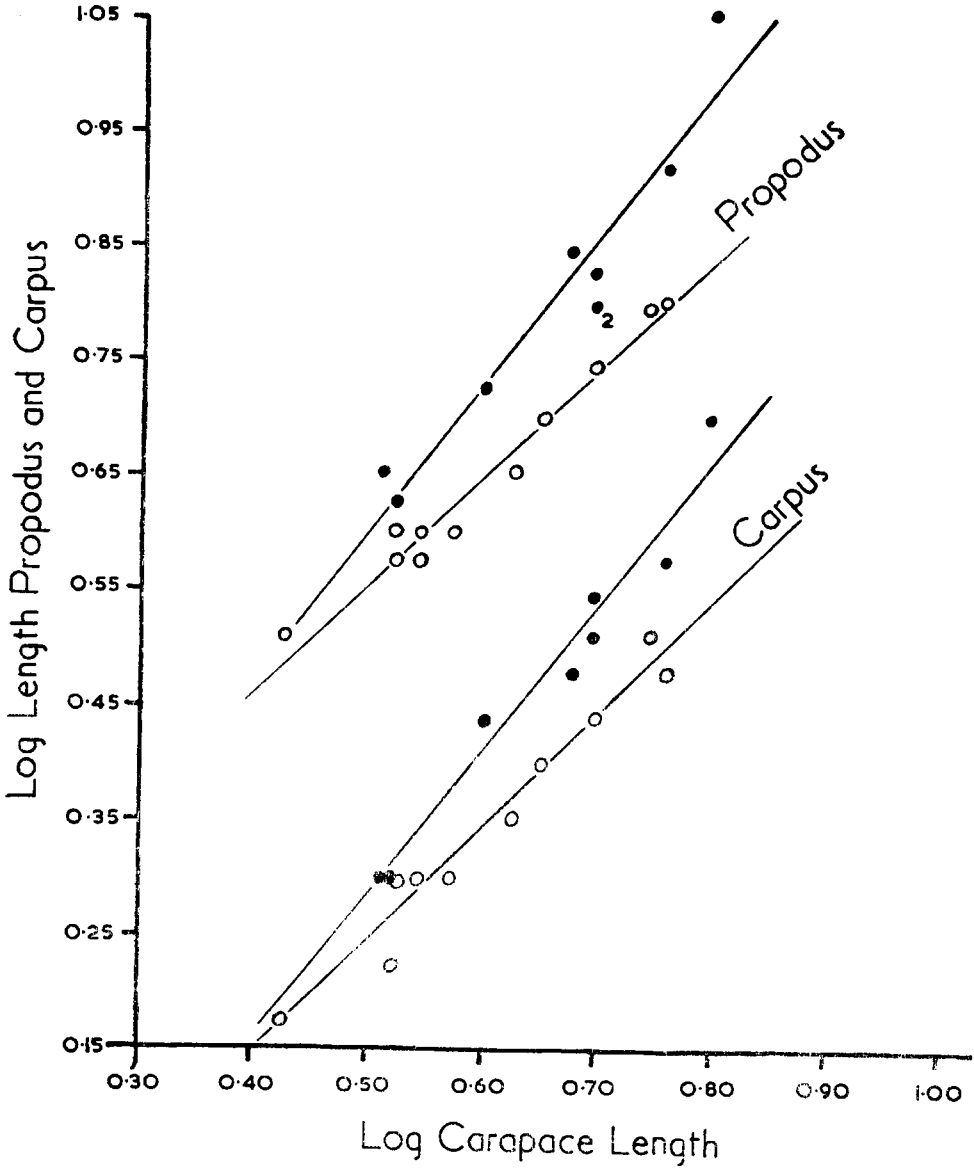

Figure 6. *Porcellana* (*Pisidia*) *latifrons*, relative growth of large cheliped in individuals from Singapore.

In connection with trend (f) it should be noted that in the smaller size ranges the number, as opposed to the size, of these spines may actually increase with increasing size. Ultimately the increasing size may result in such a reduction of the size of the spines that they completely disappear. Even then there is no *progressive* decrease in number.

Rather surprisingly the spination of the posterior margin of the merus and the carpus of the chelipeds does not appear to be affected by this general tendency towards reduction in spinosity with increasing size.

The Singapore porcellanids always show some assymetry of the chelipeds. In *Porcellana latifrons* left-handed individuals predominate and there is some evidence for a similar tendency in the genus *Polyonyx*.

GENERAL COMMENTS ON ECOLOGY

The majority of Singapore Galatheidea are rather strictly zoned in respect to the littoral region. The upper littoral, above mean tide mark, is inhabited only by species of *Petrolisthes*, which may be very abundant in suitable areas. Three species: *P. hastatus; P. teres;* and *P. kranjiensis* are found in this zone. Their detailed ecological requirements are quite distinct, so that they are seldom found together. Both *P. hastatus* and *P. teres* are usually found under stones and rocks; but the former prefers cleaner and less silted sites than those occupied by the latter. *P. kranjiensis* has been found under silted stones; but it is characteristically associated with burrows in vertical or near vertical scarps of stiff mud at the seaward edge of mangrove swamps.

Several species occur around low water spring tide mark and in the immediate sub-littoral region. These include: *Galathea spinosorotris; Petrolisthes* cf. *militaris Pachycheles sculptus; Porcellana latifrons; P. corallicola; P. picta;* and *Polyonyx obesulus. Porcellana streptochiroides* has also been collected in this zone; but in circumstances which suggest that the occurrence was accidental. *P. gordoni* and *Polyonyx triunguiculatus* have each been taken once in this zone. For these two species there is insufficient evidence to establish whether or not this is a normal habitat.

Of these species *Pachycheles sculptus* and *Polyonyx obesulus* both appear to be more abundant in offshore waters. *Porcellana latifrons* also occurs in offshore waters; but its centre of maximum abundance appears to be in the present zone. Of the remainder *P. picta* is a commensal of *Pteroeides. Galathea spinosorostris, Pachycheles sculptus,* and *Porcellana corallicola* appear to be coral commensals. The remainder are crevice dwellers. All may occur in facultative association with living coral.

The remaining species: *Galathea elegans; G. aculeata; G. longimanoides; Porcellana quadrilobata; Polyonyx denticulatus; P. telestophilus; P. biunguiculatus;* and *P. cometes,* are confined to offshore waters. It seems probable that *Porcellana streptochiroides; P. gordoni;* and *Polyonyx triunguiculatus* should be included in this offshore group, despite their occasional occurrence in littoral habitats. *Pachycheles sculptus* and *Polyonyx obesulus* are as much members of this group as of the onshore group. *Porcellana latifrons* though perhaps primarily an onshore form is frequent in offshore habitats.

The galatheidean fauna of the offshore waters is thus slightly more varied than the littoral fauna. Some 13 species have been collected in littoral habitats; but 3 do not properly belong there, and only 6 are not found also in the offshore zone. By contrast 14 species have been recorded from offshore habitats and a 15th is to be expected there on the basis of its occurrence in other areas. Of these 9 have not been found in the littoral zone.

Most of the offshore species of the galatheidea are associated with hard or clean bottoms. This is to be expected in view of the crevice-dwelling habits of the group. However, *Porcellana streptochiroides* is found on muddy or sandy bottoms, whilst *Polyonyx obesulus* appears to be largely indifferent to the overall character of the bottom, provided that some sort of crevices are available. The commensal species follow the distribution of their hosts.

The Galatheidea show strong tendencies towards commensalism; but these tendencies appear to have been exagerrated by some workers. Amongst Singapore species the following are probably safely regarded as commensals:—

of corals: *Galathea spinosorostris; Petrolisthes* cf. *militaris; Pachycheles sculptus;* and *Porcellana corallicola.*

of alcyonarians: *Porcellana picta; Polyonyx telestophilus;* and *Pseduoporcellanella manoliensis.*

of annelids: *Polyonyx cometes.*

of crinoids: *Galathea elegans* and *G. longimanoides.*

The commensalism of the last two species is possibly somewhat less well established than that of the others, in Singapore waters.

In the Galatheidea the association between colour pattern and mode of life is perhaps not very clear. It is worthy of note that the 2 crinoid commensals show colour patterns reminiscent of those shown by crinoid commensals from other groups of animals. In the Porcellanidae the species seem to be dominantly cryptically coloured. This is probably true even of the brightly coloured forms such as *Petrolisthes* cf. *militaris; Porcellana picta;* and *Polyonyx telestophilus.* Even the striking colour pattern of *Pachycheles sculptus* is best regarded as an example of disruptive colouration.

The species of *Petrolisthes* are interesting in combining a cryptic colouration, visible dorsally, with bright, presumably spodeictic colours, which are only visible from in front. It seems possible that these colour patterns are of use in species recognition. They certainly provide an effective means whereby the zoologist can distinguish the species.

In contrast with other groups in which a large proportion of the species are coral dwelling or commensal, the Porcellanidae have small eggs, produced in great numbers. Porcellanid zooeae are not uncommon in Singapore plankton; but it has not yet proved possible to identify any of these with known adults. Ovigerous females can be collected all the year round, which suggests that any seasonal variations in reproductive activity are not well marked. There are slight variations in abundance of porcellanid zooeae in the Singapore plankton (Wickstead, 1961: fig. 38c) but these may well depend on water movements, rather than on variations in reproductive activity.

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