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THE HOLOTHURIANS OF THE GENUS STICHOPUS.

BY HUBERT LYMAN CLARK.

WITH TWO PLATES.

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No. 3.— *The Holothurians of the genus Stichopus.*

By Hubert Lyman Clark.

The holothurians of the genus Stichopus are among the most conspicuous of the animals inhabiting weedy and sandy bottoms in shallow water throughout the tropics. Under normal conditions, their form and color are not unattractive and are occasionally handsome, but removal from the water, or confinement in a vessel with but little sea-water, results very soon in an extraordinary disintegration of the body-wall which soon reduces the creature to a most repulsive mass of slime. The body-wall contains so large a percentage of water that specimens even when most carefully killed undergo a very great shrinkage, often amounting to 50% or even more. If care is not taken in killing, the animal not only shrinks but becomes more or less badly distorted, and consequently most museum material gives little indication of either form or size in life. Naturally therefore the identification of specimens is not a simple task and it is not strange that with the passage of time a large number of specific names has been used in connection with Stichopus.

The difficulty of identifying species has been much increased by the attempt to use such characters as the number of tentacles, the number and distribution of pedicels, the size and arrangement of tubercles, and even the color as diagnostic factors. In life, each is of great importance and even in preserved material each may be of value but unfortunately the exceptional shrinkage and distortion to which preserved material is liable, and the alterations of color caused by alcohol, make such characters dangerous guides. Furthermore growth-changes are now known to produce some striking differences and it is necessary therefore to assign different degrees of value to the various characters in different species. The following evaluation will be of service.

Size.— All the known species reach a considerable size when adult. The two new species are unquestionably based on young specimens, and hence their size when adult remains to be determined. All of the well-known species reach a length of 200–300 mm. in life with a width of 50–100 mm. But many individuals exceed these dimensions and *variegatus* is often much bigger. Semper records specimens of that species from the Philippines 900 mm. long and 200 mm. wide. The largest Stichopus I have measured was one at Mer, Murray

Islands, which was about 725 mm. long by 125 mm. wide. In its preserved condition this specimen is now much flattened, 350 mm. long and 110 mm. wide. It is a safe assumption that any Stichopus under 100 mm. long in life is still immature; hence preserved material under 50 mm. and most of that under 70 mm. is unquestionably young.

Color.— While none of the species are brilliantly colored, pigmentation of the skin is usually very extensive. The pigment is commonly dark brown, approaching black, dark purple, dark green, and rusty-red or light reddish brown. Possibly black pigment occurs but usually the dark colors when carefully examined are seen to indicate brown, purple, or green. Unicolored individuals are common in many species but as a rule most of the species are speckled, spotted or mottled and variegated individuals with surprising combination of shades are often seen. In few species is the coloration sufficiently uniform and constant to be of value as a specific character, but in the type-species (*chloronotus*) it is very distinctive. On the other hand, in *badionotus* it seems to be of no value whatever, some individuals being uniformly light-colored, others uniformly dark and a large majority showing some combination of light and dark shades. As yet we are quite ignorant of the causes or significance of this diversity. Apparently individuals when very young, just after metamorphosis, have no pigment but this soon begins to develop, at first of light color and in more or less scattered patches. Subsequently the dark pigment develops, at first in specks or spots; it increases in most cases to form blotches and ultimately, very often completely fills the skin, giving rise to uniformly dark coloration. Light colored individuals would thus be the young, spotted and blotched the adults, and uniformly dark, the senescent. But unfortunately the problem is complicated by the entire lack of dark pigment in many cases, or by its very erratic development, and by the important fact that there is no close correlation between size and age in echinoderms. Until the life-history of some species has been completely worked out from the metamorphosis to the attainment of maximum size, we cannot interpret with confidence the diversity of color shown by certain species. But it is certain that little reliance can be placed on color or color-pattern as a specific character unless a large number of individuals of very diverse sizes have been examined in life. It is almost hopeless to draw any conclusions from the color of preserved specimens for neither alcohol nor formalin hold the natural colors satisfactorily. The distinctive colors such as red, green, blue, and yellow are particularly fugacious.

Body-form.— The body-form is quite characteristic. The ventral

surface is flat, with a broad median ambulacrum and on each side an ambulacrum half as wide. The dorsal surface is elevated but only slightly arched, the sides of the body being nearly vertical. The vertical diameter of the animal is usually about four fifths of the horizontally transverse. As a rule, the margin between the side-wall and the ventral surface is much thickened and is provided with conspicuous papillae. This marked differentiation of the upper and lower surfaces is evident even in very small individuals and is a convenient recognition-mark for the genus.

Ambulacral Appendages.— There are typically twenty equal tentacles surrounding the mouth and there is no adequate ground for thinking that the normal adult of any species has more or fewer. But specimens with only eighteen or nineteen tentacles are frequent and those with 15, 16, 17, 21, or 22 are not unknown. It seems probable that most specimens with fewer than twenty tentacles are not fully mature, but they may be, like those with more than twenty, simply individual variants. At any rate, the number of tentacles is typically the same in all the valid species, and is of no value for distinguishing species.

The papillae occur primarily along the dorsal ambulacra and especially along the lateroventral margin of the body. The latter appear first and may be the only conspicuous papillae present. In many cases, the ambulacral papillae are all well marked but the interambulacra are free from them, while in other cases, there are numerous papillae on the interambulacral regions. Papillae are particularly liable to shrinkage, contraction, and even disappearance in alcohol and hence it is often very difficult to decide what the normal condition was. There is little doubt moreover that both the number and the prominence of papillae varies with age, increasing to maturity and perhaps decreasing again in senescence. At any rate, it seems clear that as a rule the papillae can not be relied on for specific characters.

The pedicels increase in number with age and are of little taxonomic importance. In very young individuals, there is a double row of pedicels along the midventral line and a single row down each side. Later these series widen, become more densely crowded, and may even merge, so that the whole ventral surface is closely covered with pedicels. Meanwhile scattered pedicels occur on the dorsal surface and these increase in number with age, but never form definite series. Specific differences do not seem to be associated with the pedicels.

Calcareous Particles.— The body-wall is always abundantly supplied with calcareous particles and these furnish the most reliable char-

acters by which the species may be distinguished. The presence of *tables* is characteristic of all the species *sensu strictu* but these tables undergo notable changes with the growth of the individual. We do not yet know whether each table undergoes growth-changes or whether tables of very young individuals are resorbed and replaced by others. There is even a possibility that the tables of youth are lost by the sloughing off of bits of epidermis. In senescence, the tables undergo changes which seem to be unquestionably the results of resorption. The growth-changes are not yet well worked out, but those which are revealed by the tables have been well studied and set forth by Mitsukuri (1897, Ann. zool. Japon, **1**, pt. 1, 2) as they occur in *S. japonicus*. In most species, the tables are symmetrical, with a moderate, squarish truncate spire and a circular, smooth disk, but high spires, irregular disks, and even much distorted tables characterize certain species. The size of the tables is of importance, furnishing a reliable specific character in many cases.

In senescent individuals of *japonicus*, the tables are replaced by small, irregular, perforated plates. In no other species have such plates been found and there is no doubt that they represent, in *japonicus*, the disks of the resorbed tables.

In four species, true *buttons*, so characteristic of many species of Holothuria, occur. These buttons show great diversity in size and number of perforations and furnish a good specific character.

In half a dozen species, *rosettes*, or small rods several times dichotomously branched but with short, thick, curved branches, are more or less abundant. Their presence or absence may not be a good specific character, for there is some ground for belief that *simulans* which has rosettes is identical with *mollis*, which lacks them. But as yet we need evidence on the matter.

In all species of Stichopus *s. s.*, supporting *rods* occur in pedicels, papillae, and tentacles but there is little that is distinctive about them. On the other hand their absence in Thelenota and Astichopus is very characteristic. In Thelenota, minute, slender dichotomously branched *rods*, not at all like rosettes, occur in the body-wall, and their form and proportions afford a good specific character.

In many species, characteristic C-shaped bodies occur in the body-wall below the epidermis or at least beneath the layer of tables. The size of these Cs may furnish a good specific character for while there is some diversity even in one individual, it is not very great. In Astichopus, the C-shaped bodies are much stouter than in any species of Stichopus and are very commonly transformed into Os or Ss or

even into irregular rods. There seems to be more or less individual diversity in the number of C-shaped bodies. Often they are absent from one preparation of the body-wall, and present in another. Their entire absence therefore can only be determined with great care. If present at all, they will usually be found near the bases of pedicels and papillae.

In Thelenota and Astichopus, the epidermis is full of very minute spherical or biscuit-shaped granules which may be grouped, or form a uniform layer.

Terminal plates are present in the pedicels and in many of the papillae. Anal teeth are quite lacking, nor is there any indication of calcified papillae around the anus.

Calcareous Ring.—Although stress has been laid by some writers on the form of the calcareous ring as a distinctive character, I am unable to make any satisfactory use of it. It undergoes considerable increase in bulk and no little change in form in the assumption of full maturity and apparently these changes continue during senescence. In young individuals there is little difference between the dorsal and ventral-sides of the ring, but a marked difference occurs in most large specimens owing to the much greater development of the dorsal side.

Polian Vesicles.— The number of Polian vesicles is not a safe guide to specific differences, for while the number is commonly 1–3, there may be as many as six. In Thelenota and Astichopus, the Polian vesicles are very long and are branched, a most unusual condition among holothurians. In the holotype of *Stichopus paradoxus*, two of the vesicles had short lateral branches near the base.

Madreporic Canal.— Apparently the madreporic canal is always single, embedded in the dorsal mesentery, but with the madreporite itself more or less free.

Gonads.— The presence of a tuft of gonads on each side of the dorsal mesentery has long been regarded as the chief distinguishing feature. But there is need of further study on living (or fresh) material, to ascertain what the age or seasonal differences may be. Examination of all the specimens of Thelenota available lead me to think that the gonads are unequally developed in that genus and that those of one side may, at least sometimes, be wanting.

Cuvier's Organs.— Cuvier's organs are wanting in all species of Stichopus, Thelenota, and Astichopus, with the possible exception of *S. paradoxus*. In Lampert's description of this species, he says that Cuvier's organs, brown in color and 7 cm. and more in length are present. Both the color and size given suggest that some other organs

are here confused with Cuvier's organs, which in all authenticated cases are white or whitish and in preserved material are rarely more than 3 cm. long.

It is evident then that the calcareous particles are the only structures upon which much reliance can be placed in differentiating the species although the body-form and the gonads afford characters of real value in distinguishing the genus, and the Polian vesicles may also furnish a generic character.

Stichopus was established by Brandt in 1835, with three species. Of these *chloronotus* was the only member of a subgenus Perideris, while *cinerascens* and *leucospilota* were put in a subgenus Gymnochirota. Subsequent writers have agreed that the two Gymnochirotas are members of Holothuria in a broad sense, so that *chloronotus* is universally accepted as the type of Stichopus. This is most fortunate for *chloronotus* is a very well-known species with very definite characters including a fairly constant coloration (in life) and hence it is possible to define the genus in a satisfactory way.

Stichopus.

Brandt, 1835. Prod. Anim., p. 250.

Genotype:— *Stichopus (Perideris) chloronotos* Brandt, *Loc. cit.*

Aspidochirote holothurians with flattened ventral surface, markedly distinct from dorsal; pedicels more or less fully covering ventral side; dorsal surface with tubercles or papillae, at least along lateral margins; tentacles typically twenty; gonads in a tuft on each side of dorsal mesentery; no Cuvier's organs; no anal teeth or noticeable papillae around cloacal opening; numerous calcareous tables in epidermis; Polian vesicles few, unbranched; madreporic canal single.

Defined in this way the genus is easily recognized and it becomes possible to determine what its component species are. Examination of the literature shows that no fewer than eighty-one specific or varietal names have been used in connection with Stichopus, but these fall readily into four classes:— unidentifiable forms, holothurians not belonging in the genus as defined above, synonyms, and valid species. Each of these groups may be considered by itself.

Unidentifiable Forms.

Most of the names in the following list date back more than eighty years and have never been adequately diagnosed or associated with

any well-known holothurians. There is therefore little to be said about them.

albifasciatus Selenka, 1867, p. 320 = *Holothuria albifasciata* Quoy and Gaimard, 1834, p. 132. Tonga. Not identifiable from available data but collecting at Tonga might reveal the holothurian described by Quoy and Gaimard.

cinerascens Grube, 1840, p. 36. Mediterranean Sea. Obviously not *cinerascens* Brandt but absolutely unidentifiable.

fuscus Ludwig, 1875, p. 97. Patagonia. Although Ludwig gives a good description the absence of any indication of the size of the calcareous tables makes it impossible to identify the species or determine its relation to *mollis, simulans, et al.* The locality "Patagonia" seems highly improbable for a true Stichopus.

lucifugus Brandt, 1835, p. 273 = *Holothuria lucifuga* Quoy and Gaimard, 1834, p. 134. Carteret, Solomon Islands. It is possible that this is *Holothuria pulchella* Selenka but satisfactory determination of the point is out of the question.

lutea Saville Kent, 1893, p. 235. Great Barrier Reef, Australia. While the name may refer to specimens of *horrens*, it is more likely to be synonymous with *variegatus*.

luteus Brandt, 1835, p. 273 = *Holothuria lutea* Quoy and Gaimard, 1834, p. 130. Tonga. Quite unrecognizable. Selenka's comments (1868, p. 117) on *lucifugus* have been applied by Lampert (1885, p. 109) to *luteus*, by some mistake.

maculatus Lampert, 1885, p. 109 = *Sporadipus maculatus* Grube, 1840, p. 37. Mediterranean Sea. Quite unrecognizable.

monotuberculatus Selenka, 1867, p. 320 = *Holothuria monotuberculata* Quoy and Gaimard, 1834, p. 131. Mauritius. Said by Selenka (1868, p. 117) to be identical with *H. lutea* Quoy and Gaimard but that throws no light on the matter.

sitchaensis Ludwig, 1881, p. 590 = *Diploperideris sitchaensis* Brandt, 1835, p. 252. Sitka, Alaska. In spite of Ludwig's description, the lack of measurements of the calcareous particles prevents the identification of the species. Collecting at Sitka may solve the problem.

unituberculatus Brandt, 1835, p. 273 = *Holothuria monotuberculata* Quoy and Gaimard, 1834, p. 131. Mauritius. Quite unidentifiable.

Species erroneously included in STICHOPUS.

In listing here the holothurians which have been referred to Stichopus but which in my judgment are not properly members of that genus, I shall not attempt to state to what genus they should be referred unless such reference has been made by some earlier writer. Nor shall I ordinarily give the reasons which have led to the removal from Stichopus, but occasionally the decision is sufficiently novel to warrant a few words of explanation.

ananas Semper, 1868, p. 75 = *Trepang ananas* Jäger, 1833, p. 24. Celebes. Brandt (1835, p. 253) put this species in a subgenus, Thelenota, of Holothuria. This subgenus has never been recognized nor has any type been designated for it. In view of its well-marked peculiarities (see p. 48), *ananas* had best be removed from Stichopus. The name Thelenota is thus available for it and I designate it as the type of that genus. The appropriateness of the name is obvious.

challengeri Théel, 1886, p. 163. Between Marion Island and Kerguelen, 550 fms. A synallactine.

cinerascens Brandt, 1835, p. 251. Bonin Islands. Ludwig (1881, p. 597) says this is the species of Holothuria named *pulchella* by Selenka, 1867. Brandt's name must therefore replace the more familiar but later one.

flammeus Brandt, 1835, p. 273 = *Holothuria flammea* Quoy and Gaimard, 1834, p. 117. Yanikoro, St. Cruz Islands. Selenka (1868, p. 117) has shown that this name is a synonym of *Holothuria monocaria* (Lesson).

gyrifer Selenka, 1867, p. 319. Australia. Hawaiian Islands. Zanzibar. Selenka subsequently (1868, p. 117) placed this name as a synonym of *H. monocaria* Lesson.

kefersteinii Selenka, 1867, p. 318. Acapulco. Examination of type-material shows this is a Holothuria.

leucospilota Brandt, 1835, p. 251. Lagoon at Ualau, Kusaie, Caroline Islands. Ludwig (1881, p. 595) says this is the species of Holothuria named *vagabunda* by Selenka, 1867. Brandt's name must therefore replace the better known but much later one.

moseleyi Théel, 1886, p. 165. Off southern Chile, 175–345 fms. A synallactine.

multifidus Sluiter, 1910, p. 334. Tortugas, Florida. This remarkable species is best treated as type of a new genus, Astichopus (see p. 48).

natans M. Sars, 1867, p. 58. Norway: Lofoten, Bergen, Hardanger. A synallactine.

nigripunctatus Augustin, 1908, p. 7. Sagami Bay, Japan, 100 fms. Closely allied to *tremulus*, *q. v.* (p. 47).

pallens Koehler, 1895, p. 486. Bay of Biscay, 723 fms. A synallactine.

patagonicus Perrier, 1905, p. 11 = *Holothuria* (?) *patagonica* Perrier, 1904, p. 13. Santa Cruz, Patagonia. A Holothuria.

pentagonus Brandt, 1835, p. 273 = *Holothuria pentagona* Quoy and Gaimard, 1834, p. 135. Sydney, N. S. W. A Pentacta.

pourtalesii Théel, 1886a, p. 4. St. Kitts to Barbados, 208–734 fms. A synallactine.

richardi Herouard, 1896, p. 165. Gulf of Gascogne, 195 fms. A synallactine, probably.

rigidus Selenka, 1867, p. 317. Zanzibar, Society Islands, Florida. Examination of Selenka's types in the M. C. Z. collection brings out the interesting fact that while both belong in Holothuria (*sensu latu*), the one from Florida is quite distinct from that from the Society Islands. There is no

specimen from Zanzibar in the M. C. Z. I restrict the name *rigidus* to the form from the Society Islands, which is easily recognized by the small rather delicate tables; these have eight vertical rods in the spire as Selenka says and there is a single peripheral circle of small holes in the smooth disk. The buttons have 5–8 pairs of holes and relatively small knobs. Selenka figures a button but it is evidently from the Florida specimen, (*Holothuria hypamma*), also found in the tropical Pacific and which I have described (Carnegie inst. Publ., 214, 1921, p. 177). Neither of the specimens at hand has the "large, roundish ellipsoids" described by Selenka. These probably were from the Zanzibar specimen, which would thus seem to represent a third species. Under the circumstances it is hard to see how Selenka could have written: "Die exemplare von so verschiedenen Fundplätzen waren bei der genauesten Vergleichung specifisch nicht auseinander zu halten." And none of the specimens are the least like Stichopus!

sagamiensis Augustin, 1908, p. 8. Sagami Bay, Japan, 100 fms. A synallactine.

sagamiensis var. *alba* Augustin, 1908, p. 10. Sagami Bay, Japan, 100 fms. A synallactine.

selenkae Barrois, 1882, p. 47. Concarneau, France. A Holothuria, probably *forskahli* Delle Chiaje.

tizardi Théel, 1882, p. 696, 59 of reprint. Faeroe Channel, 530–555 fms. A synallactine.

torvus Théel, 1886, p. 164. Off Chile, 1375 fms. A synallactine.

tremulus Gunnerus, 1767, p. 119. West coast of Scandinavia. Both the locality and the depth indicate this holothurian is not a true Stichopus, and its apparent resemblance to species of that group is a very interesting illustration of parallelism. With *nigripunctatus* of Japanese waters it may form a distinct genus, but the material at my disposal is not sufficient to warrant diagnosis. In any case however it may be called PARASTICHOPUS, and *tremulus* may be designated the genotype.

troschelii J. Müller, 1854, p. 87 (of reprint). Celebes. When published, this was only a *nomen nudum* but Lampert (1885, p. 89) examined the specimen in Berlin labeled "Holothuria. Holoth. sp. Troschelii Müller. Celebes, Schönlein. 1182. anat. Mus.," apparently the holotype, and finds it is identical with *Holothuria gräffei* Semper.

tuberculosus Brandt, 1835, p. 273 = *Holothuria tuberculosa* Quoy and Gaimard, 1834, p. 131. Tonga. A Pentacta.

Inspection of the above list shows that the synallactine holothurians have been the most frequently referred in error to Stichopus; of the twenty-five names given, ten undoubtedly refer to synallactines. Of the remaining fifteen, nine refer to species of Holothuria, *sens. lat.*, and two to species of Pentacta. The other four seem to need new genera for which Thelenota, Astichopus, and Parastichopus are suggested.

The last, containing the species *tremulus* and *nigripunctatus*, is probably nearer to Synallactes than to Stichopus, but the other two are closely related to this last-mentioned genus. The three genera may be distinguished as follows:

Tables, or at least perforated plates representing the disks of partly resorbed tables, abundant; minute granules wanting or very rare; pedicels with supporting rods; polian vessels simple or in one case with few short branches ..... *Stichopus*

No tables or perforated plates but innumerable minute granules; no supporting rods in pedicels; polian vessels long and branched.

Granules not in groups, accompanied by dichotomously branched, slender rods ..... *Thelenota*

Granules in groups, accompanied by small C, S or O shaped, or irregularly curved rods ..... *Astichopus*

Thelenota.

Brandt, 1835. Prod. Anim., p. 253.

Genotype:— *Trepang ananas* Jäger, 1833. De Hol., p. 24; pl. 3, fig. 1.

The holothurian for which this genus is recognized is one of the most conspicuous and best known species of the East Indian region, and is one of the most important of the commercial forms known as *bêche-de-mer*. It is of interest to report a second, and very distinct species from the Murray Islands, Torres Strait.

Astichopus, gen. nov.

Genotype:— *Stichopus multifidus* Sluiter, 1910. Zool. jahrb. Suppl., **11**, heft 2, p. 334, fig. A, a, b.

This interesting holothurian was hitherto known only from the holotype, taken in the southwest channel at the Tortugas, by Hartmeyer in 1907. But there is material in the M. C. Z. collection from Port Antonio, Jamaica, collected by myself in 1897 and 1909, which adds considerably to our knowledge. The individuals seen in 1897 were noted particularly because of their large size and relatively rapid movements. Of course, their actual movement was very slow but it was perceptible which cannot be said of other large holothurians occurring at Port Antonio. Unfortunately no measurements were made in life and the only one preserved was too large for any available container and consequently was cut into pieces, only five of which were preserved. One of these is the anterior end, including the cal-

careous ring and the extraordinary Polian vesicles, and another is the posterior end. These fragments indicate that this specimen was at least 450 mm. long in life and my recollection of the individuals seen confirms that estimate. In life, the most notable feature of the coloration was the white lower surface; in particular the pedicels, conspicuous for size and great number, were very white. The upper surface was dark, more or less mottled with blackish and shades of brown. In alcohol, the fragments are all light gray without markings. These big holothurians were conspicuous in about six feet of water on sandy bottom south of Navy Island, at Port Antonio.

In 1909, on eel-grass bottom, in water 2–3 ft. deep, south of Navy Island, I found a much smaller specimen which was narcotized and preserved whole and is in fine condition. It measures now about 220 mm. in length and 40–50 mm. in width; it is thus about the same size as Sluiter's holotype. In color, the lower surface is sharply set off from the upper, as it is yellowish white, while the back and sides are dark brown with numerous small blotches and spots of fawn-color. This is as different from the uniform light gray of the older material as it is from the spotted "clear yellowish-rose" of the holotype. But this color-difference in preserved material is of little importance, since my field label shows that the present specimen, in life, was "black and white." Moreover the label adds: "Same species as big ones noted in '97 at same place." Examination of the calcareous particles shows that this opinion was correct and the identity with Sluiter's specimen from the Tortugas seems to admit of no doubt, although I did not find a specimen at the Tortugas in 1917.

In its external appearance, Astichopus is intermediate between Stichopus and Holothuria, for while it has the flat ventral surface of the former, thickly covered with pedicels, and sharply distinct from the dorsal side, the entire absence of papillae and tubercles gives the specimens, especially after preservation in alcohol, a very Holothuria-like appearance. The genus is obviously the representative in the West Indies of Thelenota, but is not at all like *T. ananas* in its general appearance. On the other hand, it is superficially very much like the new species of Thelenota from the Murray Islands, but is easily distinguished by the characteristic differences in the calcareous particles.

Synonyms.

Owing to the absence of any critical work on the species which have been added to Stichopus since 1867, the same form, owing to the great

diversities of color and of development of papillae, has again and again had a new name bestowed upon it. The following list presents all of these names which I have been able to find. It is by no means impossible that I have been too drastic in assigning specific names to this list, but it seems very important that we should make a new start by recognizing only the unquestionably valid forms.

acanthomela, Zoological record, 1900, Echin., p. 78 = *xanthomela* Heilprin, 1888. Typographical error.

albofasciatus Brandt, 1835, p. 273 = *albifasciatus* Quoy and Gaimard, 1834. Either a slip of the pen, an emendation, or a typographical error.

armatus Semper, 1868, p. 75, Japan = *Holothuria armata* Selenka, 1867, p. 330 ≒ *japonicus* Selenka, 1867.

assimilis Bell, 1883, p. 62, Angola = *badionotus* Selenka.?

cylindricus Haacke, 1880, p. 47, Mauritius = *chloronotus* Brandt, according to Ludwig, 1883.

depressus Augustin, 1908, p. 11, Sagami Bay, Japan = *Parastichopus nigripunctatus* (Augustin), according to Oshima, 1915.

diaboli Heilprin, 1888, p. 312, Bermuda = *badionotus* Selenka.

ecalcarea Östergren, 1897, p. 9, Finmark = *Holothuria ecalcarea* M. Sars, 1858, p. 170 = *Parastichopus tremulus* (Gunnerus).

errans Ludwig, 1875, p. 97, Barbados = *badionotus* Selenka.

fuscus Pearson, 1903, p. 204, Ceylon = *chloronotus* Brandt. This name was suggested only for a variety of *chloronotus* but as the characters of that variety are the color and tuberculation of two alcoholic specimens, they do not seem adequate.

godeffroyi Semper, 1868, p. 75, Samoa = *horrens* Selenka.

godeffroyi var. *b* Semper, 1868, p. 247, Samoa = *horrens* Selenka.

griegi Östergren, 1897, p. 4, Norway = *Parastichopus tremulus* (Gunnerus).

haytiensis Semper, 1868, p. 75, Hayti = *badionotus* Selenka.

hirotai Mitsukuri, 1912, p. 161, Ogasawara Islands = *variegatus* Semper.

laevis, Zoological Record, 1888, Echino., p. 12 = *levis* Sluiter. Apparently an emendation.

levis Sluiter, 1887, p. 198, Western end of Java Sea = *variegatus* Semper.

maculatus Greef, 1882, p. 158 (13 of reprint) Rolas Island, Saõ Thomé = *badionotus* Selenka.?

moebii Semper, 1868, p. 246, West Indies = *badionotus* Selenka.

naso Haacke, 1880, p. 46, Mauritius = *variegatus* Semper, and not *naso* Semper, according to Ludwig, 1883.

oshimae Mitsukuri, 1912, p. 171, Oshima Islands, Japan = *variegatus* Semper.

owstoni Mitsukuri, 1912, p. 175, Sagami Bay, Japan = *Parastichopus nigripunctatus* (Augustin), according to Ohshima, 1915.

panimensis Parker, 1921, p. 205, La Jolla, Cal. = *parvimensis* H. L. Clark. A slip of the pen.

pygmaeus Semper 1868, p. 75, Fiji, Samoa = *horrens* Selenka, juv.

roseus Augustin, 1908, p. 13, Sagami Bay, Japan = *japonicus* Selenka, according to Ohshima, 1915.
simultans Erwe, 1913, p. 388 = *simulans* Dendy and Hindle. A slip of the pen.
sordidus Théel, 1886, p. 167, New Zealand = *mollis* (Hutton).
tropicalis Fisher, 1907, p. 676, Hawaiian Islands = *horrens* Selenka.
typicus Théel, 1886, p. 161, Japan = *japonicus* Selenka, as a variety of which it was proposed.
vastus Sluiter, 1887, p. 198, Batavia Bay, Java = *variegatus* Semper.
xanthomela Heilprin, 1888, p. 313, Bermuda = *badionotus* Selenka.

The valid Species.

Having disposed of a large proportion of the names hitherto associated with Stichopus, we come to the still considerable group representing valid forms. In order that the characters which distinguish these species from each other may be set forth clearly, the following key is offered.

Key.

No buttons among the calcareous deposits.
No rosettes among the calcareous deposits.
Tables present.
Tables more or less symmetrical, usually with regular spires; disk margins smooth.
Spire of tables more or less expanded and open at top, with one or two cross-bars.
C-shaped bodies moderate or small usually less than 75 μ in length, or even wanting altogether.
Tables and C-shaped bodies, or tables alone, present.
C-shaped bodies usually plentiful but sometimes scarce.
Disks of tables, with four to eight holes, about 30 μ in diameter; C-shaped bodies about 40 μ long..... *chloronotus*
Disks of tables, with a circle of peripheral holes, about 60μ in diameter; C-shaped bodies about 60 μ long..... *badionotus*
C-shaped bodies wanting.
Disks of tables square or squarish, 55–60 μ in diameter, with four large holes and 4 somewhat smaller ones at corners ..... *mollis*
Disks more rounded, a little smaller, with the four corner holes much smaller than the others..... *anapinusus*
Tables and irregular perforated plates; no C-shaped bodies... *japonicus*
C-shaped bodies very large, 100–150 μ in length..... *macroparentheses*

Spires slightly tapered to the more or less solid top, with three or four cross-bars; C-shaped bodies wanting.

Spires rather solid with numerous teeth all over distal half... *regalis*

Spires less solid with few teeth..... *japonicus* juv.

Tables asymmetrical with more or less irregular or deformed spires, and often spiny margins..... *ludwigi*

Tables wanting, replaced by numerous small irregular perforated plates, apparently remains of table-disks..... *japonicus*, senescent

Rosettes present.

Large tables with heavy, smooth, conical spires, present in dorsal papillae..... *horrens*

No big tables with smooth, conical spires.

Large, irregular, asymmetrical tables present at least near bases of dorsal papillae..... *ecnomius*

No such big, irregular tables.

Tables 20–45 μ in disk-diameter; disks nearly circular or a little irregular, with a circle of small peripheral holes, often incomplete; rosettes with branches somewhat cylindrical not expanded at tip.

Body as wide anteriorly as posteriorly, covered with numerous small tubercles and papillae, none of which are $\frac{1}{6}$ as high as width of body; C-shaped bodies three to five times diameter of table-disks.

Middle of back with scattered tubercles as large as those on sides; coloration in various shades of brown, unicolor, or mottled..... *variegatus*

Middle of back with no large tubercles; coloration gray..... *variegatus* var. *herrmanni*

Body much narrower anteriorly than posteriorly, with large tuberculous papillae, $\frac{1}{3}$ as high as width of body; C-shaped bodies seven times diameter of table-disks..... *naso*

Tables over 50 μ in disk-diameter; disks squarish with eight holes; rosettes with ends of branches expanded..... *simulans*

Buttons present, with tables.

C-shaped deposits wanting; diameter of top of spire much less than disk; buttons over 75 μ in length.

Calcareous particles large, tables with disks 120–170 μ across, and buttons 165–190 μ long..... *johnsoni*

Calcareous particles much smaller.

Tables with disks 50–100 μ across; buttons large up to 165 μ in length *californicus*

Tables with disks about 45 μ across; buttons about 90 μ long..... *parvimensis*

C-shaped deposits present; top of spire equal to or exceeding disk-diameter; buttons small, only 45–50 μ in length..... *paradoxus*

Stichopus chloronotus.

Plate 2, fig. 1–10.

Stichopus (*Perideris*) *chloronotos* Brandt, 1835, p. 250. Lugunor and Guam.
Stichopus chloronotus Selenka, 1867, p. 315, pl. 17, fig. 20–24; 18, fig. 25.
Stichopus cylindricus Haacke, 1880, p. 47. Mauritius.
Stichopus chloronotus var. *fuscus* Pearson, 1903, p. 204. Ceylon.

It is a pity that the very characteristic color of this species is so difficult to preserve, for in life, *chloronotus* is one of the most easily recognized of holothurians. But alcoholic material quickly assumes that unattractive yellow-brown tint which has been appropriately called "museum-color." Different specimens show different shades of this color, it is true, some being light and some dark, some mottled or clouded, some unicolor, but there is rarely any indication of the original shade left.[1] It therefore seems futile to attempt to recognize the variety which Pearson (*loc. cit.*) called *fuscus*, unless study of living *chloronotus* around Ceylon shows that such a form is recognizable in life. Even then the name *fuscus* cannot be used, since there is already a *Stichopus fuscus* Ludwig. Besides color, Pearson bases his proposed variety on the laterodorsal series of tubercles being single instead of double and the C-shaped deposits being very rare indeed. Since these are both characters subject to great individual diversity, I do not think they warrant recognition of a variety.

Ludwig has examined the type of Haacke's *Stichopus cylindricus* and reports (1883) that it is simply *chloronotus*. This would indicate that Haacke was misled by a distortion of the body-form, probably due to poor preservation, and it emphasizes the point that species, in this genus certainly, cannot be characterized by features so easily affected by methods and conditions of preservation.

In life *chloronotus* reaches a length of over 300 mm., but preserved specimens do not often exceed 200. A living specimen 250 mm. long is usually about 65 mm. wide and 40 mm. high, though of course, as in all holothurians, these dimensions depend greatly on the activity or quiescence of the animal. The color is deep green; in sunshine the green is obvious but in poor light many large specimens look black. The distal portion of the big dorsal papillae, which may be 10 mm. or

[1] Selenka (1867) says the color is "olivengrun bis olivenbraun," and his observations were made only on preserved material, but he may have simply inferred the green color from the name.

more high and 4 or 5 mm. in diameter, is blackish, with the extreme tip brown-orange. The pedicels are dark gray, while the tentacles are whitish with dark gray tips. Mitsukuri (1912) speaks of a *bluish* tinge in the specimens at the Riu Kiu Islands which he describes as "deep black." While it is not impossible that the northern specimens lack the green color of those in Torres Strait, the matter needs confirmation. The figure given by Saville Kent (1893) shows the color of Australian specimens very well.

The calcareous spicules of *chloronotus* were correctly described and figured by Selenka (*loc. cit.*) but it seems desirable to refigure them magnified to the same scale as those of the other species figured in this report. The tables (Plate 2, fig. 1–3) are very small only 30–40 μ across the disks and with about eight teeth at the top of the spire. There are typically four large holes in the disk, each one beneath a side of the spire, and very commonly there is a much smaller hole opposite each corner of the spire, but one, two or three of these small holes are commonly wanting. The number of teeth at the top of the spire is often 10–12 and may be as many as 16. The C-shaped bodies are small, only 30–40 μ long. They show much diversity in shape (fig. 4–9), not infrequently being malformed, with an extra branch or with one end reversed, thus becoming S-shaped (fig. 10). They also show much diversity in abundance; usually they are very abundant, but they may be very few and scattered and hence hard to find. The supporting rods of the pedicels are well figured by Selenka.

Although the specimens at hand show considerable diversity of size, I fail to find any growth-changes. In the smallest the calcareous particles are essentially the same as in the largest, but there are no available specimens of either very large or very small size.

In Torres Strait, *chloronotus* is one of the characteristic animals of the reef-flats, where these are well covered by eel-grass (Posidonia). It does not occur under rock-fragments or among corals. It is extremely sluggish in its movements and seems to fear no enemies. Commensal annelids (Gastrolepidia) of the same green color as their host live on the back among the tubercles and are not easily dislodged therefrom.

The geographical range of *chloronotus* is extensive, from Mauritius to Hawaii, from Amami-Oshima, in the Riu Kius, on the north to the central Barrier Reef region of Australia on the south. It is not known from the Society or Hervey Islands. There are fifteen specimens in the M. C. Z., from the Hawaiian, Caroline, Fiji, and Samoan Islands, Torres Strait, Mauritius, and Mozambique. Neither Fisher nor I,

in our collecting at the Hawaiian Islands, saw *chloronotus* and there may be an error in the label of the single specimen in the M. C. Z., which is said to have been taken at Honolulu in 1874 by W. H. Jones.

Stichopus badionotus.

Plate 2, fig. 11–18.

Stichopus badionotus Selenka, 1867, p. 316. Florida. (Acapulco?).
Stichopus haytiensis Semper, 1868, p. 75, pl. 30, fig. 5. Hayti.
Stichopus moebii Semper, 1868, p. 246, pl. 40, fig. 11. West Indies.
Stichopus errans Ludwig, 1875, p. 97. Barbados.
?Stichopus maculatus Greef, 1882, p. 158 (13 of reprint). Rolas Island, Saõ Thomé.
?Stichopus assimilis Bell, 1883, p. 62. Angola.
Stichopus diaboli Heilprin, 1888, p. 312. Bermuda.
Stichopus xanthomela Heilprin, 1888, p. 313. Bermuda.
Stichopus acanthomela Zool. Rec., 1900, Echin. p. 78. *Err. typ.*

It is with no little hesitation that I unite under a single name all the species of Stichopus that have been described from the Panamic, West Indian, and West African regions, but I am quite unable after prolonged study to find any tangible characters by which they may be distinguished. This study has been based not only on the scores of specimens in the M. C. Z. collection but upon hundreds of living specimens examined at Bermuda, the Tortugas, Montego Bay, Port Antonio, and Port Royal, Jamaica. Experience has convinced me that color is absolutely unreliable as a distinguishing character and body-texture, form, and tuberculation seem to be equally hopeless. The calcareous particles too undergo growth-changes which lead into difficulties.

It may be frankly admitted that there is still much to be learned about the common West Indian Stichopus and it is by no means impossible that further knowledge will make the recognition of more than one species necessary. My only contention is that at present it is impossible to do this in any satisfactory way. I have seen no specimens from the African coast or its neighboring islands, but there is nothing in the descriptions of either Greef or Bell that would not apply to some specimens of the common species of Jamaica. To be sure Bell mentions and figures "flattened, reticulated bars" but as Théel (1886) has pointed out these seem to be the usual supporting rods of papillae or pedicels. If such bars actually occur in the body-wall proper, that would furnish a perfectly distinctive character for *assimilis*.

It is quite unusual for echinoderms on the west coast of Central America and Mexico to be identical with those of the West Indies, but I have examined with great care twelve specimens of Stichopus from Acapulco and the west coast of Central or South America (exact locality ?) labeled *badionotus*, including Selenka's cotypes, and cannot find any character or combination of characters which will separate them from the West Indian specimens. To be sure, Selenka says the C-shaped particles are entirely lacking in *badionotus*, but in this he was mistaken. They occur in all of our specimens, including his cotypes.

There are fifty-five specimens in the M. C. Z. which seem to be *badionotus*. They come from Acapulco, west coast of South America, Jamaica, Yucatan Bank, Florida, the Tortugas, Bermuda, and Tobago. They range in length from 20 to about 220 mm. and the diversity of color even in their dingy, alcoholic condition is equally great. In life, individuals over 300 mm. long are common, and such specimens are 60–75 mm. wide and 50–60 mm. high.

In 1902, while at Port Henderson, Jamaica, I examined 141 specimens of Stichopus, tabulating the color and color-patterns to see if I could find any correlation between color and size or habitat. No correlation was detected but there was some light thrown on the development of the diversity of coloration. The matter may be stated tentatively like this:— The typical and apparently the original coloration is buff with blackish or dark brown spots or blotches; this coloration is often persistent and characterizes the form which Heilprin (1888), finding at Bermuda, called *xanthomela*. From the blotched form, there are three lines of development; one in the direction of uniform blackness (*diaboli* Heilprin) through increased pigmentation; a second in the direction of brown, olive, or purple, with few blotches or markings of buff, yellowish or white, through increased pigmentation accompanied by alteration in the density or even in the color of the pigment; and third, in the direction of uniformly brownish yellow individuals through decreased pigmentation, at least so far as the dark pigment is concerned. The individuals studied were grouped in sixteen categories but even then there were many doubtful cases. The color of the tentacles ranges from almost white to almost black but is commonly yellowish. At Port Royal, Jamaica, where Stichopus is very common, uniformly dark yellowish brown individuals, and those that are buff with large dark brown blotches are about equal in number and together comprise about half the total. Another quarter is made up of those which are dark brown with yellowish spots and those which

are buff spotted with brown. Unicolored individuals of a dark shade are rare. At Bermuda, however, conditions are conspicuously reversed and the uniformly blackish individuals are very much more common than the mottled forms.

In regard to the number of tentacles my observations in Jamaica yielded some interesting results. Of eighty-two individuals, whose tentacles were accurately counted, thirty-five had twenty, fifteen had nineteen and eighteen had eighteen; thus more than 83% had 18–20 tentacles. Of the others one had but twelve, six had sixteen, five had seventeen, while only two had twenty-one. That the typical number of tentacles for the adult is twenty is indicated by the fact that of sixty individuals which from size and condition of gonads were considered adult, 50% had that number and 90% had 18–21, while of twenty-two obviously immature specimens, only 23% had twenty and only 72% had 18–20, none having twenty-one.

In regard to the tuberculation of the body, large warts or tubercles along the sides, at the boundary of the ventral surface, are generally present but in 141 specimens these warts were wanting in more than 25%. Small warts or papillae are almost always present in life usually in some numbers but these may be quite lost in alcoholic material. There is so much diversity even in life that no stress whatever can be placed on this feature as a specific character. The same is true of the pedicels, for while there is no doubt a steady increase in the number of pedicels, at least up to maturity, the rate of increase is undoubtedly a matter of individual diversity and hence in some specimens the original serial arrangement may still be evident at maturity while in others it is totally obliterated.

The calcareous particles in *badionotus* comprise tables and C-shaped bodies. The tables (Plate **2**, fig. 11–13) resemble those of *chloronotus* but are larger and more fully developed. Typically, the disk is nearly circular, about 40–50 μ across and has a peripheral circle of holes. The top of the spire usually carries 12–16 teeth. The C-shaped bodies are much larger than in *chloronotus* but vary a good deal in size, a typical one (Plate **2**, fig. 16) is about 60 μ long.

Examination of the material in the M. C. Z. has brought out some points in the matter of growth-changes which are most interesting and suggest the importance of a much more thorough study of the matter. In one of Selenka's types of *badionotus*, from Acapulco, I found the tables like those figured as typical for the species (Plate **2**, fig. 11–13) but in a second specimen of about the same size, the disks of the tables had virtually disappeared (Plate **2**, fig. 14), although in no other

respects were the specimen or the deposits peculiar. In the specimen from Florida which Selenka made a cotype of *badionotus*, the tables show still further absorption (Plate **2**, fig. 15) so that the rods of what was the spire are not connected at either top or bottom. As Selenka makes no reference to these peculiarities of the tables, my first impression was that in the fifty years which have elapsed since he examined the material, the tables had been partly dissolved, but a careful study fails to show any evidence of corrosion and I believe we have here a remarkable case of senescence similar to what Mitsukuri has shown (1897) occurs in *S. japonicus*. But it must be of rare occurrence in *badionotus* for I have found no other cases. It will also be noted that resorption in *japonicus* causes the spire to disappear leaving only the disk, while in *badionotus* the disk disappears leaving only the spire.

The youngest, or at least the smallest Stichopus I have seen from the West Indian region (except the type of *S. œconomius, q. v.*) is a specimen, now about 20 mm. long taken at the Tortugas in 1917. My field-label reads: "Dredged in 4–5 fms. In cranny of sponge-covered rock fragment. Almost transparent holothurian (probably young Stichopus) 60–70 mm. long by 12–15 mm. wide. Gradually contracted with accompanying concentration of color and opacity in $MgSO_4$ but shrunk still more in alcohol. June 14, 1917." In this specimen the tables of the body-wall are very different from those seen in any other Stichopus but it seems probable that it shows the first step in the calcareous particles of *badionotus*. This idea would not have occurred to me, had I not already discovered a similar stage in *horrens*, confirming Mitsukuri's observations on *japonicus*. The tables in this little specimen from the Tortugas have the disk (Plate **2**, fig. 18) about 75 μ across and perforated with about fifteen holes. The spire (Plate **2**, fig. 17) is about 50 μ high, conical and toothed at the top. No C-shaped bodies were found with these tables.

It is evident that resorption might alter the spire of these juvenile tables into those of the adult tables but it is incredible that the disk could by resorption alone become the disk of an adult table. Of course, resorption associated with replacement of the lime could accomplish all the changes necessary, and this may be the actual process, but if such were the case why are not more of the intermediate conditions found? It seems more likely that the youthful tables disappear by being thrown off like wandering cells and particles of excreta and that their places are taken by newly formed tables of the adult type. This is, however, little more than speculation and only emphasizes how much investigation is needed into the problem of growth-changes.

Granting that all the Stichopus occurring in the West Indian region (excepting *economius*) represent one species, the habits of *badionotus*, and its younger stages are as follows:— After metamorphosis, it settles down into some rock-cranny and there among sponges, worm-tubes, and ascidians, it leads a well-sheltered life. Up to the time it is 80–100 mm. long, it continues to live among rocks, but after that it lives more in the open and after it is 125–150 mm. long, it seldom if ever seeks the shelter of rocks. When it first settles down it is a colorless, transparent, somewhat gelatinous creature and the development of pigment takes place slowly. By the time it is 75–100 mm. long, the pigment in the body-wall has developed sufficiently to give the animal a very distinct coloration but it is still translucent and gelatinous. At this stage, young individuals are not rare on the under side of rock-fragments, or in their larger crannies. Their bright colors are noticeable; chestnut-brown ground color, with black circles around the papillae and yellow tips to papillae and pedicels. The translucent appearance and this characteristic coloration are misleading and it is difficult to believe that the individuals possessing them are only the young of *badionotus*. At a somewhat older stage, but while still dwelling among rocks and coral-fragments, the translucent appearance disappears, and buff and brown or blackish become the dominant colors. The dorsal and especially the lateral papillae are very well developed at this stage and are often prettily marked with a dark spiral line which runs from base to tip. This coloration is quite distinctive but the calcareous particles agree so completely with those of the larger individuals of the open, weedy flats that I am forced to believe these handsome individuals are only subadults of *badionotus*. After a length of 150–200 mm. is attained, *badionotus* lives altogether on the open sandy or weedy flats near shore, or at least where the water is less than three fathoms deep. Its occurrence at depths as great as ten fathoms is not, however, extraordinary. It is exceedingly sluggish in its movements and apparently is quite free from the attacks of enemies.

It is a curious fact that whereas five individuals were found at Tobago by our party in 1916, no large ones living out in the open were seen. All were in the semitranslucent, subadult stage, living under or among rocks. One specimen collected by Mr. John W. Mills, on Buccoo Reef, April 5, was so strikingly different from any other I have seen, it seems justifiable to give it a special name, although the calcareous deposits do not warrant considering it specifically different from the others. In life the tentacles, pedicels, and median ventral

surface were gray, but the entire back and sides were bright carmine-red, a most unusual shade in a shallow-water holothurian. I name this striking form *Stichopus badionotus* var. *phoenius* (Greek, φοίνιος = blood-red). In its present condition in alcohol (M. C. Z. 1,182) it is easily distinguished from the other specimens from Tobago, by the uniformly reddish brown color.

Stichopus mollis.

Holothuria mollis Hutton, 1872, p. 15. New Zealand.
Holothuria (*?Stichopus*) *mollis* Hutton, 1879, p. 308.
Holothuria robsoni Hutton, 1879, p. 308. New Zealand.
Stichopus sordidus Théel, 1886, p. 167, pl. 8, fig. 3. Queen Charlotte Sound, New Zealand.
Stichopus mollis Dendy, 1897, p. 46, pl. 7, fig. 73–82.
Stichopus mollis Dendy and Hindle, 1907, p. 96, pl. 12, fig. 12.

This is the characteristic species of central and southern New Zealand; it occurs also on the southern coast of New South Wales (Eden) and is common on the shores of Victoria (Westernport, Geelong, Altona Bay); Albany Bay, southern West Australia is the westernmost locality from which it is recorded. It is a small species; alcoholic material runs from 70 to 140 mm. in length. Hutton says it is "about 6 inches in length and $1\frac{1}{2}$ in breadth," and he adds that the color" is yellowish, largely mottled with brown above and in a lesser degree, below." Dendy says the color is brown, or brown and white, or white alone, but preserved specimens are often very dark brown, almost black, and they may have a purple or violet tinge. Nothing is recorded of its habits save that it lives in rock-pools and that the young occur near low water mark while the adults prefer deeper water. Joshua (1914) gives some notes on the occurrence of this species at Port Phillip Bay, Victoria, where it is common.

Stichopus anapinusus.

Holothuria anapinusa Lampert, 1885, p. 241, fig. 7. Sörres Island.
Stichopus anapinusus Sluiter, 1901, p. 30.

The type-locality for this East Indian species, given by Lampert as "Sörres Island," I have failed to locate on any available map, but Sluiter gives two definite East Indian localities where the Siboga took specimens. Nothing is recorded of habits, size, or color in life. Preserved specimens are small, 100–135 mm. long, and uniformly brown.

The resemblance of *anapinusus* to *mollis* is so very close that the published descriptions give no warrant for considering them distinct. But without material for comparison and as neither Lampert or Sluiter considered *mollis* at all, it seems best to keep them apart on geographical grounds (three thousand miles separates their known habitats) until actual comparison of specimens can be made. I do not expect that the distinction made in the key (p. 51) will prove to be the real difference between the species, if different they are.

Stichopus japonicus.

Stichopus japonicus Selenka, 1867, p. 318, pl. 18, fig. 33–36. Japan.
Holothuria armata Selenka, 1867, p. 330, pl.18, fig. 66. Hakodadi, Japan.
Stichopus japonicus var. *typicus* Théel, 1886, p. 161, pl. 7, fig. 2.
Stichopus roseus Augustin, 1908, p. 13. Sagami Bay, Japan.

So fully has this species been treated by Mitsukuri (1897, 1912) that there is no occasion for discussing it in detail. The growth-changes as revealed by the spicules, and the diversity shown in tuberculation is very remarkable and demand further investigation on living material. Further studies on the correlation between color and habitat are also desirable. The species is a large one, reaching a length of 430 mm. in life, and a breadth of 70–95 mm. The known geographical range is from Kagoshima, northward throughout Japanese waters, and along the eastern coast of Korea. Théel (1886) records two specimens from Hong Kong but Mitsukuri doubts the reliability of the record. Mitsukuri lists specimens from Vladivostock and even from Saghalien. The record of *japonicus* from Sitka, Alaska, (H. L. Clark, 1902) is based on a very young specimen, and is not to be relied on as evidence of the occurrence of the Japanese species on the American coast. As nothing is yet known of the growth-changes in *californicus*, which occurs at Sitka, it is not at all improbable that this small individual was the young of that form.

Stichopus macroparentheses,[1] sp. nov.

Plate 1, fig. 1–7.

Length about 50 mm.; diameter about 13 mm. Body moderately arched above (in life), flat ventrally. Tentacles nineteen. Papillae few, small, irregularly arranged along dorsolateral ambulacra. Ven-

[1] μακρος = long + παρένθεσις = parenthesis, in reference to the remarkably long C-shaped or parenthesis-shaped bodies.

tral margin fairly distinct but not marked by large papillae. Pedicels fairly numerous, in a conspicuous median series (8–10 pedicels wide) and in a somewhat less marked lateral series (4 or 5 pedicels wide) on each side of ventral surface; scattered pedicels also occur on the interambulacral areas. Mouth and anus both ventral in position. Calcareous ring well developed but not heavy; radial pieces with a conspicuous, rounded posterior notch; interradial pieces with posterior margin scarcely concave. Polian vesicle single. Madreporic canal single. Gonads in a very well-developed tuft, of more or less branched tubules, on each side of dorsal mesentery.

Calcareous particles present in several forms. Pedicels and papillae with well-developed terminal plates and numerous supporting rods of relatively large size. Epidermis full of closely crowded tables of moderate or small size; disk of the smaller ones with four symmetrical holes (Plate **1**, fig. 1); in larger ones, there are four smaller holes distal to and alternating with these, and often additional holes are present, their number ranging from one (Plate **1**, fig. 2) to twelve, very rarely more; disks range from 30 to 60 μ but the great majority are less than 50 μ. Spires of tables with one cross-bar, rather low down (Plate **1**, fig. 3); height of spire about four fifths diameter of disk; crown of spire with few, low, often minute teeth (Plate **1**, fig. 5) on the smaller tables, but on larger ones, the teeth are 12–20 in number and conspicuously long (Plate **1**, fig. 4). Beneath the layer of tables occur C-shaped bodies of relatively large size; these are widely scattered except around the bases of papillae and pedicels where they are commonly rather abundant; those of the dorsal surface (Plate **1**, fig. 6) are wide in proportion to the length, which may be over 100 μ, while those of the ventral surface are much narrower, as a rule, and reach a length of 165 μ; there is some diversity of size and not many of the "parentheses" reach these extreme measurements, but on the other hand there are few if any conspicuously smaller.

Color, in life, brown, with blackish markings dorsally; tips of papillae and pedicels, yellow. Body-wall more or less translucent. In alcohol, the translucence has disappeared and the color has become light brown indistinctly mottled with darker. Tentacle-stalks nearly white with tops yellowish.

Holotype, M. C. Z. 921. Jamaica: Montego Bay. March, 1912. H. L. Clark coll.

A paratype (M. C. Z. 1,214) was taken at Bird Key, Tortugas, in June, 1917. It is more slender than the holotype and somewhat longer, has nineteen tentacles, and there is much less brown in the coloration, which is somewhat gray.

Both specimens were found under rocks in very shallow water and were supposed to be identical with other small individuals found in similar situations which have proved to be the young of *badionotus*. While the external resemblance was so close that there was no suspicion of their difference aroused, the examination of the calcareous deposits showed that they were distinct. Further collecting and examination in life will probably reveal points by which *megaparentheses* can be readily distinguished from *badionotus* of any age.

Stichopus regalis.

Plate 1, fig. 17, 18.

Holothuria regalis Cuvier, 1817, 4, p. 22. Mediterranean Sea.
Stichopus regalis Selenka, 1867, p. 317, pl. 18, fig. 32.

This is a well-marked species confined to the western Mediterranean and eastern Atlantic coasts. It is common in the Adriatic Sea as well as on the southern and western shores of Italy. It is not yet recorded from the eastern Mediterranean although it will probably be found there. It has been reported from the Bay of Biscay and from the Canary Islands but little is as yet known of its occurrence in the Atlantic. It is said to extend down to a depth of 100 fms., but this is not based on reliable evidence and is highly improbable. The color in life is brownish or ochre-yellow, with numerous white spots; the middle of the ventral side may be reddish; the tentacles are whitish. It is a moderately large species reaching a length of 300 mm. and a width of perhaps 75 mm. The calcareous particles, tables alone, save for supporting rods and terminal plates in papillae and pedicels, were long ago well figured by Sars (1858) but I have repeated those of the tables (Plate 1, fig. 17, 18) that they might be seen drawn to the same scale as in other members of the genus.

Stichopus ludwigi.

Erwe, 1913, p. 388, 389, fig. 1, pl. 8, fig. 24*a–f*. Southwestern Australia.

This is a well-characterized form, known only from the southwestern and southern coasts of Australia. The calcareous deposits are quite distinctive, particularly the tables. The preserved material was only 100–110 mm. long and was reddish gray in color, more or less spotted, blotched and marked with brown or blackish.

Stichopus horrens.

Plate **2**, fig. 19–23.

Stichopus horrens Selenka, 1867, p. 316, pl. 18, fig. 27–29. Society Islands.
Stichopus godeffroyi Semper, 1868, p. 75, pl. 30, fig. 4. Samoa.
Stichopus godeffroyi var. *pygmaeus* Semper, 1868, p. 75. Samoa and Fiji.
Stichopus godeffroyi var. b Semper, 1868, p. 246. Samoa.
Stichopus tropicalis Fisher, 1907, p. 676; pl. 70, fig. 1–1*i*. Hawaii.

In reaching the conclusion that all the Pacific specimens, with big, smooth, single-pointed spires on the tables near the ambulacral appendages, belong to a single species, I have fortunately had the holotype of *horrens* and a cotype of *pygmaeus*, as well as a cotype of *godeffroyi*, available for study. There are also in the M. C. Z. collection, thirty additional specimens of the same form from Friday Island, Badu, and Mer in Torres Strait, from the Philippines, the Carolines, Fiji, Samoa, the Society Islands and from Hilo, Lahaina, and Honolulu in the Hawaiian Islands. This material ranges in size from very small to large and throws some light on the growth-changes which are interesting and important.

The smallest specimen is only 15 mm. long by 6 or 7 mm. in diameter in its preserved condition. It was collected by me at Papeete, Tahiti, under a coral fragment, 5 August, 1913. My field-notes say it was, in life, "$1\frac{1}{2}$ inches long. Pellucid, almost transparent." Its calcareous deposits consist of tables alone; they are closely crowded and of characteristic shape (Plate **2**, fig. 23); the disks are 90–100 μ across and the spires about four fifths as much in height. It has conspicuous dorsal and lateral papillae and rather crowded, large, ventral pedicels.

The next smallest specimen is about 40 mm. long and 12 mm. in diameter; it is the cotype of *pygmaeus* Semper. It has the tables characteristic of *horrens* (Plate **2**, fig. 19, 20) but lacks C-shaped bodies and the big simple-pointed tables. But among the usual tables, there are here and there, tables similar to those of the little specimen from Tahiti. And it was the discovery of these tables that led me to the present interpretation of the growth-changes in *horrens*.

The holotype of *horrens* is about 50 mm. long and 20 mm. in diameter. Selenka's description and figures call for little comment except in one particular. He fails to note the fact that the large tables (Plate **2**, fig. 19) occur in the vicinity of the pedicels and papillae, while the big single-pointed tables are found only about the dorsal and

lateral papillae. The largest specimens of *horrens* I have seen are about 200 mm. long; in life these were nearly or quite 300 mm. long and 60 mm. or more in diameter. The deposits are not essentially different from those of the holotype of *horrens*.

Judging then from available material, we find that in its early stages, *horrens* like *badionotus* is translucent with pedicels on the flattened ventral surface and papillae dorsally, living sheltered in the crevices of coral-rock. Its calcareous deposits consist of tables only and these have large disks with a few big holes and slender spires (Plate **2**, fig. 23). At a later stage these tables are largely or wholly replaced by smaller tables, some with only eight holes in the disk (four larger and four smaller) (Plate **2**, fig. 20) while others, near the ambulacral appendages—have a peripheral circle of holes around the disk (Plate **2**, fig. 19). Accompanying these tables, in the dorsal perisome, are scattered dichotomously branched rods, the so-called "rosettes." At this stage it is 50–75 mm. long in life (25–40 mm. in its preserved condition) and represents the stage *pygmaeus* Semper. With further growth the original tables completely disappear, tables with big single-pointed spires, develop in the papillae, and ventral pedicels as well as dorsal papillae become much more numerous; this is the stage *godeffroyi* Semper. The next step is the development of C-shaped deposits (Plate **2**, fig. 21–22) the appearance of which marks the *horrens* stage, *sensu strictu;* and then a marked development of the papillae on the dorsal interambulacra ushers in the "*godeffroyi* var. *b*" stage, *tropicalis* Fisher (1907) whose description, figures and general account leave little to be desired. Of course it must not be assumed that there is any definite correlation between size and these different growth-stages. The holotype of *horrens* is hardly one third the size of the cotype of *godeffroyi*. The development of the C-shaped bodies seems to be particularly subject to individual diversity and it is not impossible that in some individuals they never become common even in adult life. The development of the dorsal papillae is also subject to great individual diversity and so far as I can see no weight can be attached to the degree of their development.

The coloration of *horrens* is varied though not to the same degree as in *badionotus*. Fisher says that in the Hawaiian Islands the body is dark olive-green, mottled with deep brownish green, but in alcohol the color becomes yellow-ochre; the tentacles are greenish gray to whitish. None of the specimens that I saw in Torres Strait were like this but one was "olive-green of 2 or 3 shades, mottled; lower surface cream-color, as are lateral tubercles; pedicels dark." As a rule the coloration was a

bewildering medley of brown of at least four shades, blackish, gray, bluish, and white; pedicels white with yellow tip. (See Carnegie inst. Publ. 214, pl. 18, fig. 4). A specimen found at Badu was more uniformly dark.

The distribution of *horrens* seems to be distinctly in the Pacific. The westernmost record I have found is that of the single specimen taken by the Siboga at the north end of Tiur Island, which is just west of lat. 132° E. In Torres Strait, at least at the Murray Islands, at Fiji, at Samoa, and at Hawaii, *horrens* seems to be common. Unlike *chloronotus* and *variegatus*, it does not occur exposed on the reef-flats but is always found among rocks and dead coral. It is very inert, quite slimy, and altogether one of the most repulsive animals on the reef.

Stichopus ecnomius,[1] sp. nov.

Plate 2, fig. 24–29.

Length 9 mm.; diameter about 3 mm. Body-wall arched; ventral surface flat. Papillae very conspicuous in two dorsal series and a lateral one on each side, at the margin of the ventral surface; there are 7–10 papillae in each series. Pedicels scattered on the ventral surface without definite arrangement in longitudinal series, of unequal size, more abundant posteriorly than anteriorly. Tentacles closely crowded about the mouth, apparently only twelve or thirteen in number.

Calcareous deposits, tables of two kinds and rosettes. Ordinary tables (Plate 2, fig. 24) moderately large, with squarish disks and spires; disks about 60 μ across with four large and four smaller holes, and usually one or more peripheral holes in addition. Extraordinary tables (Plate 2, fig. 27–29) occur in the pedicels but particularly in the papillae, in place of supporting rods, which seem to be quite absent. These tables have no definite shape and no two are exactly alike; they range in size from 50 to 200 μ across; sometimes several rods are more or less united by cross-bars somewhat like a spire, and in other cases anastomosing branches may cause an appearance like an irregular and incomplete disk, but as a rule there is no resemblance to a true table. In a few cases the rods, 4–6 in number, lie in the same plane and show some symmetry, and these form a connecting link with the rosettes, though they are much larger, fully 150 μ across. The rosettes are very remarkable for the number of the dichotomous divisions and

[1] ἐκνόμιος = unusual, strange, in reference to the remarkable deposits.

the shortness and curvature of the branches; the two figured (Plate 2, fig. 25, 26) are the two simplest observed; as the divisions increase in number, they apparently cease to lie in one plane and the most complex rosettes are much flattened ellipses of a close and irregular network; the rosettes are usually about 60–70 μ long.

Color, in life, "yellow, with blue nodular spines"; the preserved specimen is uniformly dull yellow-brown.

Holotype M. C. Z. 890. Jamaica: Montego Bay, "on rocks in front of laboratory." 28 August, 1910. E. A. Andrews coll.

This remarkable little species is quite unlike anything I collected in Jamaica. It is obviously too young to fix its generic position, so that it is not impossible that it is not a Stichopus. The tables and rosettes, the form of the body and the arrangement of pedicels and papillae are quite Stichopus-like. The absence of C-shaped bodies is not significant in view of the youth of the specimen. On the whole, it seems more likely that it belongs to Stichopus than to any other known genus. But it is not impossible that it will prove to be a young Holothuria, and it is not inconceivable that it represents one of the earliest stages in the development of the common *H. floridana*.

Stichopus variegatus.

Stichopus variegatus Semper, 1868, p. 73, pl. 16, 30, fig. 1. Philippines, Samoa.
Stichopus naso Haacke, 1880, p. 46. Mauritius.
Stichopus levis Sluiter, 1887, p. 198, pl. 1, fig. 6. Mendano Strait and Bay of Batavia, D. E. I.
Stichopus vastus Sluiter, 1887, p. 198, pl. 2, fig. 46–48. Bay of Batavia.
Stichopus hirotai Mitsukuri, 1912, p. 161. Ogasawara Island, Japan.
Stichopus oshimae Mitsukuri, 1912, p. 171. Kageroma Island, Japan.

It may be hazardous to assert that such good observers and careful workers as Sluiter and Mitsukuri have added four synonyms to the well-known name given by Semper, when they supposed they were describing four new species, but after my observations at Mer and my examination of material in the M. C. Z., I am unable to reach any other conclusion. I grant at once that with no material from Japan and none from the Bay of Batavia, my conclusions cannot be considered final, and it is quite possible that *oshimae* will prove to be a distinct species, characterized by the very large C-shaped particles (up to 152 μ in length) and the very small tables, with disk only 20 μ in diameter.

But *variegatus* is unquestionably a very variable species and the

eighteen specimens before me show great diversity in the development of the dorsal and lateral tubercles and in the relative abundance of the different sorts of calcareous particles, as well as in size and color. I am not able to throw any light on the growth-changes never having seen a very young specimen. Preserved specimens of *chloronotus*, *horrens*, and *variegatus*, when of the same size, often resemble each other so closely that only a careful study of the calcareous particles will reveal their identity. And yet in life the three species are quite unlike and are distinguishable from each other at a glance.

The color of a typical *variegatus* is fundamentally yellow-brown or brownish yellow. Semper's colored figure shows bright red tips to the papillae but I failed to detect any red on the individuals I saw in Torres Strait. In size, *variegatus* is the largest member of the genus; one brought up by a Japanese diver at Mer from a depth of 18 fms. measured 725 mm. in length by 125 mm. in width, and was thus very much larger than Sluiter's *vastus*. Average specimens are 300 to 400 mm. long in life but shrink to about half that in preservation.

The distribution of *variegatus* is from Zanzibar, Mauritius, and the Arabian Gulf to the Fiji, Samoan, and Caroline Islands; northward it reaches the southern islands of Japan and southward it reaches Port Molle on the Queensland coast. It is not known from Hawaii or the Society Islands.

Stichopus variegatus var. herrmanni.

Semper, 1868, p. 73, pl. 17, 30, fig. 2. Philippines: Bohol.

This is apparently a well-marked variety, of which Semper says he had specimens from Samoa as well as from Bohol. If the differences are constant, and so persistent that they are clear in preserved material, it would seem proper to consider *herrmanni* a distinct species. But it is notable that the form has not been recorded since 1868.

Stichopus naso.

Semper, 1868, p. 72, pl. 18, 30, fig. 3. Philippines: Bohol, near Talibon, 8–15 fms.

Comparison of Semper's plates 16 and 18 would seem to put beyond question the distinctness of this species from *S. variegatus*, but when one looks for characters which will serve for distinguishing alcoholic specimens, the difficulties are very great. The records of *naso* from other localities than the Philippines are not reliable for Ludwig (1883)

has identified as *variegatus* the specimen from Mauritius which Haacks considered *naso*, and I have identified as *naso* specimens from Fiji and from Cebu, which reëxamination prove to be *variegatus*. Further investigations in the East Indian region may bring out more clearly what the essential characters of *naso* are, if it is really distinct from *variegatus*.

Stichopus simulans.

Stichopus mollis with "very peculiar type of spicule" Dendy, 1897, p. 48, pl. 7, fig. 83–87, Wellington, N. Z.

Stichopus simulans Dendy and Hindle, 1907, p. 97, pl. 11, fig. 5. Resolution Island.

Stichopus simultans Erwe, 1913, p. 388. East coast of Rottnest Island, West Australia.

The relationship of this species to *mollis* is indeed peculiar. Both Dendy (1897) and Joshua (1914) discovered their specimens by accident among specimens supposed to be *S. mollis*. On examining the specimens of *mollis* in the M. C. Z., I found among those from Westernport, Victoria, one that has the peculiar foliaceous rosettes of *simulans*. These rosettes are of course a very convenient recognition-mark but as the specimens that have them are otherwise indistinguishable from *mollis*, the rosettes may indicate an age or seasonal or sex condition rather than a specific difference. The matter deserves careful study by some Australasian zoölogist who can secure plenty of material at all seasons of the year. In size, color, habits, and distribution, *simulans* is remarkably like *mollis*.

Stichopus johnsoni.

Plate **1**, fig. 15, 16.

Théel, 1886a, p. 4. California: 5 miles south of Santa Barbara, 22 fms.

This well-marked species is no longer represented only by the unique holotype, for within the past few years two additional specimens have come into the M. C. Z. collection, one from Laguna Beach, California, and the other from a less definite locality —"Southern California." The calcareous particles (Plate **1**) not figured hitherto, are drawn to the same scale as in the case of other species. The buttons (Plate **1**, fig. 15) are not so very different from those of *californicus* but the tables (Plate **1**, fig. 16) are very distinctive. There is no

information available as to color or size in life, nor is anything known of the habits and habitat. It is not impossible that *johnsoni* will prove to be a form of *californicus* characteristic of deeper water, or it may possibly prove to be a growth-stage. So far as present evidence goes however these are unwarrantable assumptions.

Stichopus californicus.

Plate 1, fig. 8–12.

Holothuria californicus Stimpson, 1857, p. 524 (84 of reprint). Tomales Bay, California.

Stichopus californicus H. L. Clark, 1901, p. 164.

As the calcareous particles of this species have never been illustrated, they are figured herewith for easy comparison with the preceding and following species, to which *californicus* is very closely related. The buttons (Plate 1, fig. 8) are relatively large and usually have 5–7 pairs of holes with no smaller ones around the margin, but some of the larger ones have small holes near the margin, alternating with the pairs of large holes (Plate 1, fig. 9). The tables commonly have four large holes, with which four smaller and more distal holes alternate (Plate 1, fig. 10), but often there are smaller holes on each side of the latter (Plate 1, fig. 11). Rarely the tables are not tetramerously symmetrical, but have five or six central holes as indicated in figure 11. The spires of the tables are rather high (Plate 1, fig. 12) with two cross-bars and 20–24 teeth at the top.

This is a large species, up to 500 mm. long in life, and 100–110 mm. in width. The color in life is reported as dark red, but alcoholic material is light brown. The geographical range is known to be from southern California to Puget Sound, and it probably extends considerably to the north of the latter region. At Friday Harbor, Washington, and at Monterey, California, *S. californicus* is one of the most common holothurians. A study of its growth-changes would be most interesting and important.

Stichopus parvimensis.

Plate 1, fig. 13, 14.

H. L. Clark, 1913, p. 234. Lower California: Cedros Island.

The tables (Plate 1, fig. 13) and buttons (Plate 1, fig. 14) of this species are really diminutive when compared with those of *johnsoni*,

its nearest relative geographically. It is certainly odd that *johnsoni*, the species with the largest tables, should be intermediate in its geographical position, between *californicus* with its tables of moderate size and *parvimensis* with its very small tables. It is not improbable that both *johnsoni* and *parvimensis* have arisen from *californicus* at the southern extremity of its range, the former with its large tables extending into and occupying the deeper, cooler water of a limited area off southern California, while the latter with its diminutive tables came to occupy the shallow, warmer water of Lower California.

The three original specimens of *parvimensis* were taken in $3\frac{1}{2}$ ft. of water on a bottom covered with "sea-weed" (presumably "eel-grass"), near shore on the east side of Cedros Island, west coast of Lower California, March 12, 1911. This species is reported by Parker (1921, Journ. exper. zoöl., **33**, p. 205) under the name *panimensis* as "found in considerable numbers on the rocky shores" at La Jolla, California.

The length of the preserved specimens (about 200 mm.) indicates a species at least 350 mm. long in life. The color is now light chestnut-brown, paler below, with many of the pedicels very dark brown, and hence in their contracted condition appearing as minute black spots.

Stichopus paradoxus.

Lampert, 1885, p. 247, fig. 14, 17, 27. Australia.

This extraordinary and easily recognized species has not been met with since the original description of the unique holotype, a uniformly brown specimen, 140 mm. long.

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EXPLANATION OF THE PLATES.

PLATE 1.

PLATE 1.

Figs. 1–7. *Stichopus macroparentheses* H. L. Clark.
1. Disk of typical table.
2. Disk of more developed table.
3. Spire of same, from side.
4. Spire of same, seen from above.
5. Spire of small table, seen from above.
6. C-shaped particle.
7. C-shaped particle.

Figs. 8–12. *Stichopus californicus* (Stimpson).
8. A typical button.
9. One end of a somewhat more developed button.
10. A typical table, seen from above.
11. Part of disk margin of more developed table.
12. A typical table, seen from side.

Figs. 13, 14. *Stichopus parvimensis* H. L. Clark.
13. A typical table, seen from above. (Spire with fewer terminal teeth than usual).
14. A typical button.

Figs. 15, 16. *Stichopus johnsoni* Théel.
15. A typical button.
16. A typical table, seen from above.

Figs. 17, 18. *Stichopus regalis* (Cuvier).
17. Spire of table, seen from side.
18. A typical table, seen from above.

All figures magnified 425 ×.

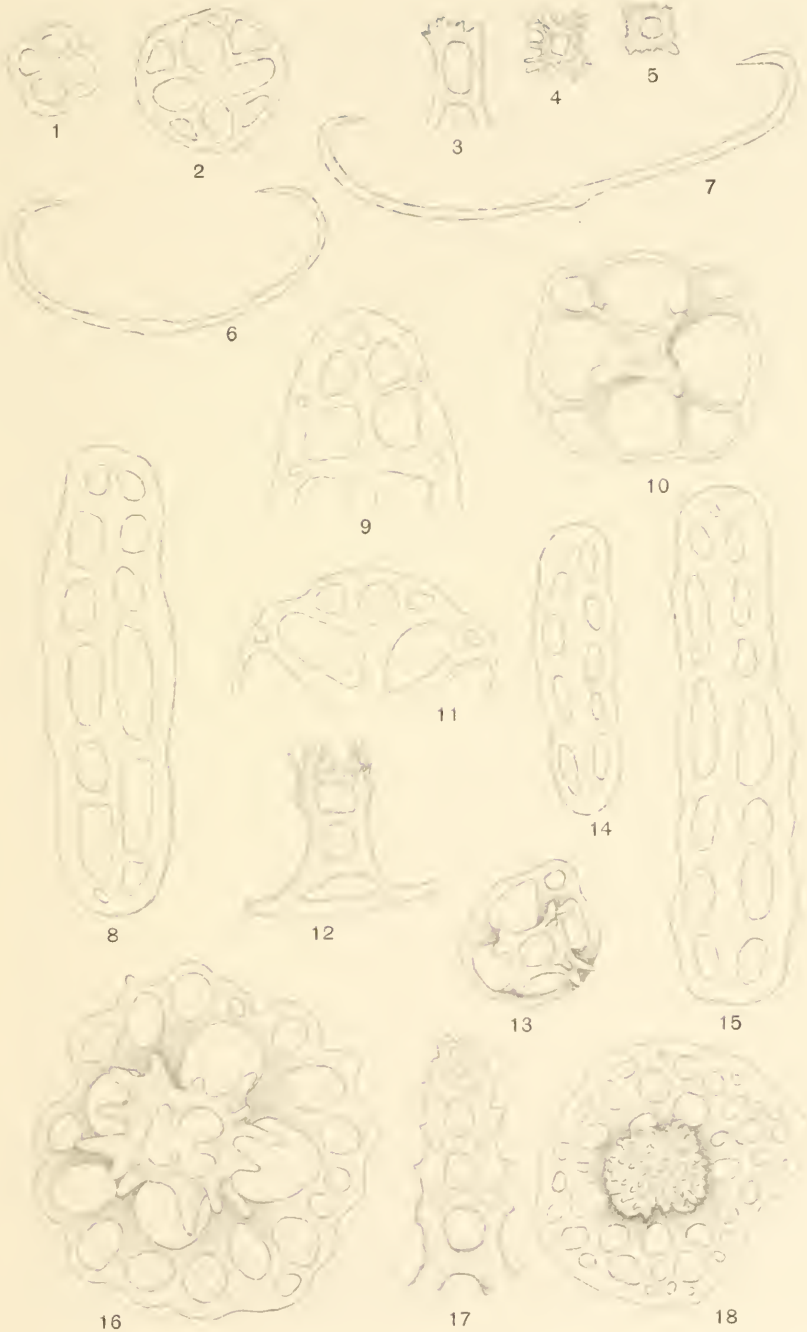
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PLATE 2.

PLATE 2.

Fig. 1–10. *Stichopus chloronotus* Brandt.

1. A typical table, seen from above.
2. A simpler, common form of table, from above.
3. The same, seen from side.

4–6. C-shaped particles of a specimen from Torres Strait.

7. An abnormal C-shaped particle of same specimen.

8, 9. C-shaped particle of a specimen from the Caroline Islands.

10. S-shaped particle of same specimen.

Fig. 11–18. *Stichopus badionotus* Selenka.

11–13. Typical tables, seen from above.

14. Partially resorbed table, seen from side.
15. More fully resorbed table, seen from side.
16. C-shaped particle.
17. Spire of table of a very young specimen.
18. Disk of same.

Fig. 19–23. *Stichopus horrens* Selenka.

19. Typical table from near papillae, seen from above.
20. Typical table of body-wall; disk only.

21, 22. C-shaped particles.

23. Table of a very young specimen, seen from above.

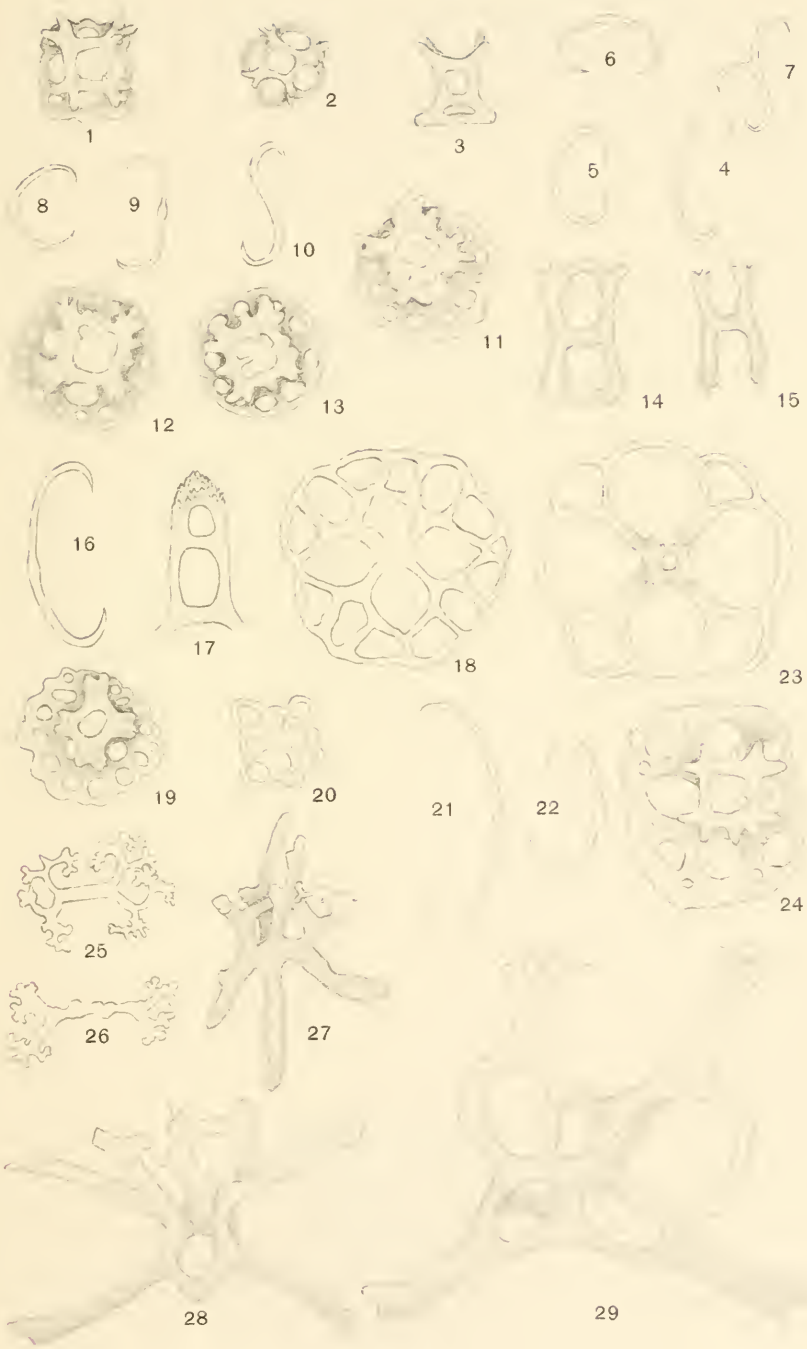
Figs. 24–29. *Stichopus economius* H. L. Clark.

24. A typical table.

25, 26. Rosettes.

27–29. Asymmetrical, irregular tables.

All figures magnified 425 ×.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