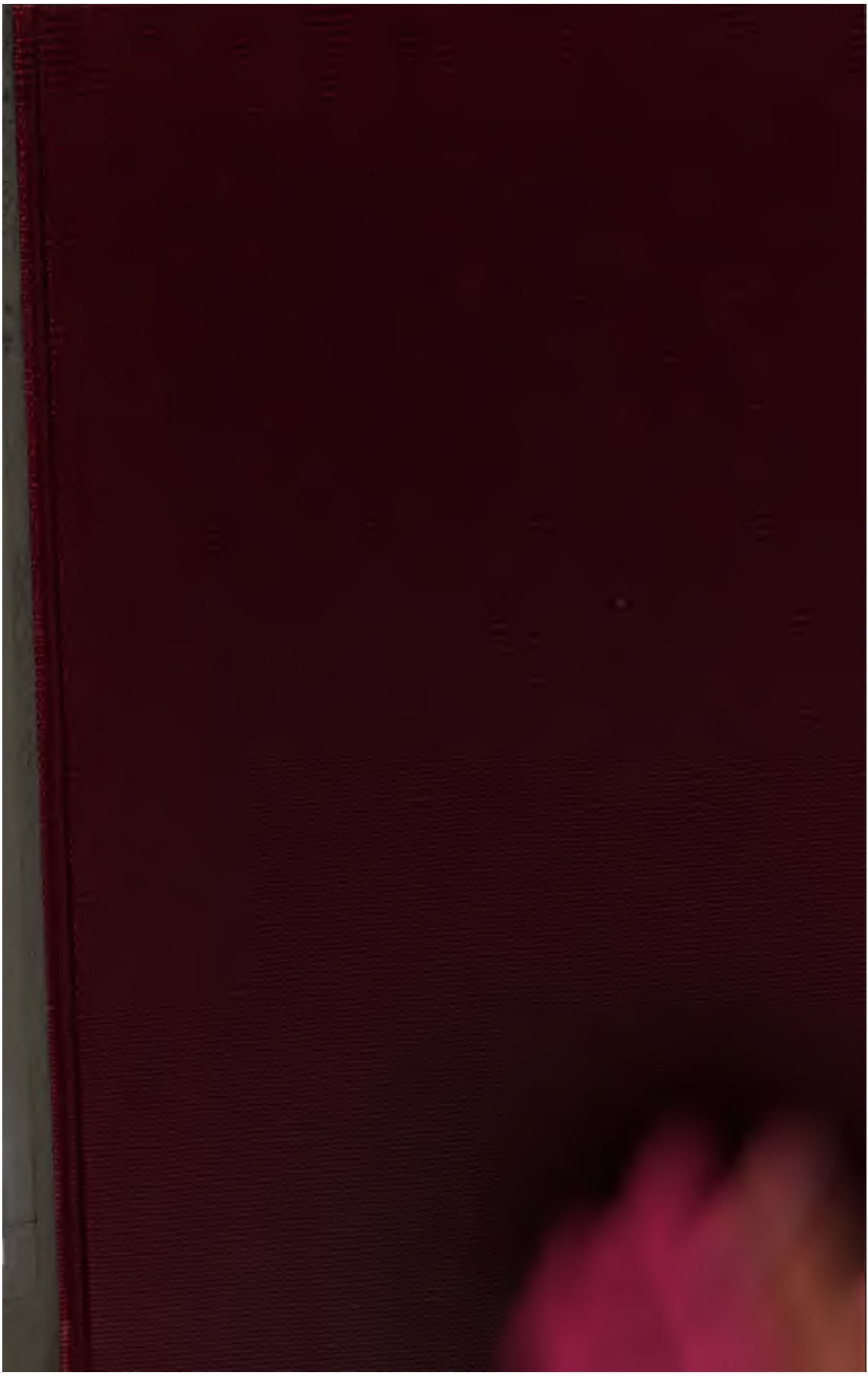

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THE CIDARIDAE.

BY HUBERT LYMAN CLARK.

WITH ELEVEN PLATES.

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No. 7. — *The Cidaridae.* By HUBERT LYMAN CLARK.

Introduction.

THE opening years of the present century have witnessed the publication of an unusual number of quarto volumes dealing with the morphology and classification of the Echini. In each of these the Cidaridae receive considerable attention, and many genera of that family, new either in name or in contents, are proposed. As the different writers reveal wide divergence of opinion as to the relative importance of the characters on which the classification of the Echini is based, the arrangement of the Cidaridae differs to an unusual degree in these several reports. Mortensen (:03)[1] practically rejects previous classifications and the principles on which they are based, and, ignoring the fossil forms, to which his method is not applicable, recognizes thirteen genera and a subgenus, defined wholly in terms of the pedicellariae, the spicules of the pedicels, and occasionally the spines. It is only fair to state, however, that the writer says frankly, these features are not "sufficient for definitive diagnoses." He includes in his classification 42 species, and lists 12 others which he is unable to place satisfactorily because of lack of information about the pedicellariae. Very soon after this volume appeared, de Meijere's (:04)[2] valuable report on the "Siboga" Echini was published. Unwilling to accept Mortensen's genera unreservedly, the writer adopts the clumsy and unsatisfactory method of recognizing only a single genus, Cidaris, and using Mortensen's names for subgenera. Later in the same year Agassiz (:04)[3] in his report on the Panamic deep-sea Echini, points out the weaknesses of Mortensen's method and the unsatisfactory nature of his results, and emphasizes anew the great morphological significance of the test (including the abactinal system). Two years

[1] The Danish Ingolf-Expedition, 4, 1. Echinoidea. Part 1. Th. Mortensen. Translated by Torben Lundbeck. 193 pp., 21 pls. Copenhagen, 1903.

[2] Die Echinoidea der Siboga-Expedition. J. C. H. de Meijere. 252 pp., 23 pls. Leiden, 1904.

[3] The Panamic Deep Sea Echini. Alexander Agassiz. Mem. Mus. Comp. Zoöl., 31, 243 pp., 112 pls. 1904.

later Döderlein (:06),[1] in an effort to avoid some of the difficulties of Mortensen's system, and yet to retain the valuable results of his work, offers a classification of the recent Cidaridae, consisting of ten genera and five subgenera, defined chiefly in terms of the pedicellariae. This classification, however, is quite different from any of its predecessors because, while Döderlein attempts to apply rigidly the recent International Code of zoölogical nomenclature, his interpretation of certain perplexing cases is quite different from either Mortensen's or Agassiz's. Finally Agassiz and Clark (:07)[2] reject the proposed innovations of both Mortensen and Döderlein and offer considerable evidence in support of their view that the pedicellariae of the Cidaridae are as unreliable for generic characters as are the spines.

It is perfectly obvious, therefore, that the classification of the Cidaridae is at the present time in a state of great confusion, and that some effort should be made to reduce it to order and place it on a permanent basis. Thanks to the great kindness of Mr. Agassiz, a very unusual amount of material, both recent and fossil, has been accessible to me during the past two years, and I have endeavored to find and formulate a natural arrangement of the Cidaridae. Needless to say, Mr. Agassiz is not responsible in any way for statements made or opinions expressed in the following pages, but whatever value my results may have are due to his constant sympathy and encouragement, and I wish here, in this inadequate way, to express my thanks to him. I have also to thank Dr. Richard Rathbun for the privilege of examining the collection of Cidaridae in the United States National Museum, and this proved to be of added interest because it has recently been studied by Dr. Mortensen, who, in many cases, left labels in his own hand, showing the views he held as to the identification of the specimens. As my point of view differs fundamentally from his, I desire to do him full justice, and the examination of a collection, a large part of which has been named by him, was therefore of special importance to me. Finally I may add that in the preparation of this report I have personally handled not less than 3,100 specimens, representing 48 of the 60 recent species which appear to me to be valid, and all of the 15 recent genera herein recognized.

[1] Die Echinoiden der deutschen Tiefsee-Expedition. Ludwig Döderlein. 290 pp., 42 pls. Jena, 1906.

[2] Hawaiian and other Pacific Echini. The Cidaridae. Alexander Agassiz and Hubert Lyman Clark. Mem. Mus. Comp. Zoöl., 34, 42 pp., 44 pls. 1907.

Historical summary.

The first writer to use the name Cidaris for a genus of Echini was Klein (**1734**), who, however, included all of the regular sea-urchins under that name. Linné (**1758**) used the same name for a *species* of Echinus, but Leske (**1778**) was the first writer subsequent to Klein who recognized Cidaris as a genus. Only one of the 28 species which he includes in the genus belongs in the family Cidaridae as understood to-day, and to that one he gave the name *papillata*. Now it is clear from both text and figures that Leske intended to include under the name "*Cidaris papillata*" all those regular Echini with the conspicuous interambulacral tubercles of the Cidaridae. His "species" is therefore a composite group, including not only the now well-known European *Dorocidaris papillata*, but also *Phyllacanthus imperialis* and several species of the restricted genus Cidaris, one of which appears to have been *tribuloides* Lamarck. The next writer to deal with the classification of the Echini was Lamarck ('**16**), and he clearly indicates and defines the group which we now call the Cidaridae. He called them "Turbans," under his genus Cidarites. So far as the Cidaridae are concerned the name Cidarites is equivalent to Leske's *Cidaris papillata* and is obviously a synonym of Cidaris. It cannot be used, therefore, at the present time for any genus of animals. Lamarck listed eleven species of "Turbans," all but one of which were recognized and described by Alexander Agassiz in 1872, in his classic "Revision of the Echini." No attempt to subdivide the genus Cidaris was made until 1835, when Brandt established the genus Phyllacanthus for a supposedly new species, *dubia*. He divided Lamarck's Cidarites into two sections, A (including the species not in B and for which he selected and named *tribuloides* Lam. as the type species) and B, Phyllacanthus, with *dubia* for the type, and including also *imperialis*, *hystrix*, *geranioides*, and *pistillaris*. Later investigation made it plain that of these four only *imperialis* and *pistillaris* are congeneric with *dubia*, and the other two were therefore returned to Cidaris. In 1872 A. Agassiz showed, however, that Lamarck's *baculosa*, *verticillata*, and *annulifera* had important features in common with *dubia* and *imperialis* and accordingly placed them in Phyllacanthus. When Agassiz and Desor ('**46**) considered the Cidaridae, they neglected Phyllacanthus, but established Goniocidaris with *geranioides* for the type, and with it associated a "new" species *quoyi*, which subsequently proved to be synonymous with Lamarck's *tubaria*. In 1854 Desor suggested as genera of fossil Cidaridae, Rhabdocidaris, Diplocidaris, Porocidaris, and Leiocidaris, and in

1858 he described the fossil Eocidaris. The same year (1858) Quenstedt named Polycidaris and Leptocidaris for fossil forms. In 1862 Cotteau described the remarkable fossil Orthocidaris, and the following year the equally interesting fossil Temnocidaris. In 1863, A. Agassiz suggested the name Stephanocidaris for Lamarck's *bispinosa*, and Prionocidaris for *pistillaris*. At the same time he proposed Chondrocidaris as a new genus for a notable species from the Hawaiian Islands, and Gymnocidaris for *metularia* Lam. and a supposedly new species, *minor*. He also proposed Orthocidaris and Temnocidaris as new genera of recent Cidaridae, but later (1869) withdrew them as preoccupied by Cotteau's fossil forms. At this later date he suggested Dorocidaris for a new species, *abyssicola*, associating with it *affinis* Phil. and *papillata* Leske. With the last Lamarck's *hystrix* is synonymous, and consequently, as a result of these various changes, there remained in Lamarck's genus "Cidarites: Turbans" only the well-known West Indian species, *tribuloides*.

In the "Revision of the Echini" (1872) A. Agassiz recognized only six genera of the recent Cidaridae, as follows: —

Cidaris Klein, with 3 species. (Including Gymnocidaris A. Ag.)
Dorocidaris A. Agassiz, with 1 species. (Including Orthocidaris A. Ag.)
Phyllacanthus Brandt, with 6 species. (Including Prionocidaris A. Ag., and Chondrocidaris A. Ag.)
Stephanocidaris A. Agassiz, with 1 species.
Porocidaris Desor, with 1 species.
Goniocidaris Desor, with 3 species. (Including Temnocidaris A. Ag.)

This classification has been maintained by Agassiz ever since, without any changes other than the addition of ten more species (1881, 1883, 1898) and the unique genus Centrocidaris (1904).

In 1877 Studer described Schleinitzia as a recent genus allied to Phyllacanthus. In 1883 Pomel divided the "Cidaridés" into three subfamilies, the Cidariens, Goniocidariens, and Rhabdocidariens. The first contains four genera, including of Agassiz's six only Cidaris, which is divided into five sections (subgenera?); the second subfamily contains four genera also, including Dorocidaris and Goniocidaris of Agassiz's list; the third contains seven genera, including the remaining three of Agassiz, though Stephanocidaris is considered only a subgenus (?) of Phyllacanthus. Although Pomel thus recognizes fifteen genera and six subgenera (?), his classification of the recent forms is essentially identical with that of A. Agassiz. The new genera which he proposes are Tylocidaris, Stereocidaris, Typocidaris, and Pleurocidaris, all for fossil

forms. His proposed subgenera of Cidaris are, Plegiocidaris, Paracidaris, Procidaris, Polycidaris, and Eucidaris. In 1884 Zittel proposed Anaulocidaris for a fossil cidaroid, and in 1885 Döderlein used the name Discocidaris for some recent Japanese species. In 1887 Döderlein published a classification of the Cidaridae, including the fossil as well as the recent forms. Of the 22 genera which he recognizes, 15 include only fossil species. He rejects Stephanocidaris altogether, and uses Desor's name Leiocidaris for Phyllacanthus. For some inexplicable reason he considers *Porocidaris sharreri* A. Ag. as a living representative of Pomel's genus Pleurocidaris. To another of Pomel's genera, Stereocidaris, he assigns three recent Japanese species which he describes. He proposes four new genera of fossil cidaroids, but only gives names to three: Mikrocidaris, Triadocidaris, and Miocidaris. In 1889 Duncan's "Revision of the Genera . . . of the Echinoidea" appeared, with a classification of the Cidaridae, which at first sight seems unique, but on examination proves to be novel only in the rank assigned to the different groups. The writer divides the family into two sections, of which the first contains four genera and one subgenus, and the second contains two genera. For recent forms only the genus Cidaris, with a subgenus Goniocidaris, is allowed, but the heterogeneous nature of such a genus is so far acknowledged that it is divided into seven "divisions," of which five contain the recent species. These five "divisions" with the subgenus Goniocidaris correspond in name and contents to the genera maintained by A. Agassiz. In 1902 Lambert proposed for certain fossil and recent Cidaridae previously referred to Stereocidaris, the name Phalacrocidaris, and in 1903 he suggested for some fossil species allied to Phyllacanthus, the name Aulacocidaris.

In 1903 Mortensen entirely rearranged the recent species of the family, uniting or separating them according to resemblances or differences in the large globiferous pedicellariae. In this way he makes thirteen genera and a subgenus, and although he uses the names of the six genera of A. Agassiz, the grouping of the species is wholly different from that writer's. Mortensen's classification is as follows: —

Dorocidaris A. Ag. (emend.), 4 species.
Tretocidaris, g. n., 3 species.
Stephanocidaris A. Ag. (emend.), 3 species.
Schizocidaris, g. n., 1 species.
Cidaris Klein (emend.), 8 species.
Chondrocidaris A. Ag., 1 species.
Acanthocidaris, g. n., 1 species.

Stereocidaris Pomel, 10 species.
Goniocidaris Desor, 4 species and subgenus Discocidaris Döderlein, 3 species.
Petalocidaris, g. n., 1 species.
Phyllacanthus Brandt (emend.), 3 species.
Histocidaris, g. n., 1 species.
Porocidaris Desor, 1 species and 1 variety.
Genus undetermined, 12 species.
Total, 56 species and 1 variety.

Of these 56 species, seven, and the one variety, are described for the first time, but only one of them is figured. Unfortunately Mortensen was handicapped by lack of material and the apparent necessity of not denuding even in part the specimens which were available, and as a consequence his descriptions are, with one exception, incomplete, and in several cases quite inadequate. Good photographs of his types would be a very great help in recognizing these supposedly new species.

In 1906 Döderlein presents his classification of the recent Cidaridae, the result of more than twenty years' study of the family. It is radically different from his earlier (1887) arrangement, not merely because no reference is made to fossil forms, but because he endeavors to make use of Mortensen's principles, which his own observations often contradict [1] and his judgment not infrequently condemns.[2] This latest arrangement of the family is as follows: —

Cidaris Leske (syn. Dorocidaris A. Ag.), 4 species.
Tretocidaris Mortensen, 3 species.
Cidarites Lamarck (syn. Cidaris emend. Mortensen).
Subgenus Dorocidaris A. Ag., 4 species.
Gymnocidaris A. Ag., 3 species and 1 variety.
Stephanocidaris A. Ag., 5 species and 7 varieties.
Chondrocidaris A. Ag., 1 species.
Goniocidaris L. Agassiz et Desor.
Subgenus Goniocidaris s. str., 6 species.
Discocidaris Död., 6 species.
Stereocidaris Pomel, 14 species.
Acanthocidaris Mortensen, 1 species.
Phyllacanthus Brandt, 1 species and 3 varieties.
Histocidaris Mortensen, 2 species.
Porocidaris Desor, 1 species and 1 variety.
Genus undetermined, 6 species.
Total: 10 genera, 5 subgenera, 57 species, and 12 varieties.

[1] Compare page 102, line 24, with page 106, lines 34–36 and page 109, lines 20–21.
[2] See p. 93 *et seq.*

In 1907 A. Agassiz and Clark published descriptions and numerous figures of nine new species of Cidaridae and instituted two new genera, Anomocidaris and Aporocidaris. They also furnished much additional information concerning Stephanocidaris, Centrocidaris, and Acanthocidaris and in regard to diversity of form in the pedicellariae of the group.

Fundamental Principles for a Natural Classification.

Before attempting to set forth a revised classification of the Cidaridae, if it is hoped to have it stable and generally acceptable, one ought to make plain the principles on which it is based. These principles must take into account not only the characters afforded by the specimens themselves and the proper estimation of the relative value of these, but also the selection of names for the genera and species held to be valid. Fortunately there is coming to be more and more general agreement among zoölogists as to the principles which should govern in the selection of names, and the very general acceptance of the International Code of Nomenclature, at least in its essentials, indicates clearly the approach of the time when nomenclature will be fixed. In the following pages adherence has been given to the rules of the International Code, but whenever there has been room for difference of opinion as to the application of those rules, that course has been followed which would cause the least possible change from currently accepted names. Consequently there are few changes from the names established or indorsed by A. Agassiz in the "Revision of the Echini" and almost universally used in the last quarter of the nineteenth century. Unfortunately there is no code by which can be determined the relative importance of the various characters which distinguish the different species and genera of Echini. Here each writer is thrown upon his own resources, and his proposed classification will stand or fall according to the judgment he displays in selecting stable and significant characters. The fundamental difficulty with the classification of Mortensen is that it is based almost wholly upon the characters of the pedicellariae alone, and the history of zoölogy shows again and again that a classification based on a single character, however suggestive it may be, is never reliable. The characters afforded by the pedicellariae are important, but those organs are, like all calcareous formations among echinoderms, liable to great diversity. It is of no special importance in this connection whether the pedicellariae are modified spines or not, the only point being whether, like the spines,

they show great individual variability. The evidence offered by A. Agassiz and Clark (:07) cannot be ignored or denied, and we are therefore forced to conclude that neither spines nor pedicellariae can be depended on to furnish unvarying characters. On the other hand, Duncan errs in placing his reliance almost exclusively on the test and in neglecting the characters afforded by the spines and pedicellariae. The classification used by A. Agassiz and the first one proposed by Döderlein ('87) show a judicious balancing of the various characters, and undoubtedly must serve as the basis for the natural classification we are seeking. Döderlein's latest arrangement of the Cidaridae does not appeal to me as being well-balanced, for many excellent characters afforded by the test and spines are neglected or given little weight, while the interesting diversities of the pedicellariae are permitted to outweigh all else. It seems to me there can be little question, either on *a priori* grounds or as a result of observation, that the characters afforded by the test are the most important in determining relationships among the Cidaridae, and that those of the corona appear to be more reliable than those of the abactinal system and actinostome. The size of the two latter as compared with each other and with the size of the test are useful factors in many cases, but there is considerable individual diversity in these proportions. This is true also of the arrangement of the plates of the abactinal system, the position, form, and size of which nevertheless often furnish characters of very great weight. The primary spines reveal obvious and tempting features, but these must be used with caution, they are generally so variable. Curiously enough, however, in certain cases a character afforded by the primaries is very constant, even though in nearly related species the same character may be very variable. The pedicellariae well repay careful examination and often reveal interesting and constant peculiarities, but, as has already been emphasized, they, like the spines, are subject to great individual diversity. Indeed, it seems to be true that a species which has very variable spines is likely to have equally variable pedicellariae. The secondary, and even the miliary, spines sometimes show characters of real value, although in certain cases they are as variable as the primaries. The calcareous particles in the tube-feet seem to be so uniform in the family but so variable, within these limits, in the individual that they afford no real help in classification.

In the classification set forth in the following pages I have attempted to place the proper value on each of the features of Cidaridean anatomy mentioned above, and I have also taken into account geographical and

bathymetrical distribution. Even the suggestions of size, color, habitat, and habits have not been ignored in the effort to learn the real interrelationships of the species. At the suggestion of Mr. Agassiz, I have included the genera of fossil Cidaridae, as well as the recent forms, in order that the result may be as useful to palaeontologists as to zoölogists, and I have endeavored to give special consideration and due weight to those characters upon which palaeontologists are obliged to rely I am forced to the conclusion, however, that in most cases little value attaches to the presence or absence of crenulation on the tubercles, to the straightness or sinuosity of the ambulacra, or to the amount of confluence of the areolae. While these features are frequently very obvious in fossils, experience with large series of specimens shows that they are very variable in individuals of the same species, and the most striking differences may be due to the age or condition of the specimen. Far be it from me to claim that the genera which I have adopted are all of equal value or that they ought to be adopted as herein defined by all future writers. The genera Phyllacanthus and Stereocidaris are notably unsatisfactory, and it is quite likely that they will be entirely rearranged in the light of further knowledge. Perhaps the same is true of Goniocidaris. But it is hoped that the classification and nomenclature set forth in the following pages may be a real step towards the ideal which we seek.

The Genera

In attempting to apply the principles outlined above, it will be convenient to begin with those genera which are accepted by A. Agassiz, Döderlein, Mortensen, and Pomel, and virtually by Duncan also. These genera are: —

Cidaris Leske.	Porocidaris Desor.
Goniocidaris L. Agassiz et Desor.	Phyllacanthus Brandt.

Döderlein (:06) has reached the very disturbing conclusion that *papillata* is the type of Cidaris, and that consequently Dorocidaris A. Ag. is a synonym of Cidaris Leske. Acting on this belief, he has introduced Lamarck's name Cidarites for Cidaris as commonly used, and divides it into three subgenera, to one of which he applies the name Dorocidaris A. Ag. In doing this, Döderlein overlooks the very important fact that Leske's *Cidaris papillata* is a composite group which was first broken up by Lamarck. It includes at least three species, — *imperialis*, which Brandt removed to Phyllacanthus; *papillata*, which

A. Agassiz removed to Dorocidaris; and *tribuloides* (or possibly *metularia*; it matters little which), which remains thus as the type of Cidaris. Moreover Brandt, who was the first writer to subdivide Cidaris, distinctly states that *tribuloides* is the type of Cidaris s. str., and as "first reviser" he undoubtedly had the right to select the type. There is therefore no need of upsetting a number of familiar names and causing considerable confusion by insisting on *papillata* as the type of Cidaris. Indeed, if we are to discuss this question, *imperialis* has a better claim than *papillata* to be the type of Cidaris, for it is undoubtedly the first species Leske names, though he has it confused with *papillata* under the varietal name *major*. In resurrecting Lamarck's name Cidarites, which is clearly a substitute for, and synonym of, Cidaris, Döderlein violates the old principle "once a synonym, always a synonym," and certainly if Dorocidaris A. Ag. is a synonym of Cidaris Leske, as Döderlein says, it cannot be used for a subgenus of Cidarites. It is surprising that so good a zoölogist as Döderlein should have committed two such errors. Since Döderlein's Cidarites equals Cidaris Mortensen and his "Cidaris" is equivalent to Dorocidaris A. Ag., the latter can be added to our list of accepted genera, which will also include several genera of recent Cidaridae adopted by Mortensen, Döderlein, and Agassiz and Clark, as follows: —

Dorocidaris A. Agassiz.	Stereocidaris Pomel.
Chondrocidaris A. Agassiz.	Acanthocidaris Mortensen.

We may also add five genera of fossil Cidaridae, accepted by Pomel, Döderlein, and Duncan, regarding which there can be little question: —

Orthocidaris Cotteau.	Polycidaris Quenstedt.
Temnocidaris Cotteau.	Diplocidaris Desor.
Tetracidaris Cotteau.	

The following genera are fully described and figured by A. Agassiz or by A. Agassiz and Clark, and their validity is not likely to be questioned, with the possible exception of Stephanocidaris, which some zoölogists may not wish to separate from Phyllacanthus. So far as the evidence goes, however, it is fully entitled to recognition.

Stephanocidaris A. Agassiz.	Aporocidaris A. Agassiz and Clark.
Centrocidaris A. Agassiz.	Anomocidaris A. Agassiz and Clark.

There still remain no less than 21 genera and several subgenera of Cidaridae which have been proposed and are entitled to consideration.

To these I have given special attention, but the great majority do not seem to me to be based on sufficiently reliable or tangible characters to warrant their recognition. The following list includes them all, with my opinion as to the proper status of each; those which appear to me to be worthy of use are indicated by black-faced type.

Rhabdocidaris Desor: not distinguishable from Phyllacanthus.
Leiocidaris Desor: " " " "
Eocidaris Desor: not distinguishable from Cidaris, or else from Archaeocidaris, according to what species is considered the type. It is true that the first species mentioned by Desor (*keyserlingi*) does not agree with the diagnosis of the genus, but since Döderlein ('87) has definitely selected that species as the genotype, Eocidaris becomes a synonym of Cidaris.
Leptocidaris Quenstedt: very probably not one of the Cidaridae.
Gymnocidaris A. Ag.: not distinguishable from Cidaris.
Prionocidaris A. Ag.: " " " Phyllacanthus.
Schleinitzia Studer: " " " "
Tylocidaris Pomel: apparently a valid genus, though allied to Cidaris.
Typocidaris Pomel: not clearly distinguishable, and too near Cidaris and Dorocidaris.
Pleurocidaris Pomel: not distinguishable from Phyllacanthus.
Plegiocidaris, Paracidaris, Procidaris, Eucidaris } Pomel: hopelessly indistinguishable.
Anaulocidaris Zittel: not distinguishable from Cidaris.
Discocidaris Döderlein: not " " Goniocidaris.
Mikrocidaris, Triadocidaris, Miocidaris } Döderlein: not distinguishable from each other and too near Cidaris and Dorocidaris.
Phalacrocidaris[1] Lambert: ?
Aulacocidaris[1] Lambert: ?
Tretocidaris Mortensen: see below.
Schizocidaris Mortensen: not worthy of separation from Goniocidaris.
Petalocidaris Mortensen: " " " " " "
Histocidaris Mortensen: " " " " " Porocidaris.

[1] I have been unable to see the original descriptions or any figures of these two genera, as the papers in which they are published are not to be found in either Cambridge or Boston. But *Aulacocidaris* (Lambert, 1903; Bull. Soc. Hist. Nat. Savoie, (2) VIII, p. 222) is evidently closely related to *Phyllacanthus* and is probably not distinguishable, while *Phalacrocidaris* (Lambert, 1902; Mem. Soc. Geol. France, Pal. IX, fasc. III, Mem. 24, p. 27) is based on Döderlein's living species of *Stereocidaris* from Japan, but includes a number of fossil forms. As *Stereocidaris* is itself only distinguishable with great difficulty, it is very unlikely that *Phalacrocidaris* is tenable.

The genus Dorocidaris is difficult to separate, on the one hand, from Cidaris, and on the other from Stereocidaris, but is particularly close to the latter, and it is almost impossible to draw a sharp line between them. Moreover, it contains a rather heterogeneous lot of species. One of these, *D. micans* Mortensen, seems to be quite unique, and I think it may well be made the type of a new genus for which I would suggest the name **Calocidaris**. The remaining species fall naturally into three groups, distinguished from each other by their abactinal systems, spines, pedicellariae, and distribution. I see no objection to recognizing these groups as genera, and such a course has some obvious advantages. A typical Dorocidaris such as *papillata* has the abactinal system irregularly angular and often indistinctly defined, and the globiferous pedicellariae have a conspicuous end-tooth on each valve. But other species have the abactinal system circular or pentagonal and sharply defined, and some of the globiferous pedicellariae are often more or less like those of Cidaris. To this group *D. bartletti* A. Ag. belongs, and as Mortensen has made that species the type of a new genus, Tretocidaris, that name must attach itself to this section of Dorocidaris, even though few of the species have the remarkable pedicellariae which Mortensen considers the distinguishing character of the genus. Finally, a group of three small species, characterized by their thickened secondaries, globiferous pedicellariae without end-tooth on the valves, sparsely tubercled abactinal system, and antarctic or subantarctic distribution, may be conveniently designated as **Austrocidaris**. The table on the opposite page gives the genera adopted in the present paper, with their authors, the year in which they were proposed, and the type-species of each. The number of recent species in each, which seem to me valid, is also indicated.

The number of fossil specimens to which specific names have been given is in the vicinity of 200; of these, Döderlein lists 135, but there is reason to believe that many of these represent different ages or individual forms of single species, and it is not unfair to assume that the number of extinct species actually known to science does not exceed the number of species now living. The following key will bring out the obvious if not the most important characters by which the 21 genera here recognized may be distinguished. It is hoped that such a key may be of use to palaeontologists as well as to zoölogists. The dimensions are given in millimeters, and the horizontal diameter of the denuded test (abbreviated for convenience to "h. d."), taken at the ambitus, is used as the unit for determining the relative proportions of the various

Genus.	Author.	Year.	Type-species.	Number of Recent Species.
Cidaris . . .	Leske. . . .	1778	tribuloides Lamarck	3
Phyllacanthus .	Brandt . . .	1835	imperialis Lamarck	5
Goniocidaris .	L. Agassiz et Desor . . .	1846	geranioides Lamarck	7
Diplocidaris . .	Desor. . . .	1854	gigantea Agassiz	0
Porocidaris . .	Desor. . . .	1854	veronensis Desor, but of recent species, purpurata Wyv. Thomson	6
Polycidaris . .	Quenstedt . .	1858	multiceps Quenstedt	0
Orthocidaris .	Cotteau . . .	1862	inermis A. Gras	0
Temnocidaris .	Cotteau . . .	1862	magnifica Cotteau	0
Stephanocidaris	A. Agassiz . .	1863	bispinosa Lamarck.	3
Chondrocidaris	A. Agassiz . .	1863	gigantea A. Agassiz	1
Dorocidaris . .	A. Agassiz . .	1869	abyssicola A. Agassiz . . .	5
Tetracidaris .	Cotteau . . .	1872	reynesi Cotteau	0
Tylocidaris . .	Pomel . . .	1883	gibberula L. Agassiz et Desor.	0
Stereocidaris .	Pomel . . .	1883	cretosa Mantell, but of recent species, grandis Döderlein .	9
Tretocidaris. .	Mortensen . .	1903	bartletti A. Agassiz	9
Acanthocidaris	Mortensen . .	1903	curvatispinis Bell	3
Centrocidaris .	A. Agassiz . .	1904	doederleini A. Agassiz . . .	1
Anomocidaris .	A. Agassiz and Clark . . .	1907	japonica Döderlein.	1
Aporocidaris .	A. Agassiz and Clark . . .	1907	milleri A. Agassiz	3
Calocidaris . .	gen. nov. . .	1907	micans Mortensen	1
Austrocidaris .	gen. nov. . .	1907	canaliculata A. Agassiz . . .	3

21 genera and 60 recent species.

parts. The other abbreviations used are self-explanatory. The "vertical diameter" means the vertical distance from the *margin* of the abactinal system, at the end of an ambulacrum, to the lowest part (usually several millimeters distant from the edge of the actinostome) of the same ambulacrum, measured with a pair of dividers. When the measurement from the *centre* of the abactinal system is normally very different from this, special reference is made to the fact. In all cases maximum measurements are used for comparison; thus, when it is said that the "abactinal system equals .40 h. d.," what is meant is that the *greatest* diameter of the abactinal system (it is not always circular) equals .40 of the greatest diameter of the test. "Primary spines about equal to h. d." means that the *longest* primary is about equal to the greatest diameter of its own test. The relative position of the pores of a pair is indicated as "horizontal" or "oblique," according to whether a line drawn outward from the tubercle on the margin of the median ambulacral area, at right angles to that margin, passes above both pores or

through the outer pore of the pair. Unless otherwise noted, the colors given are those of dried Museum specimens.

In using this, and all other keys given, it should be constantly borne in mind that the younger the individual, the less will it show generic and specific characters; in proportions, number of coronal plates, and of secondary and miliary spines, arrangement of the abactinal system, form of the primary spines, and color, the young are often quite different from the adults. They can only be identified with certainty on comparison with other specimens, old, young, and intermediate, and usually, for very young specimens, it is necessary to know the place and means of collection. On the other hand, unusually large specimens often have the abactinal system and actinostome relatively smaller than in specimens of more moderate size. Variations of five per cent or more, on either side of any mean given, may therefore be expected. The keys are all based on supposedly normal, mature specimens, the age being estimated by the presence and size of the genital openings, the appearance of the primary spines and abactinal system, and to some extent by the size. Although the radial plates of the abactinal system are not connected with any sort of light-detecting or visual organs, they have been so generally called "ocular" (*ocellar* in German and *ocellaires* in French) plates that the name is here retained, as preferable to the alternative term "radial," which Duncan uses, but which is not really quite so distinctive.

Key to the Genera.

Genera marked with an * have no living representatives.

Pores horizontal or nearly so, distant (space between the two of a pair evidently exceeding diameter of a pore); surface of interval flat, or with a groove connecting pores, never elevated. (Individuals in which this feature is obscure are characterized by stout or more or less thorny spines, 1.5–2 5 h. d. [if less than 1.5 h. d., coronal plates very few, 5 or 6], and unsunken and, even actinally, quite distinct areolae.) Recent species exclusively Indo-Pacific.

With pores in 4 more or less regular vertical series in each poriferous zone.

With 4 vertical series of coronal plates in each interradius from actinostome to ambitus . . . . . **Tetracidaris* 19

With only 2 series of coronal plates in each interradius . . . **Diplocidaris* 191

With pores in only 2 vertical series in each poriferous zone.

Ambulacral and interambulacral plates with more or less numerous, nearly circular pits, irregularly scattered . . . . . **Temnocidaris* 195

1 2 3

Ambulacral and interambulacral plates without such pits.
Abactinal system of numerous thin plates, with very large anal system around which ocular and genital plates form a single narrow ring; genitals, except madrepore, much wider than high, often twice as wide; oculars nearly as high; collar of primaries spotted with white; lowest actinal primaries with very wide collar and a short thick cap of outer layer of spine, flattened, curved, and somewhat serrate at tip, when fully developed . . . *Stephanocidaris*
Abactinal system not as above; collar of primaries not white-spotted; actinal primaries not provided with a distinct cap.
Median interambulacral area less than .30 of interambulacrum *Phyllacanthus*
Median interambulacral area more than .30 of interambulacrum, densely covered with minute tubercles . . . . . *Chondrocidaris*
Pores nearer together, usually more or less oblique, often separated by an elevation and never yoked together by a groove.
All primary tubercles large, smooth, and imperforate . . . . . **Tylocidaris*
Primary tubercles, at least at ambitus, perforate.
Ambulacra more than half as wide as interambulacra . . . . *Centrocidaris*
Ambulacra not half so wide as interambulacra, usually much less.
Coronal plates with areolae so small their diameter is less than one-quarter horizontal length of plate and only about one-half vertical height . . . . . **Orthocidaris*
Coronal plates with areolae which occupy a large proportion of plate.
Ambulacra broad, .35–.45 of interambulacra, with median area correspondingly wide, sometimes sunken and more or less bare; median space of interambulacra, especially along vertical, and inner portion of horizontal sutures, sunken deeper than areolae, especially at angles, and more or less bare; in some species, however, miliary tubercles cover so much of inner half of each coronal plate that parts of vertical suture are concealed and only short, bare, horizontal furrows are visible, and even these may be only faintly indicated. Coronal plates numerous in proportion to h. d., 6–11. Primaries always rough and more or less thorny or prickly, often flaring at tip . . *Goniocidaris*
Ambulacra less than .35 of interambulacra, or, if more than that, primaries not thorny.
Coronal plates numerous and narrow, 9–15, with areolae merging into each other throughout the whole series . . **Polycidaris*
Coronal plates rarely more than 9, areolae at ambitus and abactinally never merged together.
Primary spines long, 2–3 h. d., not at all thorny or prickly, broad and somewhat depressed at base, tapering much but gradually, often slightly curved, and with a conspicuous light-colored or spotted collar, one-fifth or more of the length *Acanthocidaris*
Primary spines very diverse, but never as above.
Only tridentate or, more rarely, bidentate, pedicellariae present, but these abundant and often very large (2–6 mm. high) . . . . . *Porocidaris*

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Globiferous pedicellariae present, but often only small ones.
Abactinal system very large (.60–.70 h. d.); ambulacral plates few, generally less than 80; poriferous zones not at all sunken; secondary and miliary spines alike, cylindrical and more or less club-shaped; no tridentate pedicellariae present . . . . . *Aporocidaris*
Abactinal system less than .60 h. d.; ambulacral plates more than 40 (except, of course, in young individuals).
Abactinal surface conspicuously bare, with no primary spines or well-developed tubercles or areolae much above ambitus; no tridentate pedicellariae present . . . . . *Anomocidaris*
Abactinal surface not so conspicuously bare; at least two primary spines well above ambitus in each interradius.
Areolae little or not at all sunken; actinostome generally larger than abactinal system, which is usually .40–.45 h. d.; median ambulacral area with only a single marginal series of tubercles, though there are usually other smaller, scattered tubercles between, and these may form 1–5 vertical series. Primaries .65–1.60 h. d. but commonly about equal to h. d., rather stout, usually blunt; secondaries broad, flat, and truncate . . . . . *Cidaris*
Areolae more or less deeply sunken; actinostome usually smaller than abactinal system; median ambulacral area usually with a double marginal series of tubercles, inner much smaller. Primaries 1–3 h. d.; secondaries diverse.
Small (25–40 mm. h. d.); abactinal system with few, generally less than 200, tubercles; secondaries, especially ambulacral, rounded, thickened, and more or less club-shaped; no tridentate pedicellariae; large globiferous pedicellariae with no end-tooth on the valves. Subantarctic, north to about 35° S. . . . . *Austrocidaris*
Larger (30–70 mm); abactinal system with more numerous tubercles; secondaries flat and thin, and usually narrow. Tridentate pedicellariae usually present and large globiferous, often with an end-tooth on the valves. Northern hemisphere, seldom south of the equator.
Abactinal system sharply defined, more or less distinctly circular or pentagonal in outline; ocular plates with outer margin convex or straight, little notched by ambulacra. Some or all of large globiferous pedicellariae, if not like small ones, have curved valves, large terminal opening, and no end-tooth, as in Cidaris . . *Tretocidaris*

Abactinal system not very sharply defined, rather irregular in outline, with re-entering angles, between ocular and genital plates; oculars with more or less concave outer margin or deeply notched by ambulacra. Large globiferous pedicellariae never as in Cidaris.

Abactinal system thick and solid, more or less elevated; genital and ocular plates with more or less convex surfaces, thickly and uniformly covered with tubercles of approximately equal size; ambulacral secondaries usually larger than those on genital, ocular, and uppermost coronal plates and often conspicuously contrasted with them. Coronal plates few, 4–7, rarely 8 or 9; uppermost 1 or 2 or even 3 without primary spines. Primaries never smooth, but provided with longitudinal rows of granules, or with ridges, 1 or more of which may be elevated to form conspicuous, though delicate, buttress-like "wings" along basal half of spine; if these buttress-like "wings" are not present, terminal portion of spine often more or less fluted and flaring. Globiferous pedicellariae, both large and small, commonly lack conspicuous end-tooth . . *Stereocidaris*

Abactinal system flat, usually not uniformly covered with tubercles, some of which are also larger than others; ambulacral secondaries not noticeably contrasted with others abactinally. Coronal plates 6–8, rarely 9, all (except usually uppermost 1, or rarely 2) with primary spines. Primaries sometimes perfectly smooth, never with "wings," and seldom with flaring tip. Globiferous pedicellariae, both large and small, commonly with conspicuous end-tooth.

Median ambulacral area .55 of ambulacrum in width; primaries shining as though polished, white more or less shaded with greenish or pink, or both . . . . . *Calocidaris*

Median ambulacral area less than .50 of ambulacrum; primaries never shining as though polished . . . . . *Dorocidaris*

The above key gives little clue to the relationships of the genera with each other, and a natural arrangement must necessarily be largely a matter of speculation. There can be little question that Cidaris is

nearest to the ancestral form and the centre from which the different genera have come. Whether Tylocidaris represents a more primitive type, because of its imperforate tubercles, is an open question. The other genera fall rather naturally into three groups, which correspond to the three "sous-tribus" of Pomel, but the lines between these groups are not clear enough to warrant any recognition of subfamilies. The following table indicates these three groups, and in the succeeding pages the genera will be taken up in the order here given, which indicates roughly their possible relationships.

	Tylocidaris.	
	Cidaris.	
Phyllacanthus.	Goniocidaris.	Dorocidaris.
Chondrocidaris.	Polycidaris.	Tretocidaris.
Diplocidaris.	Orthocidaris.	Calocidaris.
Tetracidaris.		Austrocidaris.
Stephanocidaris.		Centrocidaris.
Temnocidaris.		Aporocidaris.
		Stereocidaris.
		Anomocidaris.
		Acanthocidaris.
		Porocidaris.

Diagnoses of the Genera, and the Recent Species.

In view of the large number of recent Cidaridae described since the publication of A. Agassiz's "Challenger" Echini, a complete revision of the family will not be without value, so, to the extended diagnoses of the genera here accepted, artificial keys to the recent species contained in each are added, with a few remarks concerning each one, and a reference to a good figure when one has been published. Three apparently new species, represented in the Museum of Comparative Zoölogy by several specimens each, are also described and figured. No attempt at a synonymy is made, since the "Revision of the Echini" gives all that is needed in that line for the species long enough known to have been burdened with many names. References to published figures are given for every species which has ever been figured, and photographs are added of all species which have never been figured hitherto, except only *Dorocidaris nuda*, of which no specimen has been available.

TYLOCIDARIS.

Tylocidaris Pomel, 1883, Class. Meth. Gen. Ech., p. 109.

Plate 1054, figs. 1-7, Pal. Franç. Terr. Crét., 7, Cotteau, 1862.

Test small or of moderate size, much as in Dorocidaris; coronal plates 5–8; areolae distinctly sunken, sometimes large, and tending to merge together vertically; primary tubercles large, smooth, and imperforate; median interambulacral and ambulacral areas and poriferous zones as in Cidaris or Dorocidaris; pores large, close together, slightly oblique. Abactinal system of moderate size, about .45–.50 h. d. Actinostome somewhat smaller than abactinal system. Primary spines very stout, club- or acorn-shaped. Secondaries and pedicellariae ?

It is difficult to know how much weight can wisely be laid on the absence of perforations in the tubercles, but it is a character never shown in perfect tubercles of living Cidaridae. On the whole, the combination of imperforate tubercles with the curious short, stout spines makes the genus easy to recognize. Döderlein ('87) lists four species, all from the Cretaceous of Europe.

CIDARIS.

Cidaris Leske, 1778. Add. Nat. Disp. Ech., p. 17.

Test moderately high; vertical diameter usually about .60 h. d. (ranges from .50–.75); thick and solid (in *metularia*, thickness of an ambulacral plate at ambitus is about .55 of its horizontal length); coronal plates 6–9 (sometimes 10, very rarely 11); areolae not sunken but tending to merge together actinally; median interambulacral area little or not at all sunken, more or less uniformly tuberculated; sutural lines often not visible at all; ambulacra .20–.35 of interambulacra in width; poriferous zones little sunken; median ambulacral area with a single conspicuous marginal series of tubercles and 1–3 (rarely none, or in large specimens 4 or 5) irregular vertical series of much smaller ones between; sutural lines more or less obscured and not conspicuously sunken; pores oblique, with distance between two of same pair about equal to diameter of a pore and with surface of interval more or less elevated. Abactinal system .30–.50 h. d. Actinostome .40–.55 h. d., usually larger than abactinal system, sometimes half as large again. Primary spines about equal to h. d. (range from .65–1.60 h. d.), stout, cylindrical or terete, usually blunt, slightly rough but not thorny, covered with longitudinal series of granules which are usually low and rounded but may be conspicuous and sharp; actinal primaries not peculiar, little or not at all flattened; ends rounded and generally fluted. Secondary spines flat, truncate, rather broad and not tapering towards tip, which may indeed be widened. Pedicellariae of 3 kinds present as a rule, but tridentate may be wanting, or rarely large globiferous ones fail; latter have curved valves, large terminal opening, and no end-tooth.

This genus is one of the most easily recognized of the family, although some of the individuals with long spines approach quite nearly in appearance to *Tretoci-*

daris affinis. Indeed it is possible that some of the specimens of *C. tribuloides* with long, tapering spines, which have been collected in the West Indies, are really hybrids between that species and *affinis*, but there is no proof that this is the case. There are only 3 valid recent species of Cidaris, and they are quite sharply distinct from each other. The form which Döderlein ('87) described under the name *galapagensis* is not constantly distinct from *thouarsii* and must be referred to that species. All of the living species are littoral forms, and rarely occur at a greater depth than 50 fths., but are found along nearly all tropical and subtropical coasts. Numerous fossil species from Tertiary, Cretaceous, Jurassic, Triassic, and even Permian strata have been named. The following key to the recent species is based on the examination of 845 specimens representing all three.

Key to the Species.

Small, h. d. rarely exceeding 30 mm.; median areas .45–.60 of ambulacral width, usually bare and often sunken; abactinal system .45–.50 h. d.; genital plates always clearly in contact with each other; coronal plates 5 or 6, rarely 7 . . . . . *metularia*

Medium to large, h. d. 30–70 mm.; median areas seldom more than .40 of ambulacral width, always provided with miliary tubercles; abactinal system usually less than .45 h. d.; some or all of genital plates separated in mature specimens; coronal plates 7–10, rarely 11.

Median interambulacral area more than .10 h. d.; abactinal system usually over .40 h. d.; small spines olive, fawn-color, or red-brown, with tips usually darker . . . . . *tribuloides*

Median interambulacral area less than .10 h. d.; abactinal system usually less than .40 h. d.; small spines dark red-brown, purple, or nearly black, with tips not noticeably darker . . . . . *thouarsii*

Cidaris metularia.

Cidarites metularia Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Cidaris metularia Blainville, 1830, Zoöphytes: Dict. Sci. Nat., **9**, p. 212.

Plate 1g, fig. 1, Rev. Ech., A. Agassiz, 1873.

Although having a far more extensive range than either of the others, this species shows much less diversity in the length and form of the primary spines; they are generally about .80 h. d. and are rarely if ever 1.20 h. d. The stalks of the large globiferous pedicellariae have a well-developed "limb." The colors are generally brighter than in the larger species, and the cross-banding of the primaries is usually very distinct; some Hawaiian specimens are very red, more or less marked with yellowish or reddish white. The geographical range is from Cape of Good Hope, northward on the east coast of Africa into the Red Sea (including Madagascar, Mauritius, Bourbon, and the Seychelles), thence eastward along the

southern coast of Asia with the adjoining islands, through the East Indian archipelego and out into the Pacific, as far as the Solomon, Fiji, and Hawaiian Islands. Curiously enough, *metularia* does not seem to reach either Japan (except the Liukiu Islands) or Australia. The only difference that can be detected between Mauritian and Hawaiian specimens is that, in the latter, the median ambulacral area is somewhat broader and flatter, but the difference is very slight and inconstant.

Cidaris tribuloides.

Cidarites tribuloides Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Cidaris tribuloides Agassiz, 1835, Prodrome, p. 188.

Plate 1d, Plate 2, figs. 1-3, Rev. Ech., A. Agassiz, 1872.

Little need be said further in regard to this well-known species, save that the primary spines are frequently cross-banded, especially in young specimens, and in old specimens are almost always more or less encrusted with colonies of Bryozoa, and similar foreign material. The relative length and thickness of the primaries differ to a remarkable degree in specimens from different localities. The general appearance of specimens from the Cape Verde Islands is thus strikingly different from that of the ordinary West Indian form. On the other hand, many of the specimens dredged in the West Indies, by the "Blake," have the primaries so long and slender that there is a noticeable superficial resemblance to *Tretocidaris affinis*. Connecting forms between the extremes are, however, common. The stalks of the large globiferous pedicellariae have no "limb." The geographical range is confined to the Atlantic Ocean, from the Bermudas and Azores on the north to Brazil, the Cape Verde Islands, and Cape Palmas on the south. In the Museum are several old tests without spines, which are almost certainly this species, labelled "Mer Rouge," but a mistake in labels is always possible, and these have doubtless been mixed at some time with West Indian specimens. There is also a very small (5 mm. h. d.) but perfect specimen from "51° 26′ S. and 68° 5′ W., 57fths.," collected by the "Hassler." If there has been no mistake, this would indicate a remarkable southern range. Small specimens from Ascension Island, Atlantic Ocean, in the collection of the National Museum, like those collected by the "Challenger" at Bahia, and Fernando Noronha, Brazil, have verticillate swellings on the primaries, but are not otherwise peculiar.

Cidaris thouarsii.

Cidaris thouarsii Agassiz and Desor, 1846, Cat. Rais. Ann. Sci. Nat. (3) **6**, p. 326.

Plate 10, Jap. Seelgel, Döderlein, 1887.

This is the well-known substitute for *tribuloides* on the west coast of America. It is easily distinguished from that species by the color and other characters mentioned above. Its range is comparatively limited, however, as it is not known from south of the equator (save in the Galapagos) nor from north of the Gulf of Cali-

fornia. After a careful comparison of numerous excellent specimens from Mexico, Panama, and the Galapagos, it is clear that there is no constant character by which *C. galapagensis* Döderlein ('87) can be distinguished from *thouarsii*. Specimens from the Galapagos usually have the short and very stout spines figured by Döderlein, and apparently do not have tridentate pedicellariae, but some Galapagos specimens have long, slender, tapering spines, while some from the coast of Mexico have spines like those of most Galapagos specimens; and individuals from Panama occasionally lack the tridentate pedicellariae. Döderlein's present opinion (1906) seems to be that *galapagensis* should be regarded as a variety of *thouarsii*.

PHYLLACANTHUS.

Phyllacanthus Brandt, 1835, Prodrome, p. 267.

Test much as in Cidaris but thinner; thickness of an ambulacral plate only .30–.40 of its horizontal length; coronal plates vary greatly in different species, ranging from 5 to 11; areolae not at all sunken and usually quite distinct even near actinostome; median interambulacral area not deeply sunken, though it may be bare and sutural lines distinct; ambulacra .20–.40 of interambulacra in width; poriferous zones little sunken; median ambulacral area generally with a double series of marginal tubercles (inner much smaller than outer) and 1–4 additional, more or less regular, vertical series between; but when ambulacra are very narrow, median area may be as in Cidaris, and when very broad, median area may be bare and without additional tubercles; pores nearly or quite horizontal; distance between two usually much greater than diameter of pore; surface of interval flat or horizontally grooved, so that pores are connected by a furrow. Abactinal system much as in Cidaris. Actinostome varies greatly in different species. Primary spines exceedingly variable, usually 1.5–3 h. d. and quite stout; actinal primaries either as in Cidaris or somewhat flattened, thick and truncated at tip, slightly curved and somewhat serrate. Secondary spines flat, but length and breadth very variable. Large globiferous pedicellariae variable in form and often entirely lacking, but tridentate and small globiferous pedicellariae are generally present.

Large specimens of this genus are easily recognized, but small ones are often puzzling. In very young specimens the pores are arranged much as in Cidaris, and this condition has not wholly disappeared in specimens 20 mm. in diameter; in *thomasii* even the largest specimens do not have the interval between the pores perfectly flat. On the whole the genus is difficult to characterize properly and the recent species are not well defined. But the combination of characters mentioned in the key to genera is unlike that of any other cidaroid, and with proper care a specimen of Phyllacanthus over 30 mm. h. d. should be recognized without great difficulty. No other genus, however, shows so great diversity in the length and form of the spines, and, as might be supposed, the pedicellariae are also very variable. There seem to be only five valid species in this genus, but it must be confessed that the confusion of *baculosa* with *annulifera*, and the latter with *Stephanocidaris bispinosa*, has led to a most unfortunate situation, and there can be no doubt that a careful revision of the genus based upon abundant material from the

Red Sea, Mauritius, the East Indies, and Australia is sadly needed. In the light of such material I believe that additional species will be recognized, and it is quite possible that the genus will need to be divided. For the present, however, I see no better course than to let the genus stand as it is. It seems to be generally agreed that Studer's ('80) *Schleinitzia crenularis* is a Phyllacanthus, probably *annulifera;* while the observations of Döderlein ('87 and : 03) and de Meijere (: 04) show that *Ph. dubia* Brandt ('35) and *parvispina* Woods ('80) are apparently synonyms of *imperialis*. The species designated *australis* by Ramsey ('85) is apparently *baculosa* and *Rhabdocidaris recens* Troschel is clearly *annulifera*. All of the recent species are littoral and are confined to the Indo-Pacific region, but many extinct species have been described from Tertiary, Cretaceous, and Jurassic strata of Europe and America. The following key to the living species is based on the examination of only 118 specimens, but each of the five species is represented by at least four examples.

Key to the Species.

Ambulacra very broad, .40 interambulacra or more; median area broad, sunken and bare; median interambulacral area also sunken and bare; primaries seldom exceed h. d., provided with several whorls of vertical plate-like projections or flat, blunt thorns . . . . . *verticillata*

Ambulacra less than .40 interambulacra; median ambulacral and interambulacral areas not conspicuously sunken and bare.

Collar of primary spines without spots or longitudinal lines of deep red or purple.

Coronal plates 5–6 (rarely 7); abactinal system small (.30–.40 h. d.); actinostome large (.50–.55 h. d.) . . . . . *imperialis*

Coronal plates 6–9 (rarely 10); abactinal system nearly equals or often exceeds actinostome.

Primary spines stout 1.5–2.5 h. d., terete, slightly swollen above collar, smooth, or with granules arranged in longitudinal series, becoming ridges near tip; no conspicuous thorns or projections . . . . . *thomasii*

Primary spines not as above, sometimes flattened at base, usually with conspicuous thorns; collar smooth, reddish or purplish, unspotted . . . . . *annulifera*

Collar of primary spines with noticeable spots of purple or deep red, arranged in longitudinal rows and sometimes merged into lines . . *baculosa*

Phyllacanthus verticillata.

Cidarites verticillata Lamarck, 1816, Anim. s. Vert., **3**, p. 56.
Phyllacanthus verticillata A. Agassiz, 1872, Rev. Ech., pt. **2**, p. 151.

Plate 1f, fig. 3, Rev. Ech., A. Agassiz, 1873.

This well-known and unmistakable species reaches a diameter of 35–40 mm. The general coloration is dark brown and green, with the shades lighter in young

individuals. It ranges throughout the East Indian region, north to Anima Oshima in the Liu-kiu Islands and southward along the east coast of Australia; it has been reported from as far west as Mauritius and Zanzibar, and as far east as the Fiji, Samoan, and Hawaiian Islands. Its occurrence in the latter group seems doubtful, as it was not represented in the very extensive collections made by the "Albatross" in 1903. Although ordinarily a littoral form, a specimen from a depth of 547 fths. is reported by de Meijere (:04).

Phyllacanthus imperialis.

Cidarites imperialis Lamarck, 1816, Anim. s. Vert., 3, p. 54.
Phyllacanthus imperialis Brandt, 1835, Prodrome, p. 268.

Plate 1f, figs. 3, 6, 7, Rev. Ech., A. Agassiz, 1873. Plate 58, figs. 3, 4, Semon's gesam. Ech., Döderlein, 1903.

This is another well-known species, dark brown or purple in color, and of large size (up to 75 mm. h. d). Some or all of the primary spines frequently have two or more narrow rings of light color near the distal end. The geographical range of this species is from the Red Sea and Zanzibar to and throughout the East Indies and along the east coast of Australia. I am in doubt as to whether the varieties recognized by Döderlein are really sufficiently constant to be worthy of names.

Phyllacanthus thomasii.

Phyllacanthus Thomasii A. Agassiz and Clark, 1907, Haw. Pac. Ech.: Cid., p. 15.

Plates 27-30, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This handsome species reaches as large a size as the preceding, and the long, tapering, stout spines give it a very characteristic appearance. In the largest specimens the small spines and test are dark reddish-brown, but in specimens .30–.40 mm. h. d., the ambulacra and their spines are very pale brown, in sharp contrast to the interambulacra and abactinal system. At all ages the primary spines are salmon-colored, thickly spotted with white, and having a brown collar, but in old specimens they are more or less encrusted with foreign material which conceals the true color, and the collar is much wider and darker than in the young. This species is known only from the vicinity of the Hawaiian Islands.

Phyllacanthus annulifera.

Cidarites annulifera Lamarck, 1816, Anim. s. Vert., 3, p. 57.
Phyllacanthus annulifera A. Agassiz, 1872, Rev. Ech., pt. 1, p. 150.

Plate 58, figs. 5-11, Semon's gesam. Ech., Döderlein, 1903.

This species has been so persistently confused, on the one hand with the much rarer *Stephanocidaris bispinosa* (q. v.), and on the other with an East Indian variety of the much commoner *Ph. baculosa*, that the limits of its geographical

range are really unknown. There appears to be a variety of *baculosa* common in the East Indies, in which the primaries are cross-banded as in this species, and this form has been confused with *annulifera*. Now if de Loriol ('73) and Mortensen (:03) were correct, it would be clear that Lamarck's *annulifera* is this variety of *baculosa*, and in that case the present species should be called *lütkeni*, as de Loriol clearly figures and describes it under that name. Mortensen says he has examined Lamarck's type and it is *baculosa*, but A. Agassiz examined all of Lamarck's types some forty years ago and satisfied himself that the present species is Lamarck's *annulifera*. In a disagreement such as this it is obvious that the earlier investigation is the one least liable to error, for there had been considerably less time for a chance confusion of labels or specimens. Both de Loriol and Mortensen apparently overlook the fact that A. Agassiz examined Lamarck's types in Paris and that there has never been the slightest reason for supposing that he made any mistake in associating Lamarck's name with this species. Until it can be shown that such a mistake was made, the name it has borne so long should be retained for this species. So far as we now know, it is an Australian and East Indian form, and does not occur in the Red Sea or along the African coast. The Museum of Comparative Zoölogy has two fine specimens from the Gulf of Siam, received from the Copenhagen Museum. They were collected by Mortensen, and labelled by him "Stephanocidaris bispinosa." The species is apparently nearly as variable as *baculosa*, both in coloration and in the form of the primary spines; in some cases the secondaries are green and the primaries cross-banded with purple and green, but in other specimens the secondaries are pale brown and the primaries are dull with less distinct markings. The secondaries usually (perhaps always?) have a median longitudinal stripe, darker than the ground color. The primaries are frequently flattened and widened at the base, tapering to the tip and quite thorny, much as in Stephenocidaris, but they are often nearly cylindrical with few thorns. I am not satisfied that the varieties recognized by Döderlein are sufficiently constant to warrant their recognition by name.

Phyllacanthus baculosa.

Cidarites baculosa Lamarck, 1816, Anim. s. Vert., 3, p. 55.
Phyllacanthus baculosa A. Agassiz, 1872, Rev. Ech., pt. 1., p. 150.

Plate 1f, figs. 4, 5, Rev. Ech., A. Agassiz, 1873. Plate 59, figs. 1–5, Semon's gesam. Ech., Döderlein, 1903.

Common, variable, and widely distributed as is this much-discussed and perplexing species, its true characters and the limits of their variability are still little understood. It seems useless in the present state of our knowledge to attempt to recognize varieties, and we can only say that with all the diversity of coloration and of primary spines, the deep red or purple spots on the collar of the primaries is an obvious character almost always present. It is true de Loriol ('83) and de Meijere (:04) have described specimens with a narrow unspotted collar, but it is

quite possible that these are not really *baculosa*. It is interesting to note that the purple spots on the collar may merge together, not only longitudinally so as to form parallel vertical lines, but also diagonally, so that the collar appears checkered with light-colored, diamond-shaped spots. These spots are occasionally rounded, and then the color shows some resemblance to that of the primaries of Stephanocidaris. Further evidence of the close relationship existing between that genus and *baculosa* is found in the abactinal system of the latter, where some or all of the ocular plates may be broadly in contact with the anal system. The coronal plates are 8–10 or even 11 in the largest specimens (64 mm. h. d.), and the color is brownish-red or purplish, but is quite variable. The geographical range appears to coincide with that of *imperialis*. A remarkably handsome spine of a Phyllacanthus, quite unlike any of *baculosa* which I have seen, in the Museum collection from "Ile Bourbon," inclines me to Mortensen's (:03) view that the identity of *baculosa* and *pistillaris* is still open to question. If it is not doubtful, this species ought to be called by the latter name, as it has precedence in Lamarck's work. Döderlein (:06), on the strength of Loven's ('87) description and figure, adopts the Linnean specific name *cidaris* for this species, quite overlooking Loven's own statement (p. 146): "Be that as it may, the species name: Cidaris L., left to its fate by the author himself, is to be laid aside as without validity, though of some historical interest." In the collection of the United States National Museum there is a notably fine specimen (No. 14,032) from the Bonin Islands, labelled "*annulifera*"; the secondaries are very long, with a deep brown longitudinal stripe, and the collar of the primaries has some indistinct white spots as well as the characteristic deep purplish-red dots. It is quite possible this is an undescribed species. In the same collection is a large series of specimens from Aden (No. 21,459), which have been labelled by Dr. Mortensen "Cidaris metularia"; the primaries are remarkably short and stout, much as in Cidaris, and as Mortensen did not clean an ambulacrum, it is not strange that he failed to see the very characteristic poriferous zones. But it is hard to understand how he overlooked the conspicuous purple spots on the collar of the primaries.

CHONDROCIDARIS.

Chondrocidaris A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Test much as in Phyllacanthus, but densely covered with minute tubercles bearing miliary spines and small globiferous pedicellariae; median interambulacral area very broad, generally .35–.40 of interambulacrum, nearly flat; ambulacra narrow, only .20–.25 of interambulacra; median ambulacral area covered with about eight vertical series of tubercles, of which the marginal ones are slightly larger; pores horizontal, widely separated, connected by a groove. Abactinal system .35–.40 h. d., with ocular plates entirely excluded from anal system; genitals broadly in contact. Actinostome about equal to abactinal system. Primary spines stout, nearly cylindrical, sometimes slightly tapering, about equal to, or somewhat exceeding h. d., provided with stout, blunt, thorny projections, and often near the tip with longi-

tudinal lamellae. Secondary spines few, flat, and blunt, confined to scrobicular circles and margins of ambulacra; latter very slender. Large globiferous pedicellariae usually wanting; tridentate infrequent, with slender straight valves; small globiferous abundant, on very short stalks, with prominent end-tooth on valves.

This is a monotypic genus, closely related to the preceding but easily distinguished at a glance by the peculiarly bare appearance of both ambulacra and interambulacra.

Chondrocidaris gigantea.

Chondrocidaris gigantea A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Plate 1a, Rev. Ech., A. Agassiz, 1873.

This species is of special interest because of its huge size (up to 95 mm. h. d.), its remarkable primary spines, and its very broad median interambulacral areas densely covered with minute miliaries. The color is brown of some shade, the countless miliaries with a distinctly greenish-yellow cast. It is a curious fact that really young specimens of *gigantea* have not yet been taken, none in the collections of either the National Museum or the Museum of Comparative Zoölogy being less than 75 mm. h. d., and de Loriol's ('83) specimen, the smallest yet recorded, was more than half that size. Most of the known specimens are from the Hawaiian Islands, but it is also reported from Lifu, Loyalty Islands (Bell, '99), and Mauritius (de Loriol, '83). The latter is remarkable for having only 5 coronal plates, while Hawaiian specimens have 8–10. The record of this species from the Lepar Islands, given by Sluiter ('95), is said by de Meijere (:04) to rest only on spines of "*C.* (*Stephanocidaris*) *bispinosa*."

DIPLOCIDARIS.

Diplocidaris Desor, 1854, Syn. Ech. foss., p. 45.

Plate 1, fig. 5, Syn. Ech. foss., Desor, 1854.

Test much as in Phyllacanthus; coronal plates 7–8; areolae little or not at all sunken, sometimes merging together actinally; median interambulacral area not sunken or bare, but with few, scattered tubercles; ambulacra narrow, less than .25 of interambulacra in width; poriferous zones more or less sunken; median ambulacral area narrow, with usually only a single marginal row of tubercles, the intervening bare space sometimes conspicuous; pores nearly horizontal and widely separated, in vertically very narrow plates, which are so crowded that they have the appearance of having slipped on each other laterally, so that the pores are apparently in 4 vertical series in each zone. Abactinal system small, with large, usually angular, genital and small ocular plates. Actinostome larger than abactinal system. Primary spines very stout, with longitudinal series of low tubercles which tend to merge into ridges near the tip. Secondaries and pedicellariae?

This genus is very different from any living Cidaridae in the arrangement of the pores, but in all other respects it is strikingly like Phyllacanthus, especially some

specimens of *Ph. imperalis*. The crowding of the pores is very similar to what occurs in Asterias and other starfishes, where the ambulacral plates are so crushed together that a straight, single row of pores is forced into such a zigzag arrangement that it has the appearance of two parallel series. There is no reason to consider the arrangement in Diplocidaris as anything other than a highly specialized condition. It seems strange that it is not found in any living species of Cidaridae. Döderlein ('87) lists 5 species of this genus, all from the Jurassic strata of Europe.

TETRACIDARIS.

Tetracidaris Cotteau, 1872, Rev. et Mag. Zoöl. (2), **23**, p. 445.

Plate 29, figs. 7–11, Rev. et Mag. Zoöl. (2), 23, Cotteau, 1872.

Test large, circular at ambitus, somewhat depressed; coronal plates very numerous (16 in each complete vertical series), arranged in 4 series in each interradius from actinostome to above ambitus and thence in a double series to the abactinal system; areolae somewhat sunken; median interambulacral areas narrow and with few miliaries; ambulacra narrow, only about .20 of interambulacra in width; poriferous zones little sunken; median ambulacral area nearly bare, with a marginal series of tubercles and a few scattered miliaries; pores nearly horizontal, widely separated, and crowded into a double series in each zone, much as in Diplocidaris. Abactinal system "large." Actinostome? Primary spines rather slender, nearly cylindrical, somewhat ridged. Secondaries and pedicellariae?

In the arrangement of the pores this species is intermediate between Diplocidaris and Phyllacanthus, but it is not in any sense a connecting link between these genera. It may be regarded as a specialized offshoot of the Diplocidaris branch. Duncan ('89) thinks it may be related to Astropyga, and there is some reason for thinking it is not genetically connected with the Cidaridae at all. Only one species is known, *reynesi*, from the European Cretaceous strata.

STEPHANOCIDARIS.

Stephanocidaris A. Agassiz, 1863, Bull. M. C. Z., **1**, p. 18.

Test, ambulacra, interambulacra, and relative proportions as in Phyllacanthus, but coronal plates 6–8; abactinal system .40–.45 h. d. and actinostome either larger or smaller; anal system large and made up of numerous plates (in a specimen 42 mm. h. d. there are over 50 anal plates, and in a young specimen 12 mm. h. d. there are 25); all plates of abactinal system relatively thin; genital plates much wider than high, except madrepore, which is much larger than others; ocular plates wide and high, 4-sided, outer side convex, inner usually correspondingly concave; genitals and oculars together form a ring around anal system of

nearly uniform width except where madrepore juts in.[1] Primary spines somewhat flattened near base, conspicuously thorny; collar wide, greenish, reddish or dark with conspicuous white spots; in young specimens these white spots project as granules, but in mature specimens, collar is smooth; actinal primaries slightly curved, with a very wide collar, often more than half their length, and provided with a distinct cap of outer layer of spine; this cap is truncate, thick, and somewhat serrate. Large globiferous pedicellariae are wanting in all available specimens.

Although there can be no doubt of the close relationship between this genus and Phyllacanthus, the discovery of a new species of Stephanocidaris in the Hawaiian Islands, of which numerous specimens are available for study, shows how clearly justified A. Agassiz ('63) was in making *Cidarites bispinosa* Lamarck the type of a separate genus. The characters shown by the primary spines are exhibited in specimens only 12 mm. h. d., and even in these specimens the genital plates are widely separated; it is not, however, until a diameter of over 20 mm. has been reached that the remarkable character of the abactinal system becomes apparent. The three species here recognized are confined to the central and eastern portions of the Indo-Pacific region. The following key is based on the examination of 106 specimens of the first and third species.

[1] It is worth noting that in a young Stephanocidaris 6 mm. in diameter, the ocular plates are all excluded from the periproct, except that of the left posterior ambulacrum, which barely touches an anal plate; in a specimen 7 mm. in diameter, the left posterior ocular is clearly in contact with the anal system and the right posterior ocular barely touches it; in a specimen 12 mm. in diameter, the two posterior, and the left anterior oculars are all clearly in contact with, while the odd anterior ocular barely touches, the periproct; in another specimen of the same size, all the oculars except the right anterior are clearly included; in a specimen 14 mm. in diameter, and in all larger ones, all the oculars are broadly in contact with the anal system. It seems to be true, therefore, of Stephanocidaris that the oculars of the bivium come into contact with the periproct before those of the trivium do and of the latter the right anterior ocular is the last to enter. Examination of a series of young *Cidaris tribuloides* shows that the same course is followed in that species, except that in one specimen the odd anterior ocular was excluded, while the right anterior was no longer so. These facts are strikingly in accord with the condition often found in Tretocidaris and always in Acanthocidaris, where the right anterior ocular is the only one excluded. And I may add that in *Arbacia nigra* and *spatuligera*, in adult specimens of which the posterior oculars, and often the left anterior, are in contact with the anal system, the same course of entrance of the oculars is followed; and while I have found a very few specimens in which the odd anterior ocular is also insert, I have yet to find an Arbacia in which the right anterior ocular is not excluded. The reason for this condition is not clear.

Key to the Species.

Primary spines not red; interambulacral secondaries whitish with a longitudinal green stripe.
  Primaries stout, less than 2 h. d.; ambulacral secondaries dark green; abactinal system larger than actinostome . . . . . *bispinosa*
  Primaries slender, 2–3 h. d.; ambulacral secondaries like those of interambulacra; abactinal system smaller than actinostome . . . . *glandulosa*
Primary spines red (in young, sometimes greenish) with more or less indistinct cross-bands of white; secondary spines reddish or brownish, not longitudinally striped; abactinal system not larger than actinostome . . . . . *hawaiiensis*

Stephanocidaris bispinosa.

Cidarites bispinosa Lamarck, 1816, Anim. s. Vert., **3**, p. 57.
Stephanocidaris bispinosa A. Agassiz, 1872, Rev. Ech., pt. 1, p. 160.

Plate 1f, fig. 1, Rev. Ech., A. Agassiz, 1873.

It would be amusing were it not irritating to note how entirely recent writers have ignored Agassiz's (**'73**) description and figure of this beautiful and apparently very rare species. The trouble appears to date from de Loriol's (**'73**) figure, which is certainly not *bispinosa*, but is probably *P. annulifera*, in one of its various color phases; his figure of *lütkeni* is certainly *annulifera*, while his figure of *annulifera* appears to be *baculosa*. Koehler (**'95**) evidently refers to the same form of *baculosa* under the name *annulifera*, while his *Stephanocidaris bispinosa* is probably true *annulifera*. Bedford (**1900**) has apparently identified correctly his specimens of *annulifera*, so far as can be determined from his figures. Döderlein (**:03**) and Mortensen (**:04**) entirely ignore Agassiz's description, or else intimate that the description is inadequate because it fails to apply to their specimens. As a matter of fact, it seems clear that neither of them has seen a specimen of the real *bispinosa*, but since they call the variety of *baculosa* with banded primaries *annulifera*, they are obliged to do something with their specimens of real *annulifera*, and so they suppose them to be *St. bispinosa*, Agassiz's description and figures to the contrary notwithstanding! Their lead is somewhat reluctantly followed by de Meijere (**:04**), who is unwilling to ignore Agassiz's statements; but he, too, records *Ph. annulifera* as *St. bispinosa*. This species reaches a diameter of over 50 mm. Authentic specimens are known only from Australia and Malacca.

Stephanocidaris glandulosa.

Cidaris (*Cidaris*) *glandulosa* de Meijere, 1904, Siboga-Exp. Ech., p. 13.

Plate 1, figs. 5, 6, Siboga-Exp. Ech., de Meijere, 1904.

Among the interesting Echini collected by the "Siboga," in the Dutch East Indies, were 14 small (7–25 mm. h. d.) specimens, taken at depths of 38–51 fths.,

which de Meijere described as *Cidaris glandulosa*. There can be no question of their close relationship to *St. bispinosa*, and it is quite possible, as de Meijere (p. 5) himself suggests, that they are the young of that species. Besides the characters already mentioned in the key, these specimens were remarkable for the number of large globiferous pedicellariae, like those of *P. baculosa*, which they bore.

Stephanocidaris hawaiiensis.

Stephanocidaris hawaiiensis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 18.

Plates 24 and 25, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

A large series of specimens of this handsome species was collected among the Hawaiian Islands by the "Albatross," at depths of 20–320 fths. It is a typical member of the genus, and is not at all likely to be confused with any other species. The largest specimens are 34–42 mm. h. d. and have primaries 90–105 mm. long.

TEMNOCIDARIS.

Temnocidaris Cotteau, 1863, Pal. Franç. Terr. Crét., 7, p. 355.

Plates 1085–1087 bis, Pal. Franc. Terr. Crét., 7, Cotteau, 1863.

Test large, much like Phyllacanthus; coronal plates 6-8; areolae very distinctly sunken; median interambulacral area broad, well covered with miliary tubercles, with more or less horizontal, narrow grooves and deep, circular pits; ambulacra narrow, .20–.25 of interambulacra; poriferous zones considerably sunken; median ambulacral area with numerous tubercles, often arranged in horizontal series, and with a few deep, circular pits; pores widely separated, more or less nearly horizontal and connected as in Phyllacanthus. Abactinal system apparently larger than actinostome. Primary spines stout, as in Phyllacanthus. Secondaries and pedicellariae?

If Duncan ('89) is correct in his surmise that the pits are of post-mortem origin, Temnocidaris becomes of course a synonym of Phyllacanthus. Until this can be demonstrated, however, the genus is entitled to recognition. The three species which have been named are all from the Cretaceous.

GONIOCIDARIS.

Goniocidaris Agassiz et Desor, 1846. Cat. Rais. Ann. Sci. Nat. (3), 6, p. 337.

Test moderately high, .50–70 h. d., but not especially thick or solid; coronal plates numerous in proportion to h. d., 6–11; areolae somewhat deeply sunken; median interambulacral areas deeply and distinctly sunken (deeper than areolae, especially at angles), and usually bare along vertical suture, often with short, bare, lateral depressions along inner end of horizontal sutures; in some cases, however, vertical suture nearly concealed and only lateral furrows conspicuous; in still

other cases, even lateral furrows only faintly indicated; ambulacra broad, .35–.45 of interambulacra; poriferous zones more or less sunken; median area much broader than a poriferous zone, usually sunken and often bare along middle; each ambulacral plate bears a single secondary tubercle, a little above inner pore, and in addition 1–8 miliary tubercles, between which more or less space is left bare (amount of bare space varies greatly in different species; in *tubaria*, entire median ambulacral area is sunken and bare save for marginal tubercles, while in *mikado* scarcely any bare spaces are visible; other species clearly connect these two extremes); pores oblique or rarely horizontal; distance between two less than diameter of pore; surface of interval elevated or roughened. Abactinal system variable, ranging from less than .40 to over .50 h. d. Actinostome about equal to abactinal system or smaller. Primary spines very variable, .75–2.00 h. d., always rough, and thorny or prickly; tips of some usually more or less expanded into a large and conspicuous crown, cup, or even plate, which is often only of a little greater diameter than thickest part of spine, but may become as much as .50 h. d.; actinal primaries variable, rough or serrate, usually somewhat flattened; secondaries thick, of moderate length, more or less flattened, rounded at the end. Tridentate pedicellariae wanting, and large, globiferous ones with no end-tooth on the valves.

The typical examples of this genus, such as *tubaria*, are very easily recognized, but it is less easy to place such species as *florigera* and *mikado*. Nevertheless the genus is very generally accepted and seems to be a natural group. Mortensen (:03) has made two new genera (Petalocidaris and Schizocidaris) and a new subgenus (Discocidaris) out of the species here included in Goniocidaris, but none of these rest on anything better than some trifling peculiarity in the large globiferous pedicellariae. Whether we are to find the origin of Goniocidaris in such a form as *Phyllacanthus verticillata* may be open to question, but the median ambulacral and interambulacral areas of that species could easily be transformed into those of *G. tubaria*, while perfectly horizontal pores are found in *G. biserialis*. There can be little question, in any case, that the three southern species are closely related to each other, and the same is true of the Japanese forms, while *florigera* seems to be structurally, as well as geographically, intermediate. The genus is apparently recent and confined to the southern and western Pacific Ocean. The following key is based on the examination of 133 specimens, including all of the species, except *florigera*.

Key to the Species.

Each coronal plate with but few (30–70) secondary and miliary tubercles, median interambulacral area conspicuously bare and often sunken; median ambulacral area commonly without miliary tubercles, except near margin, so that it is often bare and usually much sunken.

Small (20 mm. or less h. d.); coronal plates, 6–8; abactinal system about .50 h. d. and actinostome nearly equal; some primaries taper to a point, while in many specimens, others, abactinal ones, are abruptly and enormously expanded at tip into a plate, diameter of which may be .50 h. d.; primaries usually more or less covered, at least near base, with a coat of woolly, calcareous hairs . . . . . *clypeata*

Moderate or large (20–50 mm. h. d.); coronal plates 6–11; abactinal system generally about .40 h. d., and only partially covered with miliary tubercles of various sizes; primaries seldom pointed and with no covering of woolly calcareous hairs.

Abactinal system equal to, or larger than, actinostome; coronal plates with tubercles near vertical suture much smaller than those next to areolae . . . . . *tubaria*

Abactinal system smaller than actinostome; coronal plates with tubercles rather large and of nearly uniform size . . . . . *umbraculum*

Each coronal plate with numerous miliary tubercles, so that median interambulacral area is usually covered by them, except on sutures; if bare sunken areas are conspicuous at all, it is only on inner half of horizontal sutures; median ambulacral area with numerous miliary tubercles, tending to cover it, so that it is never wholly sunken and bare.

Large (25–50 mm. h. d.); abactinal system almost uniformly covered with small tubercles; miliary tubercles on ambulacra, in horizontal series with deep furrows between . . . . . *geranioides*

Small (15–35 mm. h. d.); abactinal system not uniformly covered with small tubercles; miliary tubercles in median ambulacral area never conspicuous, but often filling up entire space.

Lower edge of ambulacral plates occupied by minute tubercles, leaving distinct bare spaces forming small, rectangular pits, which alternate with each other; primaries white or whitish in contrast with reddish-yellow secondaries . . . . . *florigera*

No definite arrangement of tubercles on ambulacra clear, and no distinct bare pits; primaries not "whitish in contrast with" darker secondaries.

Test high, .60–.70 h. d.; abactinal system much less than vertical diameter; primaries more or less covered with calcareous hairs and usually with a conspicuous, flat, horizontal plate just above collar . . . . . *mikado*

Test low, .50–.60 h. d.; abactinal system nearly or quite equals vertical diameter; primaries with relatively few, long and stout thorns, but otherwise smooth . . . . . *biserialis*

Goniocidaris clypeata.

Goniocidaris clypeata Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 82.

Plate 6, Plate 4, figs. 8–20, Jap. Seelgel, Döderlein, 1887.

This is one of the interesting species discovered by Döderlein in Japan, and will be easily recognized from his excellent figures and description. The prevailing color is whitish, pinkish, or brown of some shade. The material collected by the "Albatross" shows beyond question that the little cidaroid described by Döderlein (**'87**) as *Porocidaris gracilis* is a small example of this species, in which the spines with enormously expanded tips are wanting. The "Siboga" cidaroid called *C. hirsutispinus* by de Meijere (**: 04**) is also evidently a young example of this species; the secondaries of *clypeata* are frequently exactly like de Meijere's figure. Except this "Siboga" specimen, *clypeata* is known only from the vicinity of Japan.

Goniocidaris tubaria.

Cidarites tubaria Lamarck, 1816, Anim. s. Vert., 3, p. 57.
Goniocidaris tubaria Lütken, 1864, Bid. Kund. Ech., p 187.

Plate 10, fig. 5. Plate 11.

Of this well-known species, nothing further need be said than that it seems to be perfectly distinct from *geranioides*, although the color (light yellowish, red, or deep brownish-red) is the same as that of many specimens of the latter. The geographical range of this species is Tasmania and northward along the east coast of Australia; a specimen labelled "Goniocidaris geranioides? East India" is in the collection of the M. C. Z.

Goniocidaris umbraculum.

Goniocidaris umbraculum Hutton, 1878, Trans. N. Z. Inst., 11, p. 306.

Plate 10, figs. 3 and 4.

This is the New Zealand representative of the preceding species, and so far as can be determined from the three specimens at hand, is well entitled to specific rank. The bright green color of the test and the larger number of coronal plates (10, as against 8 in *tubaria* of the same size) are good characters in addition to those given in the key.

Goniocidaris geranioides.

Cidarites geranioides Lamarck, 1816, Anim. s. Vert., 3, p. 56.
Goniocidaris geranioides Agassiz et Desor, 1846, Cat. Rais. Ann. Sci. Nat. (3), 6, p. 337.

Plate 1g, figs. 3, 4, Rev. Ech., A. Agassiz, 1873.

Although this species is quite similar to *tubaria* in general appearance, the differences between them seem very constant; in addition to those mentioned above may be added the frequently darker color (nearly black) and the much less thorny spines of *geranioides*. The geographical range appears to be the same.

Goniocidaris florigera.

Goniocidaris florigera A. Agassiz, 1881, Challenger Echini, p. 46.

Plate 1, figs. 7-20, Challenger Ech., A. Agassiz, 1881.

This "Challenger" species from the East Indies shows the same extraordinary variety in its primary spines which is seen in *clypeata*, and it would be surprising if the pedicellariae were not also variable. As I have no greater confidence in the characters furnished by pedicellariae than I have in those which spines afford, I can find no good reason for recognizing the genera and species based on the "Challenger" material, which Mortensen (:03) proposes: — *Discocidaris serrata*, *Schizocidaris assimilis*, and *Petalocidaris florigera*. Certainly if they are to be

accepted, more adequate descriptions are necessary, and the differences between the three species made more tangible. That *C. fimbriata* de Meijere (:**04**) is identical with *florigera* seems to me practically certain.

Goniocidaris mikado.

Discocidaris (*Cidaris*) *mikado* Döderlein, 1885, Arch. Naturg., **51** Jhrg., **1**, p. 80.
Goniocidaris mikado Döderlein, 1887, Jap. Seeigel, p. 15.

Plate 7, Jap. Seeigel, Döderlein, 1887.

This is another of the Japanese echinoids, which Döderlein's excellent work has given us. Although undoubtedly nearly related to the preceding species and to *clypeata*, it is perfectly distinct and easily recognized. The minute, often nearly spherical, secondary spines are very characteristic. The color is almost cream-white, with a purplish tint abactinally and on the primaries. Specimens have as yet been taken only in the vicinity of Japan.

Goniocidaris biserialis.

Stephanocidaris biserialis Döderlein, 1885, Arch. Naturg., **51** Jhrg., **1**, p. 79.
Goniocidaris biserialis Döderlein, 1887, Jap. Seeigel, p. 10.

Plate 5, Jap. Seeigel, Döderlein, 1887.

This species is quite unlike the preceding in its general appearance, but resembles it in the obliteration of the bare depressed areas on ambulacra and interambulacra which characterize the typical members of the genus. The color of *biserialis* is quite variable, ranging from dull brownish-yellow, with more or less of a green tint, to yellow, olive-green, or brownish-red. It is known only from the vicinity of Japan.

POLYCIDARIS.

Polycidaris Quenstedt, 1858, Der Jura, p. 644.

Plate 79, fig. 69, Der Jura, Quenstedt, 1858.

Test of moderate size, circular at ambitus, flattened; coronal plates numerous (9–15); areolae somewhat deeply sunken, merging together throughout the entire vertical series, even at ambitus; median interambulacral areas more or less bare and depressed; ambulacra narrow, .15–.22 of interambulacra, straight; poriferous zones little sunken; median ambulacral area with only a single marginal series of small tubercles; pores oblique, near together, separated by a slight elevation. Abactinal system? Actinostome? Spines and pedicellariae?

Döderlein (**'87**) appears to think this genus is near Dorocidaris, but to me it is clear that its relationships are with Goniocidaris. Except for the narrow ambulacra and the merged areolae, *P. nonarius* is strikingly like *G. umbraculum*. Döderlein lists 5 species, all from the Jurassic strata of Europe.

ORTHOCIDARIS.

Orthocidaris Cotteau, 1862, Pal. Franç. Terr. Crét., 7, p. 364.

Plate 1088, Figs. 1-6, Pal. Franç, Terr. Crét., 7, Cotteau, 1862.

Test of moderate size, circular at ambitus, very little flattened, so that it is subspheroidal; coronal plates numerous (14 or 15); areolae very small, scarcely at all sunken, their diameter less than one-fourth the horizontal diameter of plate at ambitus, and little more than one-half its vertical height; median interambulacral area very broad, covered with miliaries and not sunken; ambulacra narrow, .23 of interambulacra, straight; poriferous zones very narrow, not sunken; median ambulacral area with about 4 vertical series of tubercles; pores oblique, separated by a low elevation. Abactinal system very small, about .25 h. d. Actinostome larger than abactinal system, subpentagonal, about .33 h.d. Spines and pedicellariae?

This is certainly a most un-cidaroid appearing sea-urchin, the straight, narrow ambulacra, the numerous small and nearly uniform miliaries, and the remarkably small areolae and primary tubercles are so unlike the Cidaridae, and yet if the areolae were sufficiently enlarged to merge together vertically, the resemblance to *Polycidaris multiceps* would be quite striking. Only one species has been named, *inermis*, from the Cretaceous of Europe.

TRETOCIDARIS.

Tretocidaris Mortensen, 1908, Ingolf-Exp. Ech., p. 16.

Test moderately high but very variable (.45–.85 h. d.); coronal plates, 4–8; areolae little or moderately sunken, tending to merge together actinally; median interambulacral area more or less depressed, bare or covered with small tubercles, sutural lines usually quite distinct; ambulacra .20–.37 of interambulacra in width; poriferous zones more or less deeply sunken; median ambulacral area with a double series of tubercles along margin, inner much smaller; intervening space may be bare, or more or less covered with scattered tubercles; pores as in Cidaris. Abactinal system .40–.55 h. d., sharply defined, circular, or pentagonal; ocular plates with convex or straight outer margin, little or not at all notched by ambulacra; miliary tubercles covering abactinal system more or less variable in size and somewhat irregularly scattered, leaving bare spaces here and there, especially along margins of genital plates. Actinostome, .37–.50 h. d., generally smaller than abactinal system. Primary spines 1–3 h.d., usually more or less cylindrical or terete, rarely with large and conspicuous thorns, but usually covered with longitudinal series of granules, which may be very low so that spine is nearly smooth or only granular, or may project sharply so that spine is prickly, or may be elevated and merged together so that spine is longitudinally ribbed; actinal primaries equally diverse; secondaries flat and not peculiar. Large globiferous pedicellariae sometimes wanting, sometimes as in Cidaris, sometimes with a very small opening and a powerful end-tooth on valves, and sometimes like small ones, which have a rather large opening and usually an end-tooth.

This genus was established by Mortensen for three recent species (*bartletti, annulata, spinosa*) hitherto placed in Dorocidaris but whose pedicellariae, he

found, were very different from those of *D. papillata*. While the pedicellariae of *bartletti* are much too variable to be used as the basis for a genus, the abactinal system of that species is so noticeably and constantly different from *papillata* that I think the genus Tretocidaris may well be recognized. There are eight other species of Dorocidaris which fall into the same group. It is a much more natural and better differentiated genus than Stereocidaris, which has been quite generally recognized in the last decade. The species of Tretocidaris are widely distributed, occurring in the North Atlantic, the Caribbean and Mediterranean Seas, the Gulf of Panama, northward along the Mexican coast, among the Hawaiian Islands, along the Japanese coast, southward into the East Indies and as far west as Ceylon. I have not attempted to determine whether any extinct species are to be referred to this genus or not. The following key is based on the examination of 938 specimens, representing all of the species recognized except *tiara*.

Key to the Species.

Test very high, .75–.85 h. d.; ambulacra very broad, .33–.37 of interambulacra, with median line bare; primaries with 8 longitudinal ridges (not notched or granular), pale pink at base, olive-green near tip . . *tiara*

Test more flattened, generally less than .70 h.d.; ambulacra generally less than .33 of interambulacra.

Median ambulacral and interambulacral areas bare along vertical sutural line; coronal plates 6–8.

Test moderately flattened or high, .50–.70 h. d.; actinostome moderate, .35–.45 h. d.; median interambulacral area .25 or more of interambulacrum in width, with several series of miliary tubercles on each coronal plate between scrobicular circle and vertical suture; abactinal system fairly well covered with tubercles; primaries 1.25–2.50 h. d.; West Indian.

Abactinal system large, .45–.55 h. d.; areolae at least actinally well-sunken; primaries seldom cross-banded, usually terete, with longitudinal series of numerous minute prickles but never thorny . . . . . *affinis*

Abactinal system small, .40–.45 h. d.; areolae very shallow; primaries prettily cross-banded with reddish (or purplish) and yellowish (or greenish), sometimes cylindrical, often terete, frequently flaring at tip, not uncommonly flattened at base, with longitudinal series of rather coarse teeth and often more or less thorny . *bartletti*

Test much flattened, .45–.55 h. d.; actinostome large (.40–.50 h. d.); median interambulacral area .20 of interambulacrum, with only 1 or 2 incomplete series of miliary tubercles on inner end of coronal plates; genital and ocular plates with margins free from miliaries; Eastern Pacific.

Primaries reddish, very slender, 1–1.50 h. d.; thickness of spine about 6 or 7% of length; covered with 14–15 longitudinal series of low, rounded granules; collar and secondaries dark, uniform, brownish-red; no tridentate pedicellariae . . . . . *panamensis*

Primaries greenish, often cross-banded with darker, stout, about equal h. d.; thickness 8–12 % of length; covered with 12–13 longitudinal series of coarse, sometimes sharp granules; collar light reddish or whitish; secondaries greenish, with a broad longitudinal stripe of brownish- or purplish-red at tip; tridentate pedicellariae common . . . . . *dubia*

Median ambulacral and interambulacral areas not at all bare.

Coronal plates 4 or 5, rarely 6 even in large specimens; primaries slightly swollen near base, terete, almost smooth; large globiferous pedicellariae wanting . . . . . *calacantha*

Coronal plates 6–8, rarely 5 even in small specimens; primaries not as above.

Areolae very small, those on largest coronal plate only .60–.65 of length of plate; abactinal system .40 h. d. and actinostome .35 h. d. . . . . *perplexa*

Areolae moderate or large, those on largest coronal plate .70–.75 of length of plate; abactinal system about .50 h. d. and actinostome about .45 h.d.

Primary spines somewhat flattened, at least near base, with about 10 longitudinal series of coarse, sharp granules which usually become fused near tip into ridges; in old specimens these ridges may occupy entire length of spine, no separate granules being visible, while in other cases granules may be conspicuous as sharp prickles almost entire length of spine; primaries white or whitish, spotted or banded with brownish-red or purple; collar very narrow . . . . . *bracteata*

Primary spines terete, with 12–15 longitudinal series of fine, sharp granules which do not lose their individuality entirely, even near tip of old spines; unicolor, white or pale yellowish; collar of moderate width . . . . . *reini*

Tretocidaris tiara.

Dorocidaris tiara Anderson, 1894, Journ. Asiat. Soc. Bengal, **63**, p. 188.

Plate 5, figs. 2, 2a, Ill. Investigator Zoöl. Ech., Alcock and Anderson, 1895.

This is one of the species collected by the "Investigator," the real position of which is somewhat doubtful, although the figures given in "Illustrations . . . Zoölogy . . . Investigator" (1895, pt. 2, plate 5, figs. 2 and 2a) indicate its position in Tretocidaris. The test is extraordinarily high, even though the measurements given by Anderson represent some other method of estimating the height of the test than that which is here used. There are several reasons why *tiara* is not synonymous with *St. indica* Döderlein, as has been suggested, but it is still more incredible that it should be *T. bracteata*, as Mortensen (:**03**, p. 173) asserts, unless Anderson's description and figures are to be entirely ignored. Either Mortensen has not seen a specimen of *bracteata*, or else his supposed specimen of *tiara* is not *tiara* at all. Anderson's figures and description are remarkably clear and complete, and unusually satisfactory, although he

fails to mention the pedicellariae. The test of *tiara* is chestnut-brown, green abactinally, especially towards the anus; the secondaries are olive-green with a darker longitudinal band. The largest specimen was 42 mm. h. d. The only recorded locality for *tiara* is off Colombo, Ceylon, in 142–400 fths.

Tretocidaris affinis.

Cidaris affinis Philippi, 1845, Arch. Naturg., 11 Jhrg., 1, p. 351.

Plate 1, fig. 5, Rev. Ech., A. Agassiz, 1872. Plate 1, fig. 1, Ingolf-Exp. Ech., Mortensen, 1903.

This well-known species has been confused with *Dorocidaris papillata* so long that it may be hard to believe it is really quite different. We are indebted to Mortensen (:03) for showing its right to specific rank (although he makes no reference to the abactinal system !), but we cannot follow him in placing it in the genus Cidaris. Mediterranean and West Indian specimens appear to be alike in all particulars ; Mortensen says the tridentate pedicellariae were wanting in his Mediterranean specimens, but those in the collection of the M. C. Z. from Cape Sagras and from the Mediterranean have them normally developed. Mortensen says the spines are 1–1.5 h. d., but our large series of specimens show a much greater range, 1.25–2.40 h. d. The largest specimen is 38 mm. h. d. The color is variable, but the small spines of the test are more or less greenish, tipped with dark red, while the entire abactinal system (or at least the sutural lines) and the bare areas on ambulacra and interambulacra are dark red ; the primaries are dull grayish, more or less pink or white near base, and with a greenish or brownish collar. In West Indian specimens the color is often very light, the secondaries and test being nearly cream-color with the former tipped with reddish. In other West Indian specimens the color is sometimes nearly slate-color, with little trace of reddish. This species ranges throughout the North Atlantic eastward into the Mediterranean, and southwestward to Barbados and the Gulf of Mexico, down to a depth of 500 fths.

Tretocidaris bartletti.

Dorocidaris Bartletti A. Agassiz, 1880, Bull. M. C. Z., 8, 2, p. 69.
Tretocidaris bartletti Mortensen, 1903, Ingolf-Exp. Ech., p. 16.

Plates 8 and 9. Also Plate 2, figs. 16–27, Blake Ech., A. Agassiz, 1883.

In his original description Agassiz called attention to the resemblance between the primary spines of this species and of Stephanocidaris. Young specimens of *bartletti*, for this reason, show quite a striking resemblance to young specimens of that genus, but a careful examination shows important differences in the primaries as well as in the test. In spite of the very great diversity exhibited in both its spines and its pedicellariae, there can be no question as to the real relationship of this species. Mortensen (:03) names two closely allied, supposedly new species, which he found in the British Museum ; one, *annulata*, I am unable to distinguish

from *bartletti*, for no characters are given which do not occur in some specimens of that species; the other, *spinosa*, may prove to be a valid species, but its affinities cannot be determined from the published description. The largest specimen of *bartletti* in the collection of the Museum of Comparative Zoölogy is 49 mm. h. d.; another (Plates 8 and 9), not quite so large (47 mm. h. d), has the longest spines 93 mm., nearly all cylindrical and not at all thorny. The test of these specimens is brown, varying from fawn-color to deep red-brown, or even deep red on the abactinal system. In the National Museum there is a magnificent specimen of *bartletti* 68 mm. in diameter. This species is known only from the West Indies in 88–397 fths.

Tretocidaris panamensis.

Dorocidaris panamensis A. Agassiz, 1898, Bull. M. C. Z., **33**, p. 78.

Plates 1, 2, Pan. Deep Sea Ech., A. Agassiz, 1904.

This handsome species is the Pacific representative of *T. affinis*, but is quite obviously distinct. The tridentate pedicellariae are wanting in all of the thirteen specimens examined, of which the largest is 35 mm. h. d. The geographical range of *panamensis* seems to be limited to the west coast of Central America and around Cocos Island, in 66–112 fthms.

Tretocidaris dubia, sp. nov.

Plate 6, figs. 3 and 4.

Test somewhat flattened; vertical diameter about .52 h. d.; coronal plates 6; areolae distinct and not very deeply sunken; median interambulacral area not sunken, very sparsely covered with tubercles, only 6 or 7 on each coronal plate in addition to the scrobicular circle; ambulacra wide, nearly .40 of interambulacra; poriferous zones broad and little sunken; median ambulacral area with a double series of rather large tubercles on each margin, with space between perfectly bare; pores slightly oblique, rather large. Abactinal system .45–.50 h. d., nearly circular, and clearly defined, elevated at centre, very sparsely covered with small secondary spines; genital plates rather large, higher than wide, with pores near outer edge; ocular plates more or less triangular, one (right anterior) or more excluded from anal system, which is about one-half of abactinal system and has an outer series of 7–10 rather large plates and 9–12 smaller ones at centre; all plates of abactinal system carry a few rather coarse tubercles of nearly uniform size; each genital plate has 14–20± such tubercles and each ocular, 8–12±. Actinostome slightly smaller than abactinal system, not at all sunken, closely covered with stout plates, 3 or 4 in each interambulacrum and about 8 or 9 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often truncate or slightly flaring at tip, covered with 12–13 low, longitudinal series of coarse, sometimes sharp granules; actinal primaries much as in Cidaris and usually longitudinally ridged at tip; secondaries long and narrow, flat and slightly widened at tip. Pedicellariae not peculiar; large and small globiferous, as in *panamensis;* tridentate much as in *affinis*. General color of test decidedly greenish, especially abactinally, but anal system reddish-brown; miliary and secondary

spines whitish, longitudinally striated with deep reddish-purple; on secondaries, striations merge to form a broad stripe at tip of spine; primary spines dull grayish, sometimes indistinctly cross-banded with brown; collar flesh-color or whitish. Largest specimen 25 mm. h. d.; vertical diameter, 13 mm.; abactinal system, 12 mm.; actinostome, 11 mm.; longest primary, 25 mm., a trifle more than 2 mm. thick at base.

That this species is closely related to *panamensis* seems clear, but that it is quite distinct is certainly indicated by the available material. None of the specimens of either are in any way intermediate. Both species were taken by the "Albatross" at Station 3378, in 112 fathoms off Galera Point, Cape San Francisco, Ecuador, but only *panamensis* was found near Cocos Island, and only *dubia* at Station 3397, in 85 fathoms off Galera Point. Possibly *dubia* is a more southern species; at any rate, it is known only from the coast of Ecuador.

Tretocidaris calacantha.

Dorocidaris calacantha A. Agassiz and Clark, 1907, Haw Pac. Ech. Cid., p. 11.

Plates 13, 14, 34, 35, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This very distinct species reaches a size of 43 mm. h. d., with spines 81 mm. long. It is very pale brown with a greenish cast, especially on the abactinal system; the secondaries each have a broad green stripe; the primaries are very faintly banded with brown and at the base are finely spotted with white. This is one of the species found by the "Albatross" at the Hawaiian Islands, where it is not rare in 127–198 fths.

Tretocidaris perplexa, sp. nov.

Plate 6, figs 1 and 2; and Plate 7, figs. 1–4.

Test somewhat flattened; vertical diameter, about .55 h. d.; coronal plates 7 or 8; areolae small, only .60–.65 of horizontal length of plate, distinct and not very deeply sunken; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra about one-third of interambulacra in width; poriferous zones, broad and little sunken; median ambulacral area with a double series of tubercles on each margin, inner much smaller, and between these, 3–6 irregular series of small tubercles which sometimes, but not always, conceal vertical suture; pores nearly horizontal, large, their horizontal diameter much exceeding vertical. Abactinal system about .40 h. d., nearly circular and clearly defined, flat and quite thickly covered with small secondary spines; genital plates rather large, nearly square or somewhat pentagonal, with pores near outer edge; ocular plates more or less triangular, with apex truncated, when in contact with anal system, either wholly excluded, or some, or all except right anterior one, in contact with a large anal plate; anal system about one-half of abactinal, with an external series of 10–12 large plates and 12–15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50–80 ± such tubercles and each ocular 20–35 ±. Actinostome small, only about .35 h. d., not at all

sunken, closely covered with stout plates, 4 in each interambulacrum and about 10 pairs in each ambulacrum. Primary spines short, about equal to h. d., nearly cylindrical, seldom tapering, but often flattened and widened at tip, covered with 14–24 longitudinal series of coarse, sharp granules; actinal primaries much as in Cidaris and nearly smooth; secondaries, long and narrow, but rather thick and often with a deep longitud.nal furrow on outer surface at tip, which is thus crescent-shaped in cross-section. Pedicellariae not peculiar; no large globiferous ones were found, but small globiferous and tridentate, like those of *dubia*, are frequent. General color of test decidedly greenish, especially abactinally; miliary spines greenish; secondary spines greenish with a broad longitudinal stripe of deep reddish-purple; primary spines dull grayish with a bright olive-green base and collar. Largest specimen, 50 mm. h. d.; vertical diameter, 27 mm.; abactinal system, 20 mm.; actinostome, 18 mm.; longest spine, 40 mm., 3 mm. thick at base, 5 mm. wide at tip.

In some ways this species is much like *dubia*, but aside from the differences in the tuberculation of the test, the small areolae, abactinal system and actinostome, and the short primaries with olive-green collar and conspicuously flattened tips, are very characteristic of *perplexa*. The resemblance between the two species in the color of the secondary spines is quite noticeable. Two of the five known specimens of this species were collected by the "Albatross" in the Gulf of California on a bottom of coarse sand, in 36–39 fathoms. The other three are said to have been picked up on the shore of Clarion Island, the westernmost of the Revilla Gigedo Islands.

Tretocidaris bracteata.

Dorocidaris bracteata A. Agassiz, 1879, Proc. Amer. Acad., **14**, p. 197.

Plate 10, figs. 1 and 2.

This is apparently the East Indian representative of *bartletti*, though it is a smaller species and obviously quite different. Mortensen (: 03), on the supposed characters of the large globiferous pedicellariae, places *bracteata* in Stephanocidaris, but as we have already seen, he probably did not have a specimen of that genus for comparison. Moreover, the pedicellaria which he figures as a "large globiferous" of *bracteata* is exactly like the *small*, globiferous pedicellariae of this species, while the large globiferous pedicellariae of this species are actually like those of Cidaris. However, these large ones are very infrequent and may be wanting, while the small ones are often very large, and it is apparently one of these latter that Mortensen has figured as the characteristic pedicellaria of Stephanocidaris! It seems to me that this serves as an illustration of the danger of relying on the pedicellariae. This species is relatively small, the largest specimen being only 29 mm. h. d. The secondaries are pale purple or rose, with or without yellowish tips, or flesh-colored with a longitudinal rosy stripe; in old specimens those of the ambulacra may be darker than those of the interambulacra, and thus noticeably contrasted with them, and the abactinal system is dark brownish-red; the primaries always show more or less clearly the dark markings, which are usually pur-

plish, but may be reddish or greenish. Originally discovered by the "Challenger" near Amboina, this species has since been taken only by the "Albatross" in Sagami Bay, Japan. Its bathymetric range is 15–114 fms.

Tretocidaris reini.

Cidaris (*Dorocidaris*) *reini* Döderlein, 1887, Jap. Seeigel, p. 7.

Plate 4, figs. 1–7, Jap. Seeigel, Döderlein, 1887. Plate 1, figs. 2, 3, Siboga-Exp. Ech., de Meijere, 1904.

Although this species is closely related to the preceding, the material at hand supports Döderlein's opinion that his Japanese specimens were a new species; curiously enough, however, he makes no reference whatever to *bracteata!* The primary spines of the two species are quite distinct, as already shown; the ocular plates of *reini* are narrower and higher than in *bracteata* and more broadly in contact with the anal system, and the difference in color is very marked; when *reini* is not uniformly yellowish with dull white spines, the uppermost coronal plates, the interambulacral miliary spines, the genital plates and the anal system are deep reddish, while the ocular plates and ambulacra with all their spines are pale yellowish in marked contrast, just the opposite of the coloration in *bracteata;* the primaries of *reini* are apparently not banded or spotted in adults, but if de Meijere's identification of his small East Indian specimens is correct, the young must be very much like those of *bracteata*. In size and in the pedicellariae, the two species agree well; the largest *reini* reported is 34 mm. h. d. Excepting the four young Cidaroids taken by the "Siboga" near the Kei Islands and Timor which de Meijere refers to this species, but which might just as naturally be called *bracteata, reini* has not been taken yet anywhere but in Sagami Bay and Kagoshima Gulf, Japan, in 83–158 fths.

DOROCIDARIS.

Dorocidaris A. Agassiz, 1869, Bull. M. C. Z., 1, p. 254.

Test much as in Tretocidaris, but ranging up to only .70–.75 h. d. Abactinal system very different, its outline not often sharply defined and rather irregular, with re-entering angles between genital and ocular plates; latter more or less pentagonal and deeply notched by ambulacra. Primary spines cylindrical, at least near base, or terete, sometimes smooth, but usually with longitudinal series of granules, or ridges, never "winged" however, and generally not flaring at tip. Globiferous pedicellariae, both large and small, with a conspicuous end-tooth on the valves; tridentate pedicellariae usually present.

Although this genus is quite easily distinguished from the preceding, the line of division between it and Stereocidaris is exceedingly hard to draw, and it is an open question whether there is sufficient ground for keeping them separate. As small genera are more convenient and wieldy, however, we may retain the division recognizing that the line is a very arbitrary one. As here used, Dorocidaris includes five species, which are found only in the Atlantic Ocean and almost entirely

north of the equator. Numerous fossil Cidaridae from Tertiary, Cretaceous, Jurassic, and possibly even Triassic strata are to be referred to either this genus or the preceding. The following key is based on the examination of 536 specimens, representing all of the living species, except *nuda*.

Key to the Species.

Primary spines more or less white and smooth, rarely conspicuously granular, prickly, or ridged, and neither flaring nor conspicuously flattened at tip; median ambulacral area less than .50 of ambulacrum and almost wholly covered with small tubercles . . . . . *abyssicola*

Primary spines more or less prickly, granular, or ridged.

Each coronal plate with only a few tubercles on inner half (generally less than 25, not counting scrobicular circle); sutural line of ambulacra usually distinctly visible; each ambulacral plate with 1 or 2, seldom 3, tubercles; primaries more or less cylindrical, often flaring at tip, and never conspicuously flattened there; median interambulacral area less than .25 of interambulacrum in width; sutural line usually quite distinctly sunken and bare.

Whole abactinal surface well covered with light-colored secondary and miliary spines . . . . . *papillata*

Whole abactinal surface appearing noticeably bare from small number of secondary and miliary spines present; test light-colored, but all spines reddish-brown or purple . . . . . *nuda*

Each coronal plate with numerous (more than 30) tubercles on inner half; sutural line of ambulacra often not visible, each plate with 2–5 tubercles.

Median interambulacral area less than .25 of interambulacrum; sutural line quite distinct; abactinal system with numerous tubercles (genital plate with 110±; ocular with 30±); primaries often flattened near tip, sometimes greatly expanded into broad flat fans . . . . . *blakei*

Median interambulacral area often more than .25 of interambulacrum; sutural line well concealed by tubercles; abactinal system with rather few, large tubercles (genital plate with 55±; ocular with 20±); primaries terete, covered with sharp granules and never either conspicuously flattened or flaring at tip . . . . . *rugosa*

Dorocidaris abyssicola.

Dorocidaris abyssicola A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 253.

Plate 1, figs. 1–4, Rev. Ech., A. Agassiz, 1872.

This species seems to be quite distinct from *papillata*, and while it is occasionally much like *blakei* or *rugosa* in certain features of the test, the primaries commonly distinguish it from either of them at a glance. In addition to the characters given in the key may be mentioned the following: the abactinal system is very large (.48–.55 h. d.), while the actinostome is relatively quite small (.35–.45 h. d. but only .70–.80 of the abactinal system); the test is usually under

.60 h. d. in vertical diameter, and it, as well as the secondaries, is pale brown or yellowish; the abactinal system is sometimes quite red; the uppermost coronal plates do not carry primaries, and even the second ones may lack a well-developed spine; the primaries are usually about 1.25 h. d. and never exceed 2 h. d. The diameter of the test is usually about 25 or 30 mm. but is sometimes 35 or 40, and the largest specimen is 68 mm. h. d. This species ranges from St. Lucia northward to the coast of South Carolina and the region south of Martha's Vineyard at depths of 100–200 fths.

Dorocidaris papillata.

Cidaris papillata Leske, 1778, Add. Nat. Dis. Ech. Klein, p. 61 (*partim*).
Dorocidaris papillata A. Agassiz, 1869, Bull. M. C. Z., **1**, p. 254.

Plate 1b, Rev. Ech., A. Agassiz, 1872.

Nothing more need be said of this well-known species than that it does not seem to occur in the western part of the Atlantic, but is apparently confined to the northern and eastern parts of that ocean and to the Mediterranean Sea. The bathymetric range is from a few fathoms down to about one thousand. Mortensen's (:**03**, p. 170) assurance that the "Challenger" specimen from St. Paul's Rock is really *papillata* is important in this connection, but I think it possible that the individual may prove to be *rugosa!* In size *papillata* reaches a diameter of 58 mm., while in color it is quite variable, ranging from grayish-white to reddish-yellow, becoming brick-red on the abactinal system, with dull grayish or yellowish primaries.

Dorocidaris nuda.

Dorocidaris nuda Mortensen, 1903, Ingolf-Exp. Ech., p. 171.

This species is apparently distinct from all the other members of the genus, but its real relationships can only be determined when it is more fully described. Possibly it is not so closely allied to *papillata* as I have assumed. The size is not mentioned, but the test is white and the spines purple or reddish-brown. It has been taken only in the Gulf of Guinea and near the Cape Verde Islands, in 53–250 fths.

Dorocidaris blakei.

Dorocidaris Blakei A. Agassiz, 1878, Bull. M. C. Z., **5**, p. 185.

Plate 4, Bull. M. C. Z., 5, 9, A. Agassiz, 1878. Plate 1, Blake Ech., A. Agassiz, 1883.

This is one of the most interesting discoveries of the "Blake," and specimens with fully developed primaries are indeed unique. The color is grayish with more or less of a yellow-brown tinge to the test. The largest specimen is 37 mm. h. d. with spines 76 mm. long. Specimens in which there are none of the conspicuously flattened primaries are easily recognized by the large abactinal system,

.45–.55 h. d., almost uniformly covered with small tubercles; the narrow poriferous zones, about .20 of ambulacra, and the numerous small tubercles on the interambulacra. This species ranges from Havana to Barbados in 197–450 fths.

Dorocidaris rugosa, sp. nov.

Plates 4 and 5. Plate 7, figs. 5–8.

Test rather high, vertical diameter about .60 h. d.; coronal plates 7; areolae deeply sunken and distinct; median interambulacral area very fully covered with tubercles, smallest next to vertical suture, which is quite distinct; ambulacra less than one-third of interambulacra in width; poriferous zones narrow and deeply sunken; median ambulacral area with a double series of marginal tubercles, inner much smaller, and between these some small scattered tubercles tend to conceal vertical suture; pores oblique, small. Abactinal system about .45–50 h. d., irregular in outline, stout and heavy somewhat as in Stereocidaris, covered with rather coarse tubercles; genital plates somewhat pentagonal, with lateral margins concave, and pores not far from centre; ocular plates more or less pentagonal, usually wholly excluded from anal system, but posterior ones sometimes in contact with anal plates, more or less notched on outer edge by ambulacra; anal system not quite one-half of abactinal, with an external series of 10–12 large plates and 12–15 smaller ones at centre; except along margins all plates of abactinal system covered with rather coarse tubercles of nearly uniform size; each genital plate has 50–60 ± such tubercles and each ocular plate 20–30 ±. Actinostome small, about .40 h. d., not at all sunken, closely covered with stout plates, 5 in each interambulacrum and about 10–12 pairs in each ambulacrum. Primary spines long, 2–2.5 h. d., terete, usually swollen just above collar, and thence tapering to tip, covered with 12–16 longitudinal series of conspicuous sharp granules; actinal primaries slightly flattened, a little curved and somewhat serrate; secondaries not peculiar, of moderate length and width, flat, blunt, or truncate at tip. Pedicellariae as in *papillata*. General color of test yellowish or brownish, more or less rose-red or brick-red, abactinally; secondaries and miliaries same as test; primaries whitish or grayish, abactinal ones sometimes bright rose; neck smooth, polished, white, brownish, or pink; collar narrow, pale brownish or rarely lighter than neck. Largest specimen in the Museum of Comparative Zoölogy, 40 mm. h. d.; vertical diameter, 24 mm.; abactinal system, 20 mm.; actinostome, 17 mm.; longest primary, 80 mm., 5 mm. thick near base, somewhat more than 1 mm. thick at tip. In the National Museum is a fine specimen 60 mm. h. d.

This species is clearly the representative of *papillata* in the western Atlantic, but may be readily distinguished from that species by the broader and more completely covered median interambulacral area, the much more fully tubercled median ambulacral area, the more uniformly tubercled abactinal system, and the terete and very prickly primary spines. The distribution of *rugosa* is only imperfectly known; the specimens I have examined are from stations between 32° N. lat. (off Savannah, Ga.) and Barbados and St. Vincent, in 164–337 fathoms. There are 8 specimens in the collection of the U. S. National Museum, several of which have been labelled by Mortensen. One (No. 21,444) is labelled "Stereocidaris ingolfiana," which is a very natural mistake, as small

specimens of the two species are very difficult to distinguish. The others are labelled "Dorocidaris papillata," which is what one would naturally call them, if *rugosa* is not to be recognized as valid.

CALOCIDARIS, gen. nov. (Greek, καλός, beautiful, + *cidaris*).

Test large and rather high; coronal plates 7 or 8; areolae distinct and considerably sunken, the most actinal tending to merge together vertically; median interambulacral area not at all sunken, covered with numerous miliaries and with more or less horizontal grooves or narrow furrows, such as occur in Temnocidaris; ambulacra about .25 of interambulacra in width; poriferous zones scarcely at all sunken; median ambulacral area very wide, about .55 of ambulacrum, with very few tubercles aside from the customary double marginal series; pores oblique, large and close together. Abactinal system not quite .50 h. d., of very irregular outline; ocular plates deeply notched by ambulacra. Actinostome very small, only about .65 of abactinal system. Primary spines 3 h. d., cylindrical, white, smooth, and polished like porcelain, more or less tinged with pink and green; actinal primaries flat and longitudinally fluted, but not notched or serrate. Secondaries flat and tapering, many bluntly pointed. Pedicellariae as in Dorocidaris.

Although in many respects like Dorocidaris, the very broad and nearly bare median ambulacral areas, the remarkable color, and especially the smooth, polished primaries, mark this genus at a glance. The largest primaries are all broken in the specimen in the Musum of Comparative Zoölogy, so that their length is not shown in the figure given. But a specimen in the U. S. National Museum, which is the most beautiful echinoid I have ever seen, is nearly perfect. The primaries are 160 mm. long, rather more than 3 times the diameter of the test, and scarcely taper at all, but are cylindrical throughout their entire length. The genus is monotypic and very few specimens are known. The above description is based on a specimen 61 mm. h. d., from near Barbados, but two other specimens in the U. S. National Museum have been examined.

Calocidaris micans.

Dorocidaris micans Mortensen, 1903, Ingolf-Exp. Ech., p. 23.

Plate 3.

This is easily the handsomest, as well as one of the largest, of the West Indian cidaroids. It reaches a diameter of more than 60 mm. The test is white, and the secondaries nearly so, but the abactinal system and adjoining coronal plates are pale green; the primaries when dry are shining white, with a pink base and occasional faint, irregular marks of the same color; they look as though artificially polished. In alcoholic specimens the spines have a greenish shade and the pink is deeper. The only known specimens of this beautiful species were taken by the "Albatross" off the northwestern coast of Cuba in 205 fths., and by the "Blake" off Barbados in 125 fths.

AUSTROCIDARIS, gen. nov. (Latin *auster*, the south wind, + *cidaris*).

Test flattened, .50–.60 h. d., but otherwise much as in Dorocidaris; abactinal system much more sparsely covered with miliaries; secondaries more or less nearly cylindrical and thickened at tip; primaries generally short, often less than h. d., and usually smooth (in individuals where primaries are long and rough, secondaries are nearly flat, so that resemblance to Dorocidaris is marked). Tridentate pedicellariae wanting and globiferous pedicellariae with no end-tooth on valves; eggs and young carried by female (*mortenseni*?).

Were it not for their geographical isolation it would hardly be worth while to attempt the separation of these three small species from Dorocidaris, but as they have the above given peculiarities in common and are probably more nearly related to each other than to any other forms, it is convenient to keep them apart. They are confined to the southern parts of the Atlantic and Indian oceans, their known range extending from 75° W. to 90° E. longitude and from about 35° to nearly 70° S. latitude. The following key is based on the examination of 70 specimens of *nutrix* and *canaliculata*.

Key to the Species.

Actinal primaries not conspicuously flat, trowel-shaped, and entire.

Median ambulacral and interambulacral areas bare and more or less deeply sunken; interambulacral area usually with a conspicuously deep vertical furrow; vertical diameter about .55–.60 h. d.; abactinal system and actinostome rather small, .35–.40 h. d., about equal, or former smaller . . . . . *canaliculata*

Median ambulacral and interambulacral areas little bare, and not at all sunken; vertical diameter about .45–.55 h. d.; abactinal system and actinostome large, about .50 h. d., about equal or former larger . . *nutrix*

Actinal primaries conspicuously flat, trowel-shaped, and entire; primaries long . . . . . *mortenseni*

Austrocidaris canaliculata.

Temnocidaris canaliculata A. Agassiz, 1863, Bull. M. C. Z., 1, p. 18.

Plate 1, g, fig. 2, Rev. Ech., A. Agassiz, 1873. Plate 2, figs. 1–3, Challenger Ech., A. Agassiz, 1881.

Some of the differences between this species and the next have already been set forth by Mortensen (:03), but he has entirely ignored the more important differences in the test and abactinal system. Moreover he has himself been led astray by the remarkable diversity which this species exhibits in its color, spines, and pedicellariae, and has described as a new species of Stereocidaris, which he calls *lorioli*, the long-spined form of *canaliculata*, which the "Challenger" collected off the mouth of the River Plate (Station 320). The Museum of Comparative Zoölogy contains one of the "Challenger" specimens from St. 320, and also a large

series of specimens from Patagonia. The latter so completely yet gradually connect the individuals having primaries 2.5 h. d. with those from the Falkland Islands in which the primaries are only .65 h. d., that their identity cannot be doubted. Had Mortensen carefully examined an interambulacrum, he probably would not have been misled. Although usually about 25–30 mm. h. d., there are specimens of *canaliculata* at hand 36 and 39 mm.; the primaries range from 16 to 63 mm. The color varies from very pale yellowish (with pink necks on the primaries) to very dark brown. This species is apparently confined to the eastern and southern coasts of Patagonia and the neighboring islands. The bathymetric range is from the shore to 600 fathoms. A specimen in the National Museum, which was obviously collected many years ago, is labelled "Navigator Islands."

Austrocidaris nutrix.

Cidaris nutrix Wyville Thomson, 1876, Journ. Linn. Soc. London, **13**, p. 62.

Fig. 4, p. 63, Journ. Linn. Soc. London, 13, Wyville Thomson, 1876.

There can be little question that this species is quite distinct from the preceding. Like it, however, it shows considerable diversity in color and the length of the primaries; some specimens are almost black, with light-colored primaries, while others have the test and secondaries, as well as the primaries, very light colored. Mortensen (:**03**) asserts, without offering any evidence to support his view, that the specimens collected by the "Challenger" at stations 147, 153 and 156 are not this species because the water was too deep at those stations for a shallow water species like *nutrix*. In view of the fact that a number of echinoderms are known with a very great bathymetric range, we can hardly consider the argument conclusive. The largest specimen of *nutrix* at hand is only 30 mm. h. d., but the primaries are 66 mm., while a specimen 26 mm. h. d. has primaries only 18 mm. This species appears to be confined to Crozet, Heard, and Kerguelen Islands, and the neighboring seas.

Austrocidaris mortenseni.

Goniocidaris mortenseni Koehler, 1902, Belgica Ech. et Oph., p. 5.

Figs. 1, 11, 17, 29, 30, Belgica Ech., Koehler, 1902.

It is quite possible that this species does not belong here, but so far as can be judged from the description and figures given it is most nearly allied to the foregoing species. Koehler says nothing about the secondaries, and as the primaries are very long, it is possible that the secondaries are not especially peculiar. The largest specimen was 26 mm. h. d., with primaries 60 mm. The color of the test and secondaries is very dark, while the primaries are reddish. Koehler says there was no indication that the species is "viviparous," but as he only had a single mature specimen, and that possibly a male, further light is needed on this point. The specimens were collected by the "Belgica" in the Southern Ocean, near 70° S. latitude and 87° E. longitude, in depths of 55–330 fths.

CENTROCIDARIS.

Centrocidaris A. Agassiz, 1904, Pan. Deep Sea Ech., p. 32.

Test very flat, vertical diameter generally less than .50 h. d.; coronal plates 7 or 8; areolae very little sunken; median interambulacral areas narrow, a little sunken, and bare; ambulacra very broad, .55–.60 of interambulacra; poriferous zones little or not at all sunken; median ambulacral area broad, flat, or somewhat depressed, with a double marginal series of tubercles, outer much larger; intervening space bare, or each ambulacral plate may carry an additional miliary tubercle; pores very large, nearly or quite horizontal; distance between two about equal to diameter of pore; surface of interval slightly elevated. Abactinal system moderate, .45–.50 h. d., with few (about 100) tubercles; genital plates much higher than wide, narrow, and bluntly-pointed externally; oculars entirely excluded from anal system, very wide and low but sharply pointed, with a markedly concave outer margin. Actinostome, .40–.45 h. d. Primary spines straight, cylindrical, slender, and nearly or quite smooth, about equal to h. d. or somewhat longer; actinal primaries not peculiar save for a wide collar; secondaries flat, thin, and narrow. All three kinds of pedicellariae usually present; large globiferous ones of two quite distinct sorts, one with broad, flat valves and neither lip nor end-tooth, the other with curved valves (like Cidaris), but with a prominent end-tooth and lip.

This monotypic genus was established for a very interesting and handsome cidaroid taken by the "Albatross" in 1891 off Cocos Island, 52 fths. In 1904–05, the "Albatross" obtained a dozen additional specimens near Hood Island, Galapagos, 100–300 fths., so that it is now possible to diagnose the genus fully. It is quite distinct from Goniocidaris, though it resembles it in the broad ambulacra, but it is doubtful if it is nearer to any other known genus.

Centrocidaris doederleini.

Goniocidaris Doederleini A. Agassiz, 1898, Bull. M. C. Z., **32**, 5, p. 78.
Centrocidaris Doederleini A. Agassiz, 1904, Pan. Deep Sea Ech., p. 33.

Plate 14, figs. 1, 2, Pan. Deep Sea Ech., A. Agassiz, 1904.

In young specimens the primary spines are very white and shining, and have 8–10 slightly elevated, glassy, longitudinal ridges, but these practically disappear with age and the spines become dull and yellowish. In alcoholic specimens the secondaries are green, slightly tipped with dark yellow, while the test is greenish with the lines between the genital and ocular plates and the bare spaces of ambulacra and interambulacra deep purplish or dull red. The largest specimen is 28 mm. h. d. and the longest spines measure 33 mm.

APOROCIDARIS.

Aporocidaris A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 86.

Test flattened, .50–.60 h. d. (but abactinal system sometimes so much elevated that vertical diameter from centre of anal system, .60–.80 h. d.), rather thin and fragile; coronal plates 6, rarely 7; areolae only slightly sunken; median interam-

bulacral area rather wide, bare, and slightly sunken along sutural line; ambulacra about .30 of interambulacra; poriferous zones almost flush with test; ambulacral plates few, 30–32 in largest specimens; median ambulacral area somewhat wider than a poriferous zone; each ambulacral plate is vertically wide and carries only a single tubercle, except in large specimens, when a second smaller tubercle is present and then vertical suture is obscured; pores very close together, somewhat oblique. Abactinal system very large, .60–.70 h. d., either flat or more or less elevated, with few or many tubercles. Actinostome .40–.50 h. d., consequently only .60–.80 of abactinal system, and notable for small number of plates borne by membrane, more or less of which near outer margin is quite bare. Primary spines slender, straight, and cylindrical, very finely prickly, white or nearly so, 1.5–3 h. d.; actinal primaries either coarsely or finely serrate or entire; secondaries and miliaries alike, cylindrical or club-shaped, blunt and more or less erect, rather scattered. Pedicellariae of only one kind, globiferous, but very variable in size.

The affinities of this interesting genus are rather obscure, for although the secondary spines resemble those of *Austrocidaris nutrix*, it is hard to believe that there is any close relationship to that species. There are no other living species of Cidaridae which approach sufficiently near the three rare species placed here to give us any real clue to their natural position. Although *A. milleri* has actinal primaries similar to those of Porocidaris, there is little else to ally it with that genus, and the other two species are even more different. The large abactinal system, few ambulacral plates, unsunken poriferous zones, somewhat bare actinostome, and the primary spines are striking reminders of Salenia. Two of the species are discoveries made by the "Albatross" and are found only in the deep waters of the Pacific Ocean; although *milleri* was once taken in 465 fths., most of the specimens are from over 1,600 fths. and *fragilis* has been taken only at depths exceeding 1,500 fths. The third species was found by the "Belgica" in much shallower water, but in the far Antarctic Ocean. The following key is based on the examination of 116 specimens of the two "Albatross" species.

Key to the Species.

Test moderately high, .55 h. d. and more; abactinal system elevated, with numerous tubercles (250–300 on a system 13 mm. across); ambulacral plates about 20, in a specimen 15 mm. h. d. . . . . *milleri*

Test flat, about .50 h. d.; abactinal system not elevated, with comparatively few tubercles (100–200 on a system 13 mm. across); ambulacral plates about 15, in a specimen 15 mm. h. d.

Color reddish- or yellowish-brown; arctic . . . . . *fragilis*

Color bay or reddish; antarctic . . . . . *incerta*

Aporocidaris milleri.

Porocidaris Milleri A. Agassiz, 1898, Bull. M. C. Z. **32**, 5, p. 74.
Aporocidaris Milleri A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 37.

Plate 6, Pan. Deep Sea Ech., A. Agassiz, 1904.

The test of this species is grayish, sometimes with a purple tinge, or yellowish, and the secondaries are of about the same color or paler. The primaries are

nearly or quite white. The largest specimen is 31 mm. h. d., while the primaries are sometimes 75 mm. long. The abactinal system is often elevated 3 or 4 mm. above the test. The "Albatross" collected this species in 1891, in the deep water between Acapulco and Panama, and the Galapagos, 465–1880 fths., while in 1904–05 she found it common in the still greater depths south and southwest of the Galapagos, 2005–2153 fths.

Aporocidaris fragilis.

Aporocidaris fragilis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 87.

Plate 23, figs. 5–8, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

Of this species, the only known specimens, the largest of which is 23 mm. h. d., with primaries over 40 mm. long, were taken by the "Albatross" in the North Pacific, south of Alaska and southwest of Kamchatka in 1557–1973 fths.

Aporocidaris incerta.

Porocidaris incerta Koehler, 1902, Belgica Ech. et Oph., p. 7.

Figs. 2, 16, Belgica Ech., Koehler, 1902.

Koehler's supposition that this species is related to *milleri* is quite correct, though in the shape of the test it is more like *fragilis*. The position of *incerta* in this genus is confirmed not only by Mortensen's (:03) examination of the pedicellariae, but by a careful comparison of Koehler's description, with a specimen of *fragilis* of the same size (15 mm. h. d.) as his largest specimen. It is difficult to make out from that description just how much difference there is between the Arctic and Antarctic species. The latter was taken by the "Belgica" about 20 degrees south of Kerguelen Island, in 55–165 fths.

Stereocidaris.

Stereocidaris Pomel, 1883, Class. Meth. Gen. Ech., p. 110.

Test very similar to Dorocidaris, but usually flatter (.50–.60 h. d.), with fewer coronal plates (4–7, rarely 8 or 9) and relatively fewer primary spines (3–7, rarely 8, in each vertical series); that is to say, uppermost coronal plate without primary spine, and second often, third very rarely, similarly bare. Abactinal system large (.85–.55 h. d., usually about .50), often convex, and noticeably thick and stout, but this character varies much within a single species; abactinal miliaries and secondaries usually very small, but this character also varies much. Primary spines usually flaring at tip, or if tapering, provided at base with conspicuous buttress-like "wings"; "winged" primaries are usually noticeably compressed, but otherwise primaries are cylindrical. Globiferous pedicellariae, large and small, commonly lack a conspicuous end-tooth on valves.

This is the most poorly defined and unsatisfactory genus in the family, and yet the species contained in it have something about their general appearance which is distinctive and makes it possible to recognize them usually at a glance. They show considerable diversity in test, spines, and pedicellariae, and some individuals are strikingly like Dorocidaris. It is only when a considerable amount

of material is available for comparison that such individuals can be properly placed. Unfortunately in preparing the following key there have been available only five species, represented by 69 specimens, and it is probable that errors have crept in which might have been avoided had a larger series of specimens been available. However, Anderson's and Doderlein's descriptions and figures are sufficiently complete and accurate to make it possible to include their species. Döderlein's (:06) measurements and figures have been of the greatest help. The Japanese species need revision based on plenty of material, and it is possible that the three species here recognized will prove to be simply forms of a single species, as the differences between them are slight. All the recent species occur in depths of 40 fathoms or over, and all but one (*ingolfiana*) are found only in the Indo-Pacific region. A number of fossil species from the Cretaceous are referred to this genus. How Döderlein (:06) can lay great stress on the form of the pedicellariae in Stereocidaris and write without qualification "Grosse und kleinere globifere Pedicellarien ohne unpaaren Endzahn" (p. 102), is incomprehensible, for his own figures (Plates XXXVI and XXXVII) contradict the statement flatly. Had I examined no specimens, the study of Döderlein's figures would have satisfied me that the pedicellariae are no more reliable than the spines.

Key to the Species.

Actinostome very small, .20–.35 h. d., usually under .30 except in young specimens.

Primary spines often more or less trigonal, but seldom with three conspicuous "wings" near base; tridentate pedicellariae wanting; pedicels contain perforated plates besides thorny curved rods.

Longest primary spines, 1.3–2.7 h. d., thickness commonly less than 8% of length; perforated plates in pedicels small, with few large holes . . . . . *indica*

Longest primary spines about 1.35 h. d., thickness about 10% of length; perforated plates in pedicels broad, with many small holes . . . *capensis*

Primary spines commonly with three conspicuous wings near base; tridentate pedicellariae common; pedicels with few or no perforated plates . . . . . *tricarinata*

Actinostome larger, almost always over .35 h. d.

Primaries pale pink or reddish, with 10–16 longitudinal series of fine prickles, which often merge into ridges, and 1 (or more) of these becomes a conspicuous "wing" or "buttress" on basal half of spine, which is also often flattened; primaries tapering towards tip; coronal plates 5 or 6 (rarely 7).

Abactinal system coarsely tubercled; median ambulacral area depressed and bare along vertical suture, each plate with only 1 or 2 tubercles; color of test and secondaries madder purple . . . *alcocki*

Abactinal system with numerous small tubercles; median ambulacral area not depressed, often elevated along vertical suture, which is seldom visible, crowded with tubercles, each plate with 4–6; color of test and secondaries brownish, usually very pale; no tridentate pedicellariae . . . . . *ingolfiana*

Primaries cylindrical, at least near base, never provided with "wings," but with more or less evident, longitudinal series of rounded or sharp granules, tending to become ridges near tip of spine, which is often flaring.

Ambulacra very narrow, only .18–.25 of interambulacra, not deeply sunken; median area closely covered with 6 series of tubercles; all miliaries very minute; neck of primaries white . . *microtuberculata*

Ambulacra .25–.38 of interambulacra in width.

Secondaries not white; actinostome much smaller than abactinal system; tridentate pedicellariae present.

Abactinal system elevated 10% or more above test; abactinal surface appears very bare from small, wide, closely appressed miliaries; primaries not white with purple collar . . . . . *grandis*

Abactinal system flat or little elevated; abactinal surface well covered with ordinary miliaries; primaries when perfectly clean, white, usually with a distinct purple collar . . . *leucacantha*

Secondaries white or whitish; actinostome nearly equal to abactinal system; no tridentate pedicellariae . . . . . *sceptriferoides*

Stereocidaris indica.

Stereocidaris indica Döderlein, 1901, Zoöl. Anz., **23**, p. 19.

Plate 10, figs. 1, 2; Plate 11, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

This species appears to be very variable, and Döderlein (**: 06**), recognizes four varieties (*integra*, *africana*, *carinata*, *sumatrana*), based upon slight differences chiefly in primary spines and pedicellariae. He says, however, that he doubts the constancy of any of these varieties except *sumatrana*, which appears to be well-marked. Döderlein's admirable descriptions and his tables of measurements are all that could be desired, but the figures given often suffer from indistinctness; they are quite good enough, however, to reveal the notable diversity in the pedicellariae of this species. The color is yellowish, each of the larger secondaries with a dark spot and the actinal primaries white. The largest specimen measured 46 mm. h. d. The distribution of *indica* is from Somali-Land to the Moluccas, in 443–715 fths.

Stereocidaris capensis.

Stereocidaris indica var. *capensis* Döderlein, 1901, Zoöl. Anz., **23**, p. 19.
Stereocidaris capensis Döderlein, 1906, Deutsche Tiefsee Exp. Ech., p. 110.

Plate 10, figs. 3–6, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

Although closely related to the preceding species, Döderlein considers the South African form entitled to specific rank. As he finds the chief and most constant character in the calcareous plates of the pedicels, the species seems to me open to serious doubt, for I do not consider that any importance can be attached to the exact form of the microscopic, calcareous particles of the Echini. The only known specimens of *capensis* were taken by the "Valdivia"

off Cape Colony in 278 fths. The largest measured 36 mm. h. d. The color is gray, with a brownish tinge, the secondaries with darker tips, and the actinal primaries whitish.

Stereocidaris tricarinata.

Stereocidaris indica var. *tricarinata* Döderlein, 1901, Zoöl. Anz., **23**, p. 20.
Stereocidaris tricarinata Döderlein, 1906, Deutsche Tiefsee Exp. Ech., p. 112.

Plate 9, Deutsche Tiefsee Exp. Ech., Döderlein, 1906.

This species seems to be rather better defined than *capensis*, but as its validity depends largely on the value assigned to certain features of the pedicellariae, there is still room for some doubt as to its proper standing. The deformed specimen to which Döderlein has given the varietal name *teretispina* is indeed very different from the typical form, but as it was a parasitized individual, its peculiarities may be pathological. The "Valdivia" collected *tricarinata* only in the vicinity of Sumatra in 206–417 fths. The largest specimen was 54 mm. h. d. The color of the test is dark reddish; the primaries are gray with rosy necks; the actinal primaries whitish; the larger secondaries have a dark spot.

Stereocidaris alcocki.

Dorocidaris alcocki Anderson, 1894, Journ. Asiat. Soc. Bengal, **63**, pt. 2, 3, p. 191.

Plate 5, figs. 3, 3a, Ill. Investigator Zoöl. Ech., Alcock and Anderson, 1895.

There can be little question of the validity of this species unless *indica* proves to be even more variable than is supposed. If the published descriptions are accurate (and there is no apparent reason for doubting them), the two species are quite distinct. The "Investigator" took *alcocki* in the Laccadive Sea in 636 fths. It is a small species, only 25–26 mm. h. d.

Stereocidaris ingolfiana.

Stereocidaris ingolfiana Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 38.

Plate 6, figs. 1–5, 11, Ingolf-Exp. Ech., Mortensen, 1903.

It is rather curious that this very distinct and interesting species should not have been described until so recently, for adult specimens are easily distinguished from any other North Atlantic or West Indian species. Even when the primary spines are missing or do not have the "wings" developed, the species may be recognized by the very numerous slender secondaries and miliaries, and the more or less elevated median ambulacral area, densely covered with minute tubercles. Mortensen's description lacks nothing, but in the table of measurements it is evident that "height" is estimated in some variable way; for while in a large series of tests of such a variable species as *D. papillata*, for example, there is sometimes a variation of 20% in the vertical diameter, Mortensen's measurements would indicate a variation of 30% among 8 specimens of *ingolfiana*; and while *papillata* is occasionally .75 h. d. in height, Mortensen gives one speci-

men of *ingolfiana* over .90 h. d., or, in other words, almost spherical! The specimens in the Museum of Comparative Zoölogy are .54–.58 h. d., while Mortensen's table gives .61–.91 h. d. as the range for his 8 specimens; it can hardly be doubted that this difference is due to the method of measurement used. In the diameter of the abactinal system and the actinostome, Mortensen's figures, .41–.54 h. d. for the former and .36–.40 h. d. for the latter, accord well with the measurements of the specimens in the Museum of Comparative Zoölogy. One error in his table occurs which may be either a slip of the pen or a misprint; the specimen 28 mm. h. d. is said to have the abactinal system only 10.5 (the same as the actinostome), while examination of the figure given on Plate 6 (which is apparently that specimen) shows the abactinal system to be about 14 mm., which is what would be expected. The largest specimen recorded is 35 mm. h. d.; the color is brownish, but not at all distinctive. The geographical range is from Iceland to Nevis, in 165–665 fths.

Stereocidaris microtuberculata.

Cidaris (*Stereocidaris*) *microtuberculata* Yoshiwara, 1898, Ann. Zoöl. Jap., 2, pt. 2, p. 57.

Plates 1 and 2.

Although this species is closely allied to the following, it is easily distinguished by the characters given in the key. The test and small spines are yellowish-brown with a greenish tinge, and the larger secondaries have a median, longitudinal stripe of a darker shade. The fully developed primaries, when clean, are white. This is the biggest member of the genus, the diameter of the largest known specimen being 86 mm.

Stereocidaris grandis.

Dorocidaris grandis Döderlein, 1885, Arch. Naturg., 51 Jhrg., 1, p. 77.
Stereocidaris grandis Döderlein, 1887, Jap. Seeigel, p. 42.

Plate 1, Plate 2, figs. 1–11, Jap. Seeigel, Döderlein, 1887. Plates 33, 36, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

The series of specimens at hand from Japan and Hawaii shows that this is a well-characterized but somewhat variable species. The primaries are quite stout (the thickness 5–7% of the length), usually deep pinkish, especially at base, but often brown, gray, or green, while the test is gray, yellowish, or greenish, and the secondaries yellowish or greenish, often with a broad, longitudinal green stripe; the general effect is greenish, more or less inclined towards yellowish. The largest specimen in the series is 40 mm. h. d., but Döderlein's largest specimen was 61 mm. Specimens of *grandis* are known not only from Japan and Hawaii, but also from the Dutch East Indies (de Meijere : **04**). It is possible that those to which de Meijere refers as having "die Halse" "hell violet" are really to be referred to the next species.

Stereocidaris leucacantha.

Stereocidaris leucacantha A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 23.

Plates 15, 32, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

Although this Hawaiian species, collected at a number of stations by the "Albatross," is very close to *grandis* in many ways, the two are easily distinguished at a glance, and no intermediate specimens have been seen. The largest specimen is 57 mm. h. d. The color is somewhat variable, that of the test and secondaries ranging from almost yellowish-white to deep purplish-gray; there is usually a decidedly purple cast actinally. The primaries are longer and more slender than in *grandis* (the thickness only 4 or 5% of the length), and are white when clean. The fully grown ones almost always have the collar deep purple, sharply contrasted with the white neck. In many specimens the secondaries show an evident green tinge.

Stereocidaris sceptriferoides.

Cidaris (*Stereocidaris*) *sceptriferoides* Döderlein, 1887, Jap. Seeigel, p. 5.
Stereocidaris sceptriferoides Döderlein, 1887, Jap. Seeigel, p. 42.

Plate 2, figs. 12–17, Jap. Seeigel, Doderlein, 1887.

This species, although it appears to be very rare, is well characterized. The globiferous pedicellariae are very slender, the valves often have a conspicuous end-tooth, and the opening may be very long and narrow. The only known specimens of this species were taken in Japanese waters.

ANOMOCIDARIS.

Anomocidaris A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 30.

Test rather flat, vertical diameter about .50 h. d., but sometimes, through elevation of abactinal system, conspicuously rounded-conical; vertical diameter from centre of anal system in such cases being about .60 h. d.; coronal plates 7–9; areolae abactinally small, very shallow and indistinct, on the uppermost plates practically wanting, but at ambitus and below deeply sunken and merging together near actinostome; median interambulacral area covered with small tubercles, not at all bare or sunken, but sutural lines distinct; ambulacra about .30 of interambulacra; poriferous zones not deeply sunken; median ambulacral area with two or three series of tubercles on each side, inner much smaller and more or less incomplete; vertical sutural line usually distinct; pores nearly horizontal; distance between two not quite equal to diameter of pore. Abactinal system moderate, about .47 h. d.; anal system small, less than .40 of abactinal system and composed of only about 20 plates and grains; oculars rather small and genitals very widely in contact with each other. Whole abactinal surface more or less densely covered with very small secondaries, miliaries, and pedicellariae. Actinostome small, .35 h. d., only about .75 of abactinal system. Primary spines slender, 1–1.50 h. d.; thickness 3–5% of length; cylindrical with longitudinal series of minute granules, sometimes nearly smooth, often flattened and widened at tip; actinal primaries very variable, some-

times flattened, curved, and entire, slightly notched or even serrate, but frequently thick, straight, and more or less smooth; secondaries flat, those on ambulacra quite narrow. Large globiferous sometimes, and tridentate pedicellariae always, wanting; small ones sometimes with, more often without, end-tooth on valves.

The above diagnosis of this interesting monotypic genus is based on a large series of specimens, 11–40 mm. h. d., which admits of little question of the identity of Döderlein's *St. japonica* and Yoshiwara's *C. tenuispinus*. Some of the peculiarities are given by those writers in their original descriptions of the only species, which they regarded as a Stereocidaris. While its nearest relatives are probably to be found in that genus, it is quite distinct from them and is well entitled to generic rank. For a full discussion of this genus and its type species, see A. Agassiz and Clark, 1907, Bull. M. C. Z., **51**, p. 112–114.

Anomocidaris japonica.

Dorocidaris japonica Döderlein, 1885, Arch. Naturg., **51** Jhrg., 1, p. 76.
Stereocidaris japonica Döderlein, 1887, Jap. Seeigel, p. 34.
Cidaris (*Stereocidaris*) *tenuispinus* Yoshiwara, 1898, Ann. Zoöl. Jap. **2**, pt. 2, p. 57.
Anomocidaris tenuispina A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 30.
Anomocidaris japonica. A. Agassiz and Clark, 1907, Prelim. Rep. Albatross 1906 Ech., Bull. M. C. Z., **51**, p. 112–114.

Plate 31, figs. 5–8, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907. Plate 3, Jap. Seeigel, Döderlein, 1887.

The only known specimens of this species have been taken in Japanese waters, in 40–284 fths. The largest specimen is 40 mm. h. d. The color of test and secondaries is commonly some shade of brown, often reddish, sometimes greenish, while the primaries are grayish or brownish, often with a decidedly olive-green tinge, rarely rosy-reddish; the neck is brown, usually polished and shining.

ACANTHOCIDARIS.

Acanthocidaris Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 21.

Test high, .60–.70 h. d.; coronal plates 7 or 8; areolae not at all sunken and very distinct, even actinally; median interambulacral area somewhat sunken and bare along vertical suture; ambulacra about .25 of interambulacra; poriferous zones little sunken; each ambulacral plate slightly curved, with a single large tubercle near upper margin of median portion, a much smaller one near lower margin halfway to inner end, and a very minute one (which usually carries a pedicellaria) just beneath largest; this arrangement is remarkably constant, regardless of age and size; it is well shown in a specimen 9 mm. h. d., and is not essentially different in one 52 mm. h. d.; in some very large specimens, however, another small secondary tubercle may be borne on inner end of plate; median vertical suture usually visible, but there is no noticeable median bare strip; pores oblique much as in Cidaris. Abactinal system about .45 h. d., very flat; peculiar in that all oculars are broadly

in contact with anal plates except right anterior one; this ocular is wholly or very nearly excluded; instead of being an individual peculiarity (as sometimes occurs in Tretocidaris *et al.*), this curious arrangement is remarkably constant, and is as evident in a specimen 17 mm. h. d. as in those over 40 mm. Actinostome .35–.40 h. d., generally about .90 of abactinal system. Primary spines unique, 2.5–3.3 h. d., straight or somewhat curved, nearly smooth; base broad and depressed, somewhat triangular in cross-section, with more or less evident traces of longitudinal series of granules, but in large specimens these are scarcely visible; collar enormously wide, .20 or more of length of spine, and abruptly contrasted with remainder in color; this remainder bears 10–20 sharply distinct longitudinal ribs, which are seemingly continuations of series of granules on collar; outer limit of collar not straight, *i. e.* forming a ring around spine, but more or less deeply concave on both sides, especially actinally; tip of primary blunt or more or less expanded; actinal primaries conspicuously capped and serrate as in Stephanocidaris, but much stouter than in that genus; secondaries long, slender, and flat. All three kinds of pedicellariae present; globiferous, both large and small, lack an end-tooth on valves; stalks of large ones usually with a "limb."

This notable genus will be recognized at first sight by the peculiar, handsome spines somewhat resembling those of Coelopleurus. The above diagnosis is based upon the examination of fifty fine specimens of *hastigera*, representing all ages. The type of the genus is the species named by Bell ('93) *curvatispinis*, but nothing is known of its test or abactinal system, for neither Bell nor Mortensen (:03) has attempted any description beyond spines and pedicellariae. It is interesting to find that the "Siboga" collected in the East Indies a third species of this genus, which de Meijere (:04) has named *Cidaris maculicollis*. His careful description of the primary spines leaves no doubt as to the proper relationship of this new form, although the describer, in spite of the primaries, places it in the same subgenus with *C. metularia, tribuloides*, etc., because he considers the large globiferous pedicellariae like those of Cidaris. As a matter of fact, however, the valve of a pedicellaria which de Meijere figures is quite as near Acanthocidaris as it is to typical Cidaris. On account of the broad collar and the serrate actinal primaries, de Meijere (:03) originally described *maculicollis* as a Porocidaris, but it really has as little in common with that genus as with Cidaris.

Key to the Species.

Collar of primary spines very light-colored, unspotted; remainder of spine reddish or brownish.
  Secondaries cream-color or yellowish; base of primaries with distinct angles, which may be somewhat serrate . . . . . *curvatispinis*
  Secondaries dark reddish-brown; base of primaries with rounded angles, not in the least serrate . . . . . *hastigera*
Collar of primary spines greenish, with red spots; remainder of spine whitish with 3 or 4 cross-bands of reddish . . . . . *maculicollis*

Acanthocidaris curvatispinis.

Cidaris curvatispinis Bell, 1893, Trans. Zoöl. Soc., London, **13**, p. 303.
Acanthocidaris curvatispinis Mortensen, 1903, Ingolf-Exp. Ech., **1**, p. 29.

Plate 38, Trans. Zoöl. Soc. London, 13, Bell, 1893.

Nothing is known in regard to this species, except that Bell has figured the entire animal and Mortensen the pedicellariae. The type specimen in the British Museum, and a second specimen in Paris, are both from Mauritius and are the only ones known. The type specimen is about 50 mm. h. d., with primaries 150 mm. long; many of the latter are banded near the tip with brownish and yellowish.

Acanthocidaris hastigera.

Acanthocidaris hastigera A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 39.

Plates 37–42, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

In addition to the differences mentioned above, this species may be distinguished from the preceding by the stouter primaries and their entire lack of any cross-barring or bands of color. It was found by the "Albatross" to be common among the Hawaiian Islands. When cleaned, the test is nearly white in young specimens, with the median ambulacral area red, the actinostome decidedly green, and the abactinal system dull greenish-red; in older specimens the white is replaced by reddish-cream color, and there is little green evident anywhere. When uncleaned the test is, like the secondaries, dark brownish-red, much lighter in very young specimens. The largest specimen is 52 mm. h. d.; the longest primaries are 145 mm. All of the "Albatross" specimens were taken on sandy bottom in comparatively shallow water, 23–222 fths.

Acanthocidaris maculicollis.

Porocidaris maculicollis de Meijere, 1903, Tijdsch. Ned. Dierk. Vereen. (2) **8**, p. 1.

Plate 3, figs. 18, 19, Siboga-Exp. Ech., de Meijere, 1904.

The secondaries of this species are described as having "a dark longitudinal stripe," but the ground color is not mentioned. The four specimens collected by the "Siboga" were all small (10–18 mm. h. d) and were evidently young ones. They were taken at depths of only 39–53 fths., and at each of the three stations mussel-shells formed a characteristic feature of the bottom.

POROCIDARIS.

Porocidaris Desor, 1854, Syn. Ech. Foss., p. 46.

Test rather high, .60–.75 h. d.; coronal plates, 7–9; areolae more or less sunken and merging actinally; median interambulacral area with vertical sutural region somewhat sunken and bare; ambulacra .18–.34 of interambulacra; poriferous zones very little sunken; median ambulacral area with a single marginal row of tubercles,

and even this may be incomplete in small specimens; between are more or fewer scattered tubercles, but there is never a complete second series even in very large specimens; vertical sutural line, bare; pores oblique, close together, surface of interval rough or elevated. Abactinal system variable in size, oculars and especially genitals with noticeably wide bare margins. Actinostome .30–.45 h. d., with few or no interambulacral plates. Primary spines, when fully developed, long, 1.5–4 h. d. cylindrical or nearly so, white (sometimes tinged with rose, purple, or yellow) with a darker collar; actinal primaries flat, somewhat curved, coarsely and sharply serrate; secondaries flat and not peculiar. No globiferous pedicellariae whatever; tridentate pedicellariae very variable in size (.30–6.0 mm.) and form, with 2–4 (generally 3) unusually stout, wide valves.

This is one of the most distinct and easily recognized of the genera of recent Echini, but the species it contains are most perplexing and are exceedingly difficult to distinguish from each other. The genus has a wide geographical range, as it occurs in the North Atlantic Ocean, the Caribbean Sea, among the Galapagos Islands, the Hawaiian Islands, the East Indian Islands, and the Nicobar Islands, along the coast of Japan, near Australia, and along the east coast of Africa, it depths ranging from 169 to 799 fths. Several species from the Tertiary have been named, and serrate spines, like the actinal primaries of Porocidaris, occur in the Jurassic. There is little diversity of color in the genus, for the test, the collar of the primaries, and the small spines are commonly some shade of brown, often becoming very dark or deep purple with age, while the primaries are usually very white. The following key is based on the examination of 54 specimens representing all the species, except *misakiensis*.

Key to the Species.

Pedicellariae all with 2 valves . . . . . *purpurata*

Pedicellariae mostly with 3 valves.

Abactinal system .40–.55 h. d.; primaries rather stout (thickness of large ones 3–6% of length), finely and sharply thorny. (These prickles are not always easily seen with the unaided eye, but are so distinct that a spine cannot be drawn upward between thumb and finger when lightly closed upon it.)

Small spines in interambulacra, outside scrobicular circles, above ambitus, very few; ambulacra almost wholly bare between marginal rows of tubercles; primaries stout, 1.5–2.5 h. d. (thickness 5–6 per cent of length), often becoming larger and fluted near tip, with numerous (25–30) longitudinal series of prickles . . . . . *sharreri*

Small spines more numerous on upper half of test; ambulacra usually with scattered tubercles; primaries somewhat less stout, with about 12–15 longitudinal series of prickles, more or less tapering and never enlarged and fluted at tip, but occasionally with large projecting thorns near base.

Primaries less stout (thickness 3–4 per cent of length); no special depression on inner surface of valves of large pedicellariae above hypophysis; test, secondaries, and collar of primaries light reddish- or yellowish-brown . . . . . *elegans*

Primaries stouter (thickness about 4.5 per cent of length); a distinct triangular impression on inner surface of valves of large pedicellariae above hypophysis; test, secondaries, and collar of primaries deep, dark brown . . . . . *misakiensis*

Abactinal system .35–.45 h. d.; primaries very long and slender, 2.5–4 h. d. (thickness only 2–3 per cent of length); very nearly smooth (slip easily between thumb and finger).

Large pedicellariae always with 3 valves, which are distinctly pointed; anal system about .50 of abactinal; median ambulacral area about .37 of ambulacrum; size small, under 35 mm. h. d.; color pale, and primaries very white and shining . . . . . *cobosi*

Large pedicellariae very variable, sometimes with only 2 or with 4 valves, which are usually broad and are rounded at tip; anal system about .45 of abactinal; median ambulacral area about .50 of ambulacrum; size large, up to 85 mm. h. d.; color usually very dark and primaries yellowish . . . . . *variabilis*

Porocidaris purpurata.

Porocidaris purpurata Wyville Thomson, 1872, Ann. Mag. Nat. Hist., (4) 10, p. 302.

Plate 59, Porcupine Ech., Wyville Thompson, 1875.

One needs only to compare a specimen of this cidaroid with any other member of the genus to reject Mortensen's (:03) proposed genus "Histocidaris," for aside from the pedicellariae, the only feature in which *purpurata* differs noticeably from the others is the presence of an exceptionally wide collar on *some* of the primaries of *some* specimens, and that can hardly be considered a very useful character. Moreover Mortensen's proposed variety *talismani*, which he thinks may even be a distinct species, cannot be recognized, for the primaries with swollen, fusiform, violet collars occur in typical *purpurata*, and one is figured by Thomson ('75), though they are not present in all specimens. The small spines and some of the abactinal primaries are light reddish- or purplish-brown. The largest recorded specimen is 50 mm. h. d. This species is known only from the North Atlantic, save for the specimen from the Nicobar Islands, collected by the "Valdivia," and referred to *purpurata* by Döderlein.

Porocidaris sharreri.

Porocidaris Sharreri A. Agassiz, 1880, Bull. M. C. Z., 8, p. 71.

Plate 3, Blake Ech., A. Agassiz, 1883.

This handsome West Indian species was dredged by the "Blake" off Georgia in 279 fths. (in company with *St. ingolfiana*) and also near Barbados in 356 fths. The general color is red-brown and not at all purplish. The largest specimen is 69 mm. h. d., with spines 114 mm. long.

Porocidaris elegans.

Porocidaris elegans A. Agassiz, 1879, Proc. Amer. Acad., **14**, p. 198.

Plate 3, Challenger Ech., A. Agassiz, 1881.

Originally collected by the "Challenger" off New South Wales and southeast from the Philippines, specimens of Porocidaris, referred to this species, have since been taken by the "Valdivia" near Sumatra, and off the east coast of Africa, and by the "Siboga" among the Dutch East Indies. One of the specimens collected by the latter vessel measured 85 mm. h. d. The specimen from the Bay of Biscay reported by Koehler (**'96**) is doubtless not this species; but probably *purpurata*, though it might be *sharreri*, with which species *elegans* agrees in coloration and many other points. The 5 specimens taken by the "Siboga" which de Meijere (**:04**) calls "*Cidaris elegans juv.?*" are rather peculiar, especially the pedicellariae, and their real relationship is doubtful. The specimens taken by the "Valdivia" differ from *elegans*, not only in their remarkably light coloration, but in their small abactinal system, actinostome and anal system, the very thorny primaries, and their large number of coronal plates. It is quite likely that they are a distinct species.

Porocidaris misakiensis.

Cidaris (*Porocidaris*) *misakiensis* Yoshiwara, 1898, Ann. Zoöl. Jap., **2**, pt. 2, p. 58.

Plate 2, fig. 16, Siboga-Exp. Ech., de Meijere, 1904.

This is the most dubious species of the genus, especially as no complete description or figures have appeared. Aside from the original preliminary description, the only available information about *misakiensis* is contained in de Meijere's "Siboga" report (**:04**). He found one specimen which might be referred to this species, but the difference between it and *elegans* is difficult to understand, and it will be surprising if the two prove to be really distinct. Yoshiwara's specimen was 39 mm. h. d., and de Meijere's was 50 mm. The color is said to be dark brown.

Porocidaris cobosi.

Porocidaris cobosi A. Agassiz, 1898, Bull. M. C. Z., **32**, 5, p. 74.

Plate 9, Pan. Deep Sea Ech., A. Agassiz, 1904.

This is the handsomest species of the genus, and except *purpurata*, the easiest to recognize. It has been taken only once, and then by the "Albatross," near Chatham Island, Galapagos, on a rocky bottom in 385 fths. The largest specimen is only 35 mm. h. d.

Porocidaris variabilis.

Porocidaris variabilis A. Agassiz and Clark, 1907, Haw. Pac. Ech. Cid., p. 32.

Plates 16–22, 23, figs. 1–4, Haw. Pac. Ech. Cid., A. Agassiz and Clark, 1907.

This species was found by the "Albatross" to be common among the Hawaiian Islands, and some very fine specimens were secured. The largest is deep purple, and measures 85 mm. h. d.; the others are various shades of brown, and one was very light-colored, like *cobosi*. It is possible that if *misakiensis* is really distinct from *elegans*, this species may prove to be identical with Yoshiwara's.

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EXPLANATION OF PLATES.

PLATE 1.

Stereocidaris microtuberculata Yoshiwara. Nat. size.
Abactinal view.

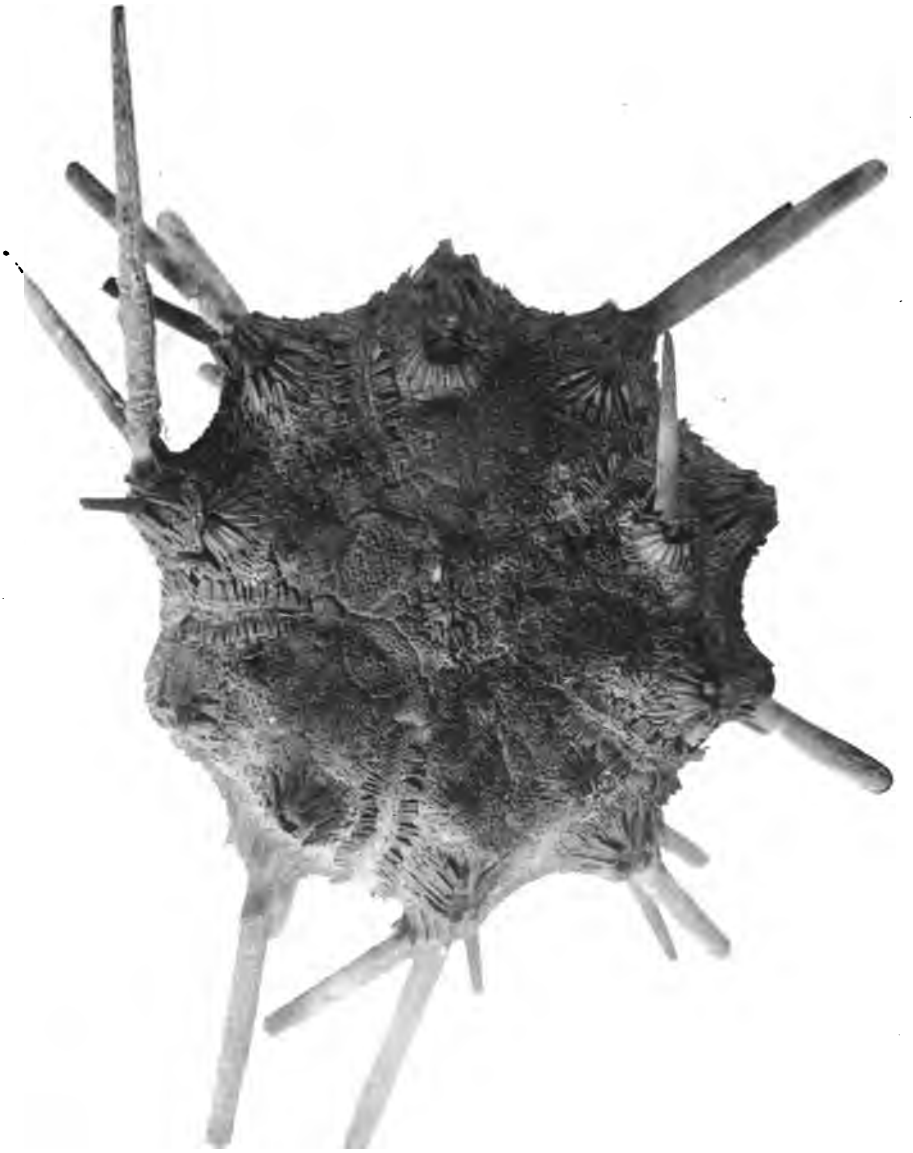

PLATE 2.

Stereocidaris microtuberculata Yoshiwara. Nat. size.
Side view of same specimen as Plate 1.

PLATE 3.

Calocidaris micans (Mortensen). Nat. size.

1. Ambulacral view of partly cleaned specimen; all primary spines broken.
2. Abactinal view of same.

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PLATE 4.

Dorocidaris rugosa, sp. nov. Nat. size.
Abactinal view.

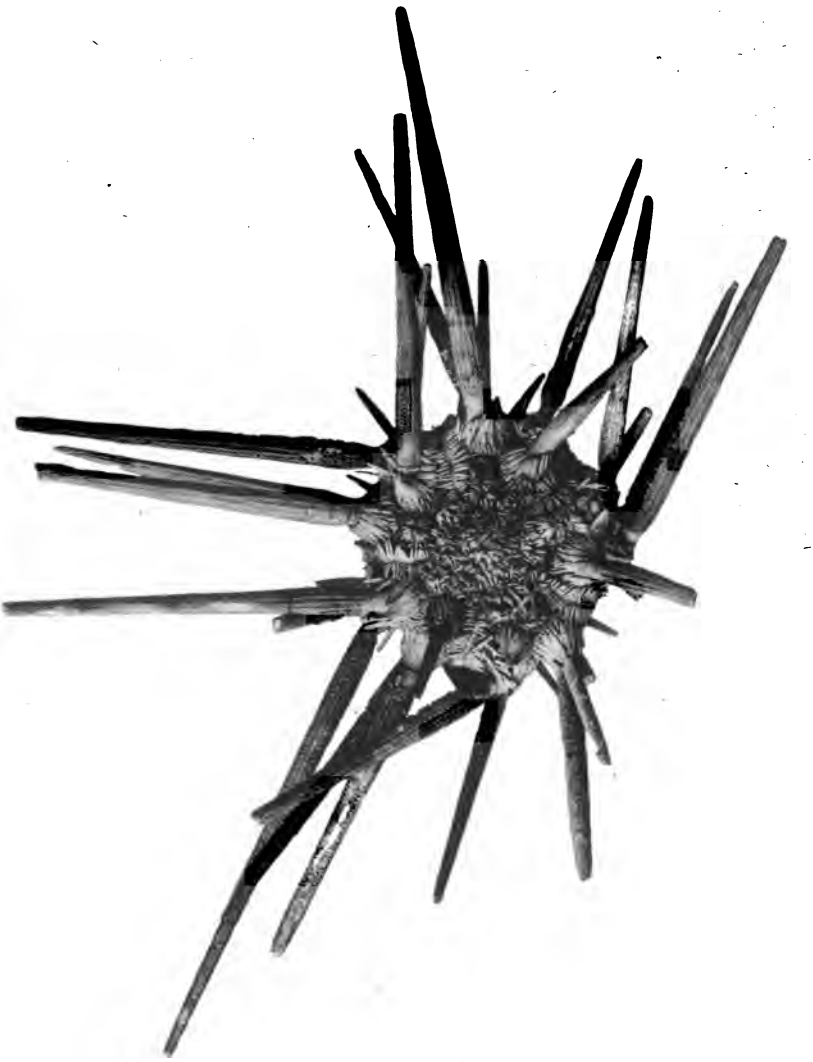

PLATE 5.

Dorocidaris rugosa, sp. nov. Nat. size.
Actinal view.

PLATE 6.

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1. Abactinal view.
2. Actinal view.
3–4. Tretocidaris dubia, sp. nov. Nat. size.
3. Abactinal view of partly cleaned specimen.
4. Actinal view of same.

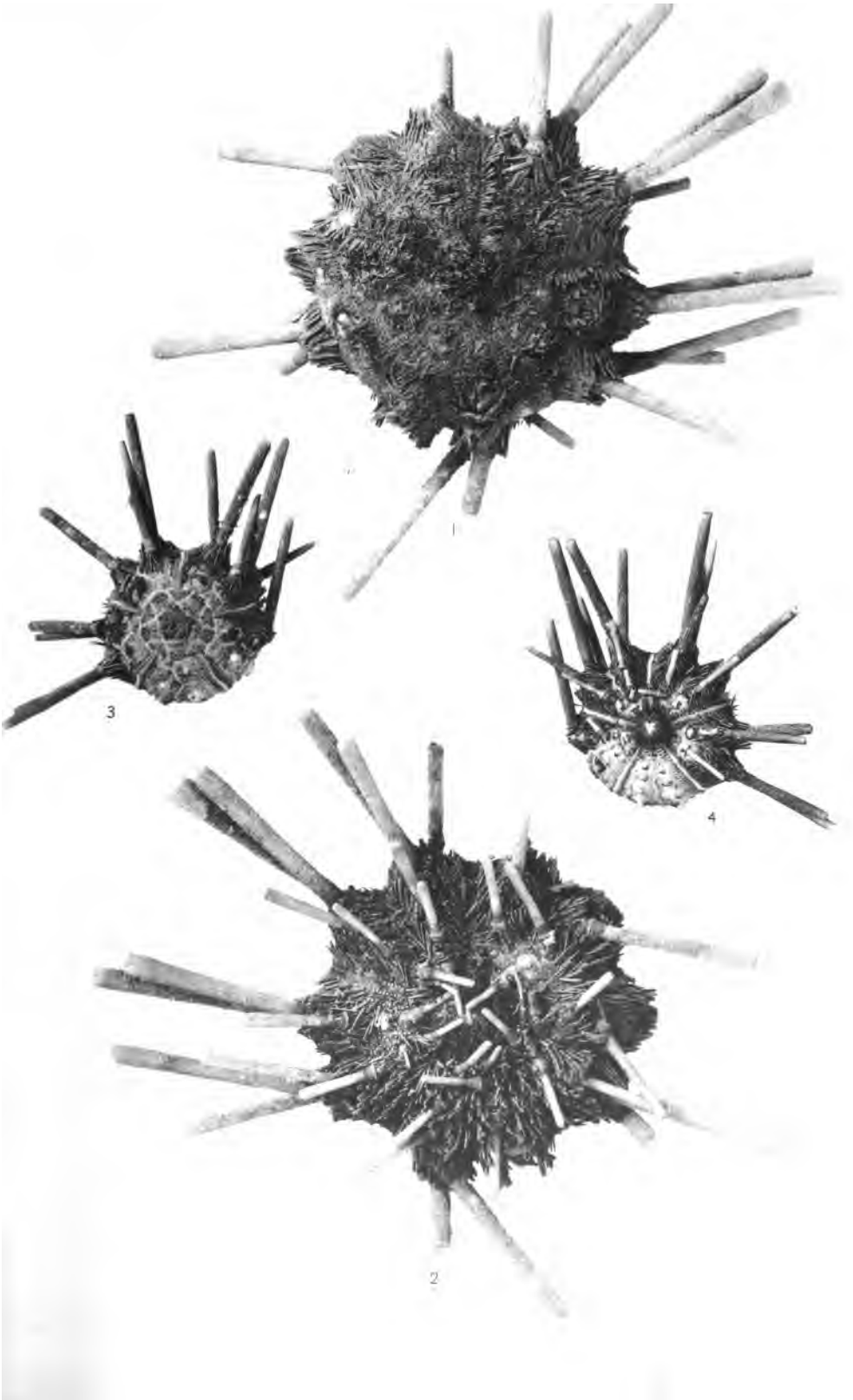
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PLATE 7.

1–4. Tretocidaris perplexa, sp. nov. Nat. size.
1. Abactinal view of partly cleaned specimen.
2. Actinal view of same.
3. Interambulacral view of same.
4. Ambulacral view of same.

5–8. Dorocidaris rugosa, sp. nov. Nat. size.
5. Abactinal view of partly cleaned test.
6. Actinal view of same.
7. Interambulacral view of same.
8. Ambulacral view of same.

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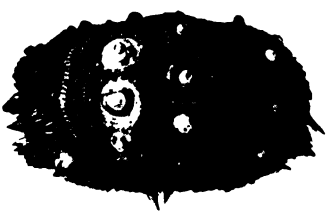

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PLATE 8.

Tretocidaris bartletti (A. Agassiz). Nat. size.
Abactinal view of specimen with cylindrical spines.

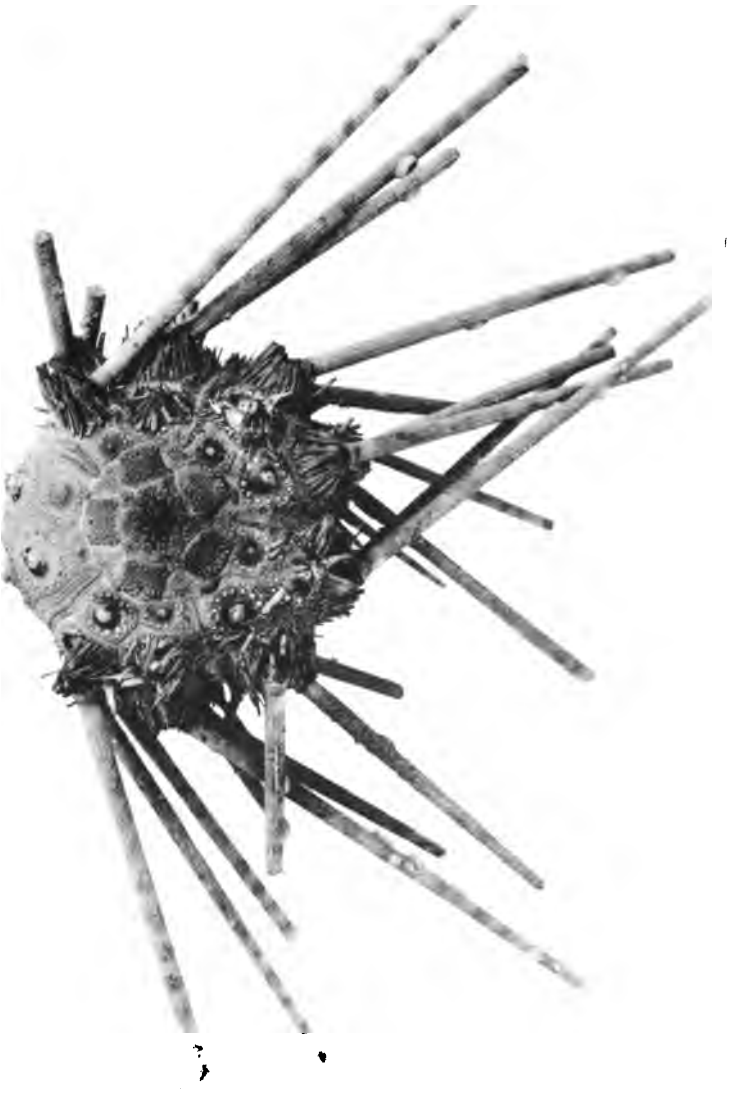

PLATE 9.

Tretocidaris bartletti (A. Agassiz). Nat. size.
Interambulacral view of same specimen as Plate 8.

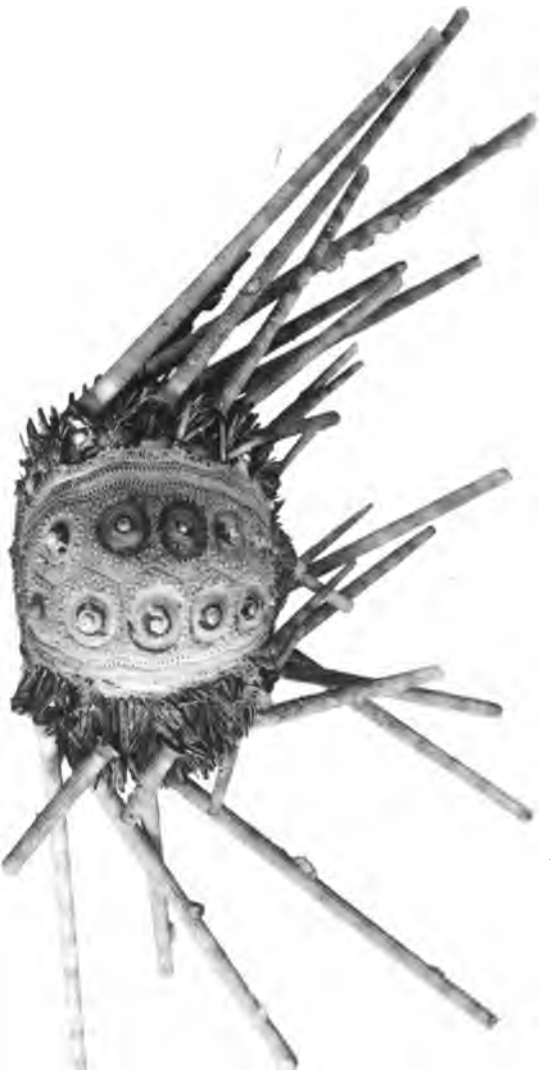

PLATE 10.

1–2. Tretocidaris bracteata (A. Agassiz). Nat. size.
1. Abactinal view of partly cleaned specimen.
2. Side view of same.
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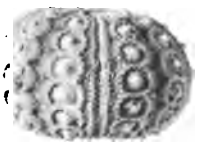
Interambulacral view of partly cleaned, small specimen, with slender spines.

1

2



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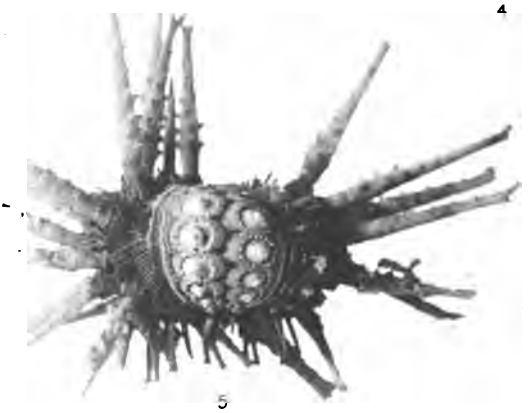

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PLATE 11.

Goniocidaris tubaria (Lamarck). Nat. size.

1. Abactinal view of partly cleaned, large specimen with short, stout spines.
2. Side view of same.

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