XII.—*On the Spicula of the Regular Echinoidea.* By CHARLES STEWART, *Esq.*
Communicated by Professor HUXLEY, F.L.S.

(Plates XLVII., XLVIII., XLIX., L.)

Read November 16th, 1865.

THE subject of the present paper is an account of those calcareous bodies that are found imbedded in certain parts of the perisoma of the Echinoidea, and also in the membrane and its reflections that line the interior of their shells. They are generally to be found in the external branchiæ and ambulacral tubes, and internally in the madreporic canal, ovaries, intestine, and mesentery, and sometimes in the ambulacral vessel and the membranes and ligaments about the base of the jaws.

Although the forms of the spicula of the Cirrho-vermigrade Echinodermata have been found to be of the greatest value in the determination of species, but little notice has been taken of them in the regular Echinoidea.

Valentin, in his monograph on the genus *Echinus*, mentions their occurrence in various parts, and gives M. Miescher as an authority for their being found in the ovary, but strangely remarks that "it remains to be proved whether these little calcareous bodies are artificial products, or exist as well in the living animal." He figures those of the external branchiæ of *Echinus lividus*, and of one called by him *E. brevispinosus*, which, however, I believe is identical with *E. Dröbachiensis* of our northern coasts, the spicula, which are very peculiar, being identical with those of that species; and I have since been confirmed in this opinion by Dr. Herapath, of Bristol, whose examination of the pedicellaria led him to a similar conclusion.

These spicula vary greatly in the amount of their development in different genera and species; and in this respect, as well as in their different forms, they will, I believe, be found to afford most valuable and interesting additional points of generic and specific distinction.

The bihamate is the usual shape they present. Such are figured by Valentin, mixed with reticulated plates as they occur in the external branchiæ; to these must be added perforated or reticulated plates often attaining a large size, having irregular or smooth margins, and triradiate, acerate, biclavate, bihamate, and irregularly branched or curved spicula. In many, more especially in those of the bihamate form, there is a great tendency to the formation of a spheroidal enlargement at the centre, which sometimes, by increased development, forms a spine projecting either from their concave or convex border; many specimens seem to show that this spheroidal body is often first formed, and that from it the other parts of the spiculum are subsequently extended. Between all these forms intermediate conditions can be found, by which their identity in structure and mode of development with the other shelly parts can be clearly demonstrated. The striking resemblance to the spicula of Sponges and to those of some Mollusca, from which many, particularly those of *Echinometra*, could not, I think, be distin-

guished, seems to point to a similar mode of development of the skeleton in these widely separated members of the animal kingdom.

With regard to the intimate structure of these spicula, I may mention that many, when mounted in balsam, present a much paler appearance than others, probably owing to their possessing a less refractive power, and that many apparently identical, when examined by polarized light, show a total absence of depolarizing property which in others is well marked, and also that the spicular plates of *Cidaris* frequently have their two halves in a state of tension, the one at right angles to the other, although no other evidence of structural difference can be detected.

The proportion of animal matter varies considerably—charring frequently demonstrating a line of it running through the centre of the spicula, such as is found in those of the *Spongiadæ*.

It would perhaps be interesting to those who may be desirous of extending these observations, to describe briefly the means used by me in investigating these structures.

As all the Echinoidea I examined were in the dry state, and had been for the most part preserved for a long time in museums, their softer parts were covered with mould, which could only be removed by very careful washing under water with a camel's-hair pencil: liquor potassæ does not dissolve this fungus; besides, its use would only show the separate forms of the spicula; it can, however, be advantageously employed in some instances.

The membranes so cleaned were then dried on a slide, and mounted in balsam in the ordinary way.

As specimens of the genus *Cidaris* are rare and generally preserved whole, it is difficult to procure examples of their internal parts; those of my own cabinet I partially sacrificed by removing the anal plates of those in which the oral surface was most perfect, and *vice versâ*: by this means the whole of the viscera, &c., could be obtained without much injury.

After these general remarks I now proceed to a description of the various modifications these spicula present in the different genera I have examined.

In *Cidaris* the ovaries, or testes, contain perforated plates, which, in the membranes of the base, often attain the $\frac{1}{16}$ th of an inch in diameter, and are so crowded as to overlap each other. Owing to the rigidity imparted by their presence, the ovarian tubes retain their shape in old and dry specimens. Similar plates sometimes extend laterally on each side of the ovarian branches, and in a more delicate form are found in the fibrous bands that frequently terminate or connect the branches together (Plate XLVII. figs. 1, 2, 3). Their shape is usually irregularly ovate; but in *Cidaris tribuloides*, in which the ovary is converted into a solid organ by the union of its parts, the plates are evidently formed on a triradiate type (Plate XLVII. fig. 5). In another species a portion of the plate projected as a spine (Plate XLVII. fig. 4). I have only found one exception to this condition of the ovary—in a small *Cidaris* from Malta, in which all the internal parts examined were devoid of spicula, although the ambulacral tubes possessed similar ones to those of other *Cidaridæ* (Plate XLVIII. fig. 12); the species probably really belongs to the genus *Orthocidaris* of Agassiz.

In the walls of the intestine there are numerous small plates having irregular or smooth margins (Plate XLVIII. figs. 1, 2, 3).

In the mesentery they are usually large, and in some species have an acicular or tri-radiate character (Plate XLVIII. figs. 4, 5); a superficial layer of irregular, generally delicate, reticulate spicula is frequently found on the surface of the mesentery, from which it can be easily removed, when, owing to their interlacing, its character as a membrane is retained (Plate XLVIII. fig. 6). Where the mesentery is united to the intestine, and on the inner border where the loops of intestine are strengthened by a free membrane, the plates assume the form of spines projecting from the membrane, in which their bases are inserted; they have generally a solid axis, with a dextrally spiral arrangement of the areolæ on their surface (Plate XLVII. figs. 6, 7, 8, 9).

The membranous and ligamentous bands at the base of the lantern are generally abundantly supplied with spicula; in the one which extends inwards from the transverse muscle they are sometimes of large size, interlocking and overlapping by their lateral processes (Plate XLVIII. figs. 9, 10); this membrane has sometimes a tuft of spines on its inner border (Plate XLVII. fig. 10).

The spicula of the ambulacral tubes are most numerous towards their free extremity, and lie transversely to their length, are curved to adapt them to their cylindrical form, smooth on the concave and with rings of short spines on their outer or convex border; they are frequently branched or acicular in character, these more irregular forms being usually of less refractive power. The dorsal ambulacral tubes have the spicula reduced to a few irregular calcareous threads; and the rosette, &c., which in the oral ambulacral tubes is well developed, is here represented by a few delicate plates of indefinite form (Plate XLVIII. figs. 11, 12).

In *Goniocidaris* the walls of the intestine are crowded with triradiate spicula, having their points generally rounded, although frequently one is produced as a sharp curved spine projecting at an angle of 45° to the plane of the others (Plate XLVIII. fig. 13); towards the edge of the intestine they assume the form of perforated plates, but show well-marked evidence of their triradiate origin (Plate XLVIII. fig. 14). As in *Cidaris*, the intestine is fringed by spines along at least one of its borders; they are, however, more slender than in that genus; and the basal plate from which they spring being narrow and much produced makes them resemble the letter T (Plate XLVIII. fig. 15).

In the ovaries they are very abundant, and coarser than in other parts, but retain the same triradiate plan of growth. (Plate XLVIII. fig. 16, *b*.)

The spicula of the ambulacral tubes differ but little from those of *Cidaris*; they are, however, much smaller, and somewhat more branched and spinous in proportion to their size, than is generally the case in that genus. (Plate XLVIII. fig. 16, *a*.)

In *Diadema* the intestine has imbedded in its substance a very few small irregularly curved and sometimes branched spicula, having often an enlargement about the centre (Plate XLVIII. fig. 18, *a*); in a membrane obtained from near the anus I found similar spicula, but much larger and more numerous (Plate XLVIII. fig. 17, *b*); in a small *Diadema* from China they were much branched, and often on a triradiate type (Plate XLVIII. fig. 18, *b*).

The ambulacral tubes are abundantly supplied with spicula, usually triradiate, but larger and more irregular towards their free extremity. (Plate XLVIII. fig. 17, *a*.)

In the ovary I have as yet been unable to detect any.

In *Echinometra* the spicula are perhaps the most interesting of any, both from their great variety and number, and from the transitional forms they present between straight, hooked, and triradiate spicula, and perforated plates.

The ovary is crowded with bundles of long acerate spicula resembling those of many sponges; from the sides of these frequently project secondary processes, which, reuniting to it, convert the spiculum into a perforated plate; bihamate spicula and small plates of various forms are also abundantly scattered through its substance. (Plate XLIX. figs. 1, 2.)

In the intestine and its free inner membrane are numerous small plates and hooks, varying in their proportionate number in different parts, and in shape and dimensions in the species. (Plate XLIX. figs. 3, 4, 5, *a*, *b*.)

The mesentery also is abundantly supplied with spicula, having their long axes in the direction of its fibres, and often closely resembling those of the ovary. (Plate XLIX. figs. 3, 4, 5, *c*.)

The spicula of the ambulacral tubes are generally of the bihamate variety, differing in size and amount of curvature in the various species, and having sometimes the form of a ring, owing to the union of their points. In one specimen triradiate spicula were found at the base of the ambulacral tubes; but these may be the spicula of a sponge accidentally entangled amongst them, although every available precaution was taken to prevent such an accident, and in this species the spicula of the ovary and mesentery presented a more than usual tendency to that form. (Plate XLIX. fig. 6.)

In the genera previously described the principal variations in the form of the spicula occurred in the internal parts, those of the ambulacral tubes and branchiæ undergoing but few modifications; in the genus *Echinus*, however, the internal spicula are always of the bihamate form, varying only in their size and curvature, and the amount of development of the central nodule; sometimes, also, one of the hooks is repressed or reversed (Plate L. figs. 2, 3, 5, *b*, *c*); they are generally most numerous in the ovaries, pharynx, and œsophagus; in the madreporic canal they are also abundant.

The spicula of the ambulacral tubes and external branchiæ, from the former of which they are sometimes entirely absent, present, however, great diversities of shape and dimensions, although in most the bihamate type prevails. Plate L. fig. 2 *a* is the most frequent form; fig. 3 *a* are those of *E. Dröbachiensis*, described by Valentin under the name of *E. brevispinosus*, and *E. neglectus* by Forbes; the plane hooks are found immediately behind the terminal rosette.

The largest and strangest spicules I have yet found occurred in a small, long-spined specimen from India (Plate L. figs. 1, 4), which, although labelled "*Echinus*," evidently does not belong to that genus, but seems to answer more to the description of *Heliocidaris* given by Dujardin and Hupé.

They are found in the ambulacral tubes, in which they arise as irregular, finely spinous, perforated plates, by the thickening of which the perforations are converted into tubes

more or less branched, running from side to side of the spiculum; they open on the surface in the depressions between the spines; the smaller hooked spicula are occasionally found at the base of the ambulacral tubes. In a fragment of membrane obtained from the interior of the shell, delicate branched spicula were found in moderate abundance.

The spicula of an *Echinus* (*Tripneustes**) from the New Hebrides, and called by the natives Nēhvei, are also extremely interesting, as they approximate in character the miliary and tentacular spicula of *Synapta* and *Chirodota*, in which the dumb bells, passing into the hooked condition, are of such frequent occurrence: their various forms are shown in Plate L. fig. 5, *a*; and in Plate L. figs. 10, 11, the spicules of *Chirodota* and *Synapta* are figured for comparison.

Although in *Acrocladia* the test and spines attain so great a size, the spicula are very scanty in comparison with most other genera. Those of the ambulacral tubes are about as numerous as in *Echinus*; they are, however, more long and straight, with abruptly curved points (Plate L. fig. 6, *a*). I have not been able to find any in the ovaries or intestine; but the ambulacral vessel contains some similar to those of the internal parts of *Echinus*.

In *Podophora* I have found spicula only in the ambulacral tubes, not differing from those of *Echinus*, although I had abundance of the internal parts for examination, showing in this respect a greater affinity to *Acrocladia* than *Echinometra*, in which genus it used to be included. (Plate L. fig. 7.)

In *Mespilia* spicula were found in the ambulacral tubes and ovaries; they were of the bihamate form, large, but slender. (Plate L. fig. 8.)

Bihamate spicula were also found in a fragment obtained from the exterior of the shell of a *Temnopleurus*: they were mixed with irregular perforated plates; so it may probably be considered a portion of the external branchiæ, in which such plates are, I believe, of constant occurrence in most, if not all, of the genera in which these organs are present. (Plate L. fig. 9.)

I was unable to find any in *Arbacia*, although the ambulacral tubes, intestine, and ovaries were examined with great care.

I have only, in concluding, to return my most sincere thanks to Dr. Gray and Mr. Flower for the kindness with which they permitted me to examine the valuable specimens in their charge; nor can I fail to record my obligations to the late Mr. S. P. Woodward, who most freely allowed me to study those of his private collection.

* Since the above paper was read, I find that the *Echinus* from the New Hebrides really belongs to the genus *Tripneustes*. *E. Dröbachiensis* is also placed with *E. lividus*, &c., in that of *Toxopneustes*. The propriety of this, together with some other subdivisions of the old genera *Echinus* and *Cidaris*, seems to me, however, to be doubtful.

DESCRIPTION OF THE PLATES.

PLATE XLVII.

- Fig. 1. Portion of ovarian tubes, *Cidaris grandis*.
 Figs. 2, 3. Extremities of ditto, showing terminal and connecting fibrous bands.
 Fig. 4. Extremity of ovarian tube, *Cidaris* — ?
 Fig. 5. Spicula from ovary of *Cidaris tribuloides*.
 Fig. 6. Fringe of spines along the inner border of the intestine of *Cidaris grandis* (in situ).
 Fig. 7. Spines from the mesenteric border of ditto.
 Fig. 8. Spines from the inner border of ditto.
 Fig. 9 *a*. Spine from mesenteric margin of *Cidaris* — ?; *b*, from inner border, showing its solid axis.
 Fig. 10. Spines from interradial membrane at the base of the lantern of *Cidaris tribuloides*.

PLATE XLVIII.

- Fig. 1 *a, b*. Different portions of intestine of *Cidaris grandis* (spicula *in situ*).
 Fig. 2. Ditto *Cidaris* — ?
 Fig. 3. Ditto *Cidaris tribuloides*.
 Fig. 4. Portion of mesentery of *Cidaris* — ? (spicula *in situ*).
 Fig. 5. Ditto *C. tribuloides*.
 Fig. 6. Superficial layer of spicula from the mesentery of *C. tribuloides*.
 Fig. 7. Spicula *in situ* from free inner membrane of *C. tribuloides*.
 Fig. 8. Ditto *Cidaris* — ?
 Fig. 9. Plate from interradial membrane of *Cidaris* — ?
 Fig. 10. Spicula of external oblique ligament of lantern of *Cidaris* — ?
 Fig. 11. Spicula from an ambulacral tube of *C. tribuloides*.
 Fig. 12 *a*. Ditto from ambulacral tube of oral surface of *Cidaris* from Malta; *b*, ditto from dorsal surface.
 Fig. 13. Spicula of the intestine of *Goniocidaris geranoides* (in situ).
 Fig. 14. Spicula from its inner border.
 Fig. 15. Spines from border of intestine.
 Fig. 16 *a*. Spicula from ambulacral tubes; *b*, from ovary.
 Fig. 17 *a*. Spicula from ambulacral tube of *Diadema*; *b*, from internal membrane near the anus (*in situ*).
 Fig. 18 *a*. Spicula of intestine of same *Diadema*; *b*, ditto *Diadema* from China.

PLATE XLIX.

- Fig. 1. Spicula from the ovary of *Echinometra* (D. 153 Royal Coll. Surgeons).
 Fig. 2. Ditto *Echinometra*, Wh.
 Fig. 3 *a*. Spicula of intestine; *b*, inner margin; *c*, mesenteric band of *Echinometra*, D. 153 (*in situ*).
 Fig. 4 *a, b*. Spicula of different parts of the intestine of *Echinometra*, Wh. (*in situ*); *c*, from mesentery.
 Fig. 5 *a*. Spicula of intestine; *b*, inner border (*in situ*); *c*, from mesentery of *Echinometra*, Ol.
 Fig. 6 *a*. Spicula of ambulacral tube of *Echinometra*, D. 153; *b*, ditto *Echinometra*, Wh.; *c*, *Echinometra* from China, *d*, E. Ol.

PLATE L.

- Fig. 1. Spicula from ambulacral tube of *Helicidaris* ?
- Fig. 2 *a*. Spicula from ambulacral tube of *Echinus sphæra*; *b*, from ovary.
- Fig. 3 *a, b*. Ditto, ditto, *E. Dröbachiensis*.
- Fig. 4 *a*. Edge of large spiculum of *Helicidaris*, showing the tubular and reticulate character of the areola; *b*, side view of smaller spiculum; *c*, Hooked spicula from base of ambulacral tube.
- Fig. 5 *a*. Spicula from the ambulacral tube; *b*, internal membrane from near the anus; *c*, from ovary of *Echinus* from Aneiteum, New Hebrides.
- Fig. 6 *a*. Spicula of an ambulacral tube of *Acrocladia trigonaria*; *b*, from ambulacral vessel.
- Fig. 7. From ambulacral tube of *Podophora atrata*.
- Fig. 8 *a*. From ambulacral tube; *b*, intestine; *c*, ovary of *Mespilia*.
- Fig. 9. Spicula from *Temnopleurus*.
- Fig. 10 *a*. Tentacular (?) spicula of *Chirodota*; *b*, *Synapta*, from Japan.
- Fig. 11 *a*. Miliary plates of *Synapta inherens*; *b*, ditto *Synapta* from New Zealand; *c*, ditto *Synapta digitata*; *d*, *S. bidentata* (*c* & *d*, after Woodward and Barrett).