

two species of Deer—*Cariacus paludosus*, frequenting the open marshy spots, and *Cariacus simplicicornis*, inhabiting the woods; and two Peccaries (*Dicotyles torquatus* and *D. labiatus*). Of Carnivora, the Jaguar was the most frequently seen; the Puma being equally abundant but less conspicuous, owing to its inhabiting the open campo. In the waters of the river near the mouth an Otter (*Lutra paranensis*) was abundant.

As the expedition proceeded farther up the Pilcomayo, the channel became narrower, and a great fall in the level of the water taking place, progress became much obstructed. Still, however, the 'Bolivia' struggled to get onward, but eventually came to a full stop about 300 miles from the mouth of the river, in the midst of a parched and salt-saturated country, consisting almost entirely of open campo, in which animal and vegetable life of all kinds was marked by extreme poverty and lack of variety. The greater part of the men here deserted, the leader and the doctor both died; and the remainder, numbering nine in all, after a detention of over four months, were ultimately rescued by a military search-party sent out by the Argentine Government. Mr. Kerr was compelled to leave the steamer 'Bolivia' in the Pilcomayo, and with it the greater part of his collections. The more portable portions—the bird-skins and the plants—were brought off on mule-back. The birds have been worked out, and an account of them has been published in the 'Ibis' for January 1892; while the Botanical collections are being investigated at Kew.

In illustration of his remarks, Mr. Kerr exhibited a series of 14 views taken from his own negatives, representing the progress of the expedition, and the life of the district traversed by it.

The following papers were read:—

1. A Contribution to the Classification of Ophiuroids, with Descriptions of some new and little-known Forms. By F. JEFFREY BELL, M.A., Sec. R.M.S.

[Received February 15, 1892.]

(Plates XI. & XII.)

1. The Calycinal Plates of a young Ophiuroid, p. 175.
2. The Classification of Ophiuroids, p. 176.
3. Account of *Ophioteropsis elegans*, g. et sp. n., p. 178.
4. The Subdivisions of Ophiuroids, p. 179.
5. The Relation of *Ophioteropsis* to Fossil Forms, p. 182.
6. The Radial Shields of *Ophiomaza obscura*, p. 182.
7. *Ophiomyraa hystrix*, p. 183.

1. THE CALYCINAL PLATES OF A YOUNG OPHIURID.

Among the valuable collections recently made by Messrs. J. J. Walker, R.N., and P. W. Bassett-Smith, R.N., of H.M.S. 'Penguin',

<sup>1</sup> Forwarded to the British Museum through the Hydrographer.

on the north-west coast of Australia, are a number of young Echinoderms; in many cases it is not possible to assign them a definite specific place, but to the morphologist they will offer charms less patent to the systematist.

Among them there is an Ophiurid which is remarkable for the large size of what are now generally regarded as the plates of the calycinal area, and which my lamented friend P. Herbert Carpenter in his valuable essay<sup>1</sup> called respectively centro-dorsal, under-basals, and radials. These plates are so well marked that it is quite impossible for the most sceptical to regard them as anything else than the components of a vestigial calyx, and I think their relations to the rest of the organism are perhaps better shown in the drawing given herewith than in any previously published figure of an Ophiurid (Plate XI. figs. 6, 7).

It is certain that the specimen is the young of a species of *Pectinura* or of some form closely allied to that genus.

## 2. CLASSIFICATION OF OPHIUROIDS.

Since the year 1867, when Dr. Ljungman<sup>2</sup> published his still valuable classification, no serious attempt has been made to classify the Ophiuroidea, and it is possible that some doubts remain as to the relations of the genera that compose that class; the question whether the simple-armed *Ophioderma* or the much-branched *Astrophyton* has the more archaic characters is one which systematists have neither asked nor answered. The majority of naturalists would probably confess that their impression was that the many-branched forms had succeeded those with simple arms.

At any rate all are agreed that there are two equivalent orders or groups—the Ophiuræ and the Euryalæ of Johannes Müller, the Ophiuridæ and Astrophytidæ of Theodore Lyman; if these two groups are really sharply separated from one another, it will follow that we must look upon one as derived from the other and now separated from it by the disappearance of the connecting-links, or we must suppose that they had long ago a common ancestor and have since been evolved along distinct lines; the latter is the view adopted by Prof. Hæckel in his 'Generelle Morphologie.'

Mr. Lyman, though retaining the bifid division of the class, recognizes the resemblance of some of the Ophiuridæ to the Astrophytidæ, for his "group III." is called "Astrophyton-like Ophiurans." One striking point in which *Sigsbeia* and *Hemicuryale*, for example, two members of the group, resemble *Astrophyton* is the power of rolling their arms. And the function has a corresponding similarity of structure. In most brittle-stars the "several ossicles of the arm have a certain power of movement on one another, but this is limited by the development of processes and pits analogous to the zygosphenes and zygantra of the Ophidian vertebræ. In such

<sup>1</sup> Quart. Journ. Micr. Sci. xxiv. (1884) pp. 1-23.

<sup>2</sup> Öfv. Vet.-Akad. Förhandl. xxiii. (1867) p. 303.

Ophiuroids, however, as are, like *Astroschema*, capable of twisting or twining their arms round a straight Gorgonian, the saddle-shaped faces are well developed, but the limiting pits and processes are absent"<sup>1</sup>. The former plan of structure may be spoken of as zygospondyline and the latter as streptospondyline; there can be no doubt that the latter is the simpler, and there is much evidence to support the view that this simplicity is archaic and not secondarily acquired. For example, no *Astrophytid*, all of which exhibit the streptospondyline type, has the investiture of the central arm-ossicles differentiated into upper, lower, and side arm-plates; the madreporites are inconstant in number and position, and pedicellariæ, never known among Ophiurida, may be present.

If the possession of streptospondyline ossicles is an archaic character in the *Astrophytidae*, it is so also in the *Ophiuridae*. Have any of them other archaic characters? *Ophioscolex* has no upper arm-plates; *Neoplax* has a single, incomplete, upper arm-plate; species of *Ophiomyxa* have or have not arm-plates, which, when present, may be in two pieces; the tentacle-scales, which are so characteristic of most Ophiurids, are wanting from *Ophiomyxa* and *Ophiobyrsa*, are small and single in *Neoplax*, small and narrow in *Ophiochondrus*; the teeth and teeth-papillæ of *Ophiobyrsa* are spiniform; and the teeth-papillæ are wanting in *Ophiomyxa*, *Ophiochondrus*, *Sigsbeia*, and *Hemieuryale*.

Such a combination of characters points to the forms just mentioned as the simpler of the class; they might have led to the vegetatively multiplying Gorgon's-head or to the more highly differentiated *Ophiothrix*.

Before coming to any definite opinion, let us consider the value of the evidence of the calycinal plates. But little is known of the development of any streptospondyline Ophiurid; indeed, all that we do know is, I think, contained in one passage in Mr. Lyman's 'Challenger' Report. There we read of the young *Gorgonocephalus* (p. 252): "Above there is in the centre a group of six or seven primary plates, each encircled by a superimposed line of grains." Later on, the "disk-plates" become obliterated. Mr. Lyman's observations show that there is no regularity of the plates, which, as he calls them primary, we may suppose to be the representatives of the calycinal plates of recent Echinoderm Morphology.

But, after all, this is what may well be expected; now that we are, as I hope, delivered from the theory of the pelmatozoic<sup>2</sup> origin of the Echinoderms, we may go a step further and recognize, as the Cystidea teach us to do, that the calyx did not appear at once with all the diagrammatic regularity that it has retained during the manifold changes in name that its parts have suffered.

It is, then, among those Cystid-like forms in which a definite pentamerous arrangement was not permanently established<sup>3</sup> that we must seek for the ancestor of the Ophiurid. At present, palæonto-

<sup>1</sup> Bell, *Comp. Anat. & Physiology*, p. 316.

<sup>2</sup> See *Ann. & Mag. N. H.* viii. (1891) pp. 206 *et seq.*

<sup>3</sup> Cf. Bather, *Quart. Journ. Geol. Soc.* 1889, p. 166.



logists have no form known to them which gives any certain indication of Ophiurid affinities.

The considerations which I have urged will perhaps induce the student to regard the streptospondyline type as earlier than the zygospondyline. I have now to show how that type is modified.

Mr. Lyman has shown how the "Astrophyton-like Ophiurans" make an attempt to acquire the saddle-shaped ossicle of the Astrophytidæ; we have among the several genera various modifications of the type which is seen at its simplest in *Ophioteropsis*.

### 3. ACCOUNT OF OPHIOTEROPSIS ELEGANS.

Among the specimens collected by Dr. Copping, of H.M.S. 'Alert,' while in the waters of the Western Indian Ocean, were some examples of a remarkable Ophiurid, the explanation of the structure of which was quite unattainable at the time when I was engaged in preparing a portion of the Report published by order of the Trustees of the British Museum, under the editorship of Dr. Günther, F.R.S.

#### *Description of the General Appearance of a Specimen.*

This form is particularly elegant in appearance, owing to the green colour of the upper surface of the arms and the margins of the disk, and the ornamentation by light, wavy, meandering lines of the central portion of the disk with its dark background. Below, the colour is pale yellow, except in the interradial portions of the disk, which are dark, and marked by white wavy lines. The contour of the disk, which is of moderate size in proportion to the arms, is more or less distinctly pentagonal; the regularity of the disk is, no doubt, due to the large size of the radial shields. These, however, are not apparent from the outer surface, for, like all the rest of the animal, they are enclosed in a thick softish skin. The oval slits are provided with teeth and tooth-papillæ, but there are no mouth-papillæ. The arms twist and coil on themselves; at their sides the spines form mere papilliform projections, owing to the fact that their bases are encased in the thick investing skin; on the middle line of their lower surface there is a distinct groove.

#### *Anatomical Details.*

Since the publication of Mr. Lyman's 'Challenger' Report, in which so many valuable figures were given of the characters of the ossicles of which the arms of various species of Ophiuroids are made up, every student of the group turns first to an examination of these parts of the skeleton.

Those of *Ophioteropsis* are particularly interesting from the extremely generalized condition which they present. As will be seen from the drawings (figs. 4 and 5, Plate XI.), the recesses on the adoral side of the ossicle are excessively shallow, and, in correspondence with that, the articulating elevations on the aboral side are very slight and inconspicuous. But, at the same time, it is to be noted that

the saddle-shaped face of the *Astrophytid* ossicle is not seen here; we have merely a generalized *Ophiurid* ossicle, without knobs or pits.

The most remarkable character of this *Ophiurid* (see Plate XI. figs. 3 and 4) is the complete absence of a ventral plate; no other existing brittle-star is known to want this plate. The upper plates are definitely double, and the side-plates, instead of lying flat against the side of the central ossicles, are wider than long and stand out from the sides of the arm. The radial shields are very large and extend almost to the centre of the disk; they have the form of right-angled triangles, the hypotenuses of which face, but do not touch, one another; there are no other plates on the surface of the disk.

It is necessary to form a new genus for this form, which may be called *Ophioteresis*<sup>1</sup>.

#### *Definition of the Genus and Species.*

*Ophioteresis* is a streptospondyline *Ophiurid* in which the covering-plates of the arms are double above, wanting below, and wedge-shaped at the sides; the radial shields are well developed, and there are ordinary teeth and teeth-papillæ.

*Ophioteresis elegans* has the disk more or less distinctly pentagonal, of moderate size; arm-spines five. Elegantly coloured, the upper surface of the arms and the margins of the disk green, the central portion of the disk dark, with an irregular pattern of meandering white lines; interradial portions of lower surface of disk dark, with white lines; the rest of the lower surface yellow.

*Hab.* Seychelles, 4-12 fms. In coll. B. M.

From this simple form differentiation would seem to have preceded along two lines; there has been an increase in complexity of articulation, associated with the fixation of certain ossicles and spines, or there has been vegetative repetition and branching with a more primitive inconstancy and irregularity of anatomical characters.

Around the primitive stock some forms—those which Mr. Lyman calls the "*Astrophyton-like Ophiurans*"—have remained, such as *Ophiacolex*, *Ophiobyrsa*, *Neoplax*, and *Ophioteresis*.

#### 4. THE SUBDIVISIONS OF OPHIUROIDS.

It will perhaps be found convenient to give distinctive names to the three groups; for brevity's sake I add here the definition of *Ophiuroids* which I ventured to publish last September<sup>2</sup>.

The *Ophiuroidea* are caliculate, actinogonidial, eleutherozoic, azygopodous *Echinoderms*, in which there is no distinct ambulacral groove. The "arms" are sharply marked off from the disk, are very rarely more than five in number, and are sometimes elaborately branched. The digestive system, which is aprocous, and the generative are confined to the area of the disk, as is also the specialized respiratory apparatus, which takes the form of deep clefts.

The *Streptophiuræ* are *Ophiurids* in which the ambulacral

<sup>1</sup> *Τηρησις*, alertness.

<sup>2</sup> *Z. c.* p. 214.

ossicles articulate with one another by means of a more or less simple ball-and-socket joint; the covering plates are more or less regularly developed as superior, inferior, and two lateral, the last of which bear spines.

The *Astrophieuræ* (s. *Cladophieuræ*) are Ophiurids in which the ambulacral ossicles articulate with one another by means of hour-glass-shaped surfaces, and are covered by granular deposits in the thick integument; the arms may be simple or branched repeatedly.

The *Zygophieuræ* are Ophiurids in which the movement of the ossicles on one another is limited by the development of lateral processes and pits; superior, inferior, and lateral spine-bearing plates are always developed as a covering for the arms, which are always simple, and incapable of coiling round straight rods.

### *The Streptophieuræ.*

The following facts justify the vagueness of the definition offered.

- a. *Upper arm-plates*: absent in *Ophiomyxa vivipara*, double in *O. pentagona*, of several pieces in *O. floccida*; double in *Ophioteropsis*; in *Hemieuryale* a mosaic of small plates; single but incomplete in *Neoplax*.
- β. *Under arm-plate*: absent from *Ophioteropsis*, alone among existing Ophiuræ.
- γ. *Tentacle-scales*: absent from *Ophiomyxa*, *Neoplax*, and *Ophiobyrsa*.
- δ. *Tooth-papillæ*: absent from *Sigsbeia*, *Hemieuryale*, *Ophiochondrus*, and *Ophiomyxa*.
- ε. *Radial shields* are small and short in *Ophiobyrsa*, small and irregular in *Ophiomyxa*, rather large in *Ophioteropsis*, large in *Hemieuryale*, and very large in *Sigsbeia*; on the other hand, they are absent from *Neoplax*.

The order in which the genera just mentioned should stand to one another is a question which cannot be discussed now, nor can that of the relation, clearly enough marked in many points, between the *Streptophieuræ* and the lowest of the *Zygophieuræ*: the "articulating peg" in *Ophioscolex* is described as minute; it, *Ophiambix*, *Ophiosciasma*\*, *Ophiogeron*\*, *Ophiichelus*\*, and *Ophiotholia* have no upper arm-plates, while in *Ophiomyces* they are, if present, minute; in the three genera marked with an asterisk the arm-ossicles retain the embryonic character of being nearly divided into two.

In addition to the genera placed under the "Astrophyton-like Ophiurans" of Mr. Lyman—*Ophiobyrsa*, *Ophiomyxa*, *Ophiochondrus*, *Hemieuryale*, and *Sigsbeia*—to which, of course, must be added *Neoplax*, I would place in the *Streptophieuræ* the genera *Ophiomyces*, *Ophiotholia*, *Ophiichelus*, *Ophiosciasma*, *Ophiambix*, and *Ophioscolex*.

Mr. Lyman says of *Ophioblenna*, which he places next to *Ophioscolex*, "Of its skeleton I am quite ignorant." I applied, therefore, to Dr. Lütken, who has charge of the only known specimens, and he



most kindly informs me the arm-ossicles remind him most of those of *Ophiotricha* and *Ophiacantha*.

The Streptophiuræ may be thus arranged:—

- A. No under arm-plates . . . . . 1. *Ophioteresis*.
- B. Under arm-plates imperfect . . 2. *Ophiosciasma*.
- C. Under arm-plates moderate or well developed.
  - a. No upper arm-plates.
    - I. No radial shield . . 3. *Neoplar*.
    - 4. *Ophiohelus*.
    - 5. *Ophiotholia* (?).
    - II. Radial shields present.
      - 6. *Ophioscala*.
      - 7. *Ophiambia*.
      - 8. *Ophiogeron*.
      - 9. *Ophiobyrsa*.
      - 10. *Ophiomyra* (pars).
  - β. Upper arm-plates minute or formed of scattered plates.
    - 11. *Ophiomyra* (pars).
    - 12. *Ophiomyces*.
    - 13. *Ophiochondrus*.
    - 14. *Hemicuryale*.
    - 15. *Sigsbeia*.

It will be gathered that I regard the simple-armed Astrophiuræ as the more archaic, and I propose, therefore, an arrangement of the genera which is altogether different from that of Mr. Lyman:—

- A. Arms simple.
  - i. Disk large . . . . . 1. *Astrotoma*.
  - 2. *Astronyn*.
  - 3. *Astrachele*.
  - ii. Disk moderate (about one-tenth of the length of the arms) . . . . . 4. *Astragomphus*.
  - 5. *Astroporpa*.
  - iii. Disk small, even very small.
    - 6. *Ophiocreas*.
    - 7. *Astroschema*.
    - 8. *Astrocera*.
- B. Arms branch a few times near their free ends.
  - 9. *Trichaster*.
  - 10. *Astroclon*.
  - 11. *Astrocnida*.
- C. Arms branch much and from near their base.
  - 12. *Euryale*.
  - 13. *Gorgonocephalus*.
  - 14. *Astrophyton*.

These three groups (A, B, and C) correspond to the subfamilies of Ljungman—Astronycinæ, Trichasterinæ, and Gorgonocephalinæ; and the fact that it should be so, notwithstanding the multiplication almost by three of the genera of Astrophiuræ since 1866, is another

proof, if more were needed, of the acumen of the distinguished naturalist who proposed them.

For the Zygophiurans assistance in classification will be gained from Ljungman's well-known work<sup>1</sup>, and the families may be disposed thus :—

- |                      |   |   |
|----------------------|---|---|
|                      | { | I. Arm-incisures on the disk.                 |
| a. No dental papillæ |   | 1. <i>Ophiidermatidæ</i> .                    |
|                      |   | 2. <i>Ophiolepididæ</i> .                     |
|                      | { | II. Arms inserted on ventral surface of disk. |
|                      |   | 3. <i>Amphiuridæ</i> .                        |
| β. Dental papillæ.   | { | I. Oral papillæ present.                      |
|                      |   | 4. <i>Ophiocomidæ</i> .                       |
|                      |   | II. No oral papillæ.                          |
|                      |   | 5. <i>Ophiothricidæ</i> .                     |

#### 5. THE RELATION OF OPHIOTERESIS TO FOSSIL FORMS.

Zittel places in the suborder Euryaleæ (= Cladophiuræ) the genera *Onychaster* and *Eucladia*, of which he says (Handh. d. Pal. p. 444) that they are "die einzigen fossilen Formen, welche mit einiger Sicherheit zu den Euryaliden gestellt werden können." But *Eucladia*, as described by Dr. Woodward (Geol. Mag. 1869, p. 241), has the madreporite on the abactinal surface, whereas all Ophiuroids have that plate actinal in position. As I purpose to confine myself for the present to the Ophiuroids, I need not discuss what is the exact systematic position of *Eucladia*, beyond urging that it should be recognized as a form which cannot be placed in the group Ophiuroidea, as now recognized.

*Onychaster* has the granular investment which is now found only in Astrophiuroids, but the articular surface of the arm-ossicles appears to be rather on the Streptospondyline than the Astrophiuroid (hour-glass-shaped) type.

*Taniaster* (Billings, Geol. Surv. Canada, Canadian Organic Remains, dec. iii. p. 80) and *Protaster* (Forbes, Mem. Geol. Surv. U. K., dec. i. pl. iv.) are examples of a group of which the most salient known fact is the absence of ventral arm-plates. I have no information as to the character of the faces of their arm-ossicles; but, as the arms of both are flexible, I have no doubt that their proper place is with the Streptophiuræ.

#### 6. THE RADIAL SHIELDS OF OPHIOMAZA OBSCURA.

In his description of this species Herr Ljungman (*op. cit.* p. 333) says, "in dorso scutis radialibus maximis gibboso-carinatis." So far as I can discover, this species has not been seen by any subsequent student of the group, and no figure of this very interesting species has been published.

Its discovery by Mr. Bassett-Smith off the N.W. coast of Australia (Bassett-Smith Bank, 9 fathoms) extends its geographical range, as the type was taken off Singapore. The figure which is now given

<sup>1</sup> *Op. cit.*



(Plate XII. fig. 1) shows very well the definite carination of the radial shields; the term carination has been and is applied to keels varying so much in depth that it is difficult to gauge how slight or how great it may be in any particular case. Herr Ljungman says "*Brachia longitudine diametrum disci ter hanc æquantia*," but in the specimen before me the proportions are nearly 5 to 1; I cannot suppose that this difference is of specific value.

#### 7. OPHIOBYRSA HYSTRICIS.

The largest Streptophiurid found within the British area is the species so named by Mr. Lyman. Readers of Sir Wyville Thomson's 'Depths of the Sea' will remember that (on p. 123) there is a brief account of "a very large Ophiurid with thick arms, upwards of three decimetres long, and a large soft disk resembling that of *Ophiomyxa*, to which genus it seems to be allied. The specimens which have been hitherto procured are scarcely sufficiently perfect to allow of its being thoroughly worked out." There is not complete concordance between these measurements and that of Mr. Lyman, who gives the length of the arm as 187 mm.; as the diameter of the disc is 20 mm., the total spread would be very nearly four decimetres.

Among the specimens collected by the Rev. W. Spotswood Green during the dredging-expedition of the 'Flying Fox' off the S.W. coast of Ireland was one example of this species; it is a good deal broken and was, most unfortunately, dried. The figure, however, now given of it (Plate XII. fig. 2) will give a good idea of its general appearance. The diameter of the disk is 35 mm., and the arms must have been at least 310 mm. long. As Thomson states that the specimens he obtained were in a bad condition, it is not improbable that he did not preserve his largest but merely noticed its size.

Mr. Green dredged this example in 315 fathoms; the 'Porcupine' found specimens in 345 fathoms.

#### EXPLANATION OF THE PLATES.

##### PLATE XI.

- Fig. 1. *Ophioteresis elegans*, nat. size.  
 2. Disk and arms from above, to show the large radial shields,  $\times 8$ .  
 3. The same from below,  $\times 8$ .  
 4. Aboral surface of arm-ossicle, to show the double dorsal plates, the simplicity of the articular cavities (*a*), the absence of a covering plate to the ventral surface of the ossicle, the form and position of the side arm-plates (*b*), and the position of the spines.  $\times 24$ .  
 5. Adoral surface of arm-ossicle, to show the double dorsal plates (*d*) and the simple articulating convexities.  
 6. General view of a young *Pectinura*, to show the preponderating size of the calycinal plates,  $\times 2$ .  
 7. Disk of the same  $\times 8$ , to show the form and character of the calycinal plates.

##### PLATE XII.

- Fig. 1. *Ophiomaza obscura*, upper surface of disk, to show the carinated radial shields,  $\times 2$ .  
 2. *Ophiobyrsa hystericis*, from below, nat. size.  
 3. The same from above, nat. size.