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THE TRANSACTIONS OF THE LINNEAN SOCIETY OF LONDON.

CONTENTS.

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TRANSACTIONS

OF

THE LINNEAN SOCIETY.

I. *On the Genus* Actinometra, *Müll., with a Morphological Account of a new Species* (A.) polymorpha *from the Philippine Islands.*—Part I. *By* P. Herbert Carpenter, *M.A., Assistant Master at Eton College.* (*Communicated by* W. B. Carpenter, *C.B., M.D., LL.D., F.R.S., F.L.S.*)

(Plates I.-VIII.)

Read June 21st, 1877.

The principal part of the investigations, of which the results are set forth in the following pages, were carried on during the year 1876, in the Zool.-Zootomical Institute of the University of Würzburg, under the superintendence of its director, Prof. C. Semper. I would here express my most sincere thanks to Prof. Semper, not only for the generous manner in which he placed at my disposal all his specimens of *Act. polymorpha*, which he had himself collected in the Philippine Islands, but also for the ready and valuable advice which he constantly afforded me during the progress of my work, and for the free use which he permitted me to make of his extensive library. I am also greatly indebted to Dr. Sandberger, Professor of Geology in the University of Würzburg, to the authorities of the University Library, and to Professor Dr. Halm, of the Royal Library at Munich, for the means of reference to many books which would otherwise have remained inaccessible to me; and I desire to record my best thanks to all these gentlemen for the ready kindness with which they met my frequent and numerous wants.

I. Historical.

(§ 1) In the remarkable work of Linckius[1] upon the "Sea Stars," the modern family Comatulidæ (J. Müller) is described under the name of Crinitæ, or Comatæ Stellæ, as a group distinct not only from the Asteridæ, but also from the Ophiuridæ and from *Astrophyton* (*Euryale*, Lamarck), with which they have been united by many later systematists.

[1] Johannis Henrici Linckii Lipsiensis 'De Stellis Marinis liber singularis,' Lipsiæ, 1733, p. 53.

Linck included three genera in this family, or, as he called it, "Classis." The first of these he named Δεκάκνημος, to indicate "stellam marinam decem caudis crinitis radiantem;" and he referred to it three species:—(1) The "*Crocea zaffarana Neapolitanorum*," or δεκαδασυακτινοειδής of Fabius Columna [1], whose description he quotes; (2) the *Decempeda* Cornubiensium of Llhuyd [2], which Linck figured and named "*Stella δεκάκνημος rosacea*;" and (3) the "Δεκάκνημος *fimbriata* Barrelieri" [3], which was named by Linck *barbata*, as he supposed it to be different from the other two. All three, however, are really identical, being simply local varieties of one and the same species, viz. the British *Antedon rosacea*, or the *Comatula mediterranea* of Lamarck. Thus, Fabius Columna described the Neapolitan variety, and Barrelier another obtained at the mouth of the Tiber, while Llhuyd based his description upon specimens found upon the coast of Cornwall near Penzance.

Linck's second genus, the Τρισκαιδεκάκνημος, was based upon a specimen with thirteen arms, previously described by Petiver [4] as "*Stella chinensis*;" this specimen, however, was suspected by Linck to have been mutilated. His third genus he called "*Caput-Medusæ*," and described it as including those specimens which "ex centro corporis parvi umbonatique per quinque truncos primum bifidi, mox nullo constanti numero multifidi, in 60 et plures surculos geniculatos rectos simplices abeunt, quos gracilescentes fibrillæ aliæ pilorum instar vestiunt."

Linck referred two species to this genus, viz. *Caput Medusæ cinereum* and *C. brunnum*; and he gave good figures of both (tab. xxi. n. 33, and tab. xxii. n. 34), from which it may be determined with tolerable certainty that they represent species now known to belong to two different types among the Comatulæ—namely, to the genera *Antedon* and *Actinometra* respectively.

(§ 2) Although Llhuyd [5], and after him Rosinus [6], had explicitly pointed out the relationship between the recent Comatulæ and the fossil Crinoidea, and although Linck, while supporting and repeating Llhuyd's views, had clearly differentiated the former from the Asteroidea and Ophiuroidea, yet Linnæus [7], instead of adopting the more correct views of some of his predecessors as to the true relations of the Crinoidea, was so misled by the jointed structure of their stems as to rank them among zoophytes in his genus *Isis*, whilst he grouped the Comatulidæ, together with all the other Starfish, under one common name *Asterias*. Linck's three species of *Decacnemus* were rightly regarded by him as identical; and he placed them, together with Petiver's *Stella chinensis*, in one species, *Asterias pectinata*, to which he also referred a specimen previously described by Retzius [8]. We now know, however, that this last is an *Actinometra*, dif-

[1] Phytobasanus, sive Plantarum aliquot Historia. Neapoli, 1592.

[2] EDUARDI LUIDI 'Lithophylacii Britannici Ichnographia' p. 149. Londini, 1699.

[3] JACOBI BARRELIERI 'Plantæ per Galliam, Hispaniam et Italiam observatæ' Paris, 1714, p. 131.

[4] 'Gazophylacium Naturæ et Artis,' Londini, 1711; and also 'Aquatilium animalium Amboinensium Icones et Nomina,' 1713.

[5] Prælectio de Stellis marinis Oceani Brit. nec non de Asteriarum, Entrochorum, et Encrinorum Origine, pp. 149–155, Oxford, 1733.

[6] Tentaminis de Lithozois ac Lithophytis olim marinis, jam vero subterraneis, prodromus; sive de stellis marinis quondam, nunc fossilibus, disquisitio. Hamburg, 1719.

[7] 'Systema Naturæ,' editio decima tertia (Lipsiæ, 1788), pars vi. p. 3166.

[8] Nova Acta, Stockholm, 1783, p. 234, n. 12.

fering very considerably from the type represented by *Decacnemus* (*Antedon*) *rosacea*, although resembling it in only having ten arms.

In like manner both of Linck's species of his genus *Caput-Medusæ*, the one an *Antedon* and the other an *Actinometra*, were united by Linnæus, together with a many-armed specimen described by Retzius, into one species, *Asterias multiradiata*.

(§ 3) For some years after the commencement of the present century the Linnean nomenclature held its own, and the few species of recent Comatulæ with which the naturalists of that time were acquainted were described as different species of the Linnean genus *Asterias*.

The first among the post-Linnean zoologists who recognized the claims of this form of Sea Star to a distinct generic rank was De Freminville [1], who in 1811 presented to the Société Philomatique de Paris a " Mémoire sur un nouveau genre de Zoophytes de l'Ordre des Radiaires," to which he gave the name of *Antedon*. His definition of the genus was as follows :—" Animal libre, à corps discoïde calcaire en dessus, gélatineux en dessous, environné de deux rangées de rayons articulés, pierreux, percés dans leur largeur d'un trou central; ceux du rang supérieur plus courts, simples, et d'égale grosseur dans toute leur longueur; ceux du rang inférieur plus longs, allant en diminuant de la base à la pointe, et garnis dans toute leur longueur d'appendices alternes également articulés; bouche inférieure et centrale."

It is not very clear which of the two apertures on the ventral (or, as he called it, inferior) side of the disk was regarded by De Freminville as the mouth; it is very probable that, as he was only able to examine a spirit-specimen, he failed to recognize more than one—that namely, which, placed at the extremity of a long tube projecting from a point near the centre of the disk, we now know to be the anus.

Adams [2], who had studied living specimens of Linck's *Decacnemus rosacea*, had, however, pointed out some years previously the existence of two orifices to the digestive cavity; but his observations seem to have escaped notice; for Lamarck [3], Miller [4], and many other naturalists, all regarded the aperture at the end of the anal tube either as the mouth alone or as a combined mouth and anus; and it was not till 1823 that the existence of distinct oral and anal orifices was fully recognized.

It was announced as a new discovery by Leuckart [5], in a letter to Von Schlotheim; and he was followed shortly afterwards by Meckel [6], Gray [7], and Heusinger [8].

[1] Nouv. Bull. d. Scien. par la Soc. Philomat. tom. ii. p. 349. Paris, 1811.

[2] "Description of some Marine Animals found on the Coast of Wales," Trans. Linn. Soc. vol. v. p. 7 (1800).

[3] Système d'Animaux sans Vertèbres, 2me éd. (Paris, 1816), tom. ii. p. 532.

[4] A Natural History of the Crinoidea (Bristol, 1821), p. 128.

[5] Von Schlotheim, Nacht. z. Petrefact. Abth. ii. p. 48 (Gotha, 1823); and Leuckart, "Einiges über Asteriden Geschlecht *Comatula* Lam. überhaupt, und über *Com. mediterranea* insbesondere," Zeitsch. für organ. Physik, iii. p. 385 (1833).

[6] "Ueber die Oeffnungen des Speisekanals bei den Comatulen," Meckel's Archiv für Physiol. Band iii. p. 470 (1823).

[7] "Notice on the Digestive Organs of the Genus *Comatula* and on the *Crinoidea* of Miller," Ann. of Philos. n. s. vol. xii. p. 392 (1826).

[8] "Bemerk. über d. Verdauungskanal der Comatulen, Meckel's Archiv" für Physiol. 1826, p. 317; and "Anat. Untersuch. d. *Comatula mediterranea*," Zeitsch. für organ. Physik, iii. p. 366 (1833).

De Freminville's specimen was found on the keel of a vessel which had come from a warm climate; it had ten arms and twenty cirrhi, and was named by him *Antedon gorgonia.* He gave no further description of it, but simply referred to the figure of *Stella decacnemus rosacea*, Linck, in the 'Encyclopédie Méthodique'[1], which represents the ordinary European *Comatula rosacea*, as it is now called.

This species, however, is not identical with De Freminville's *Antedon gorgonia*, which was referred by Lamarck[2] to his *Comatula carinata*, under which name he described some specimens brought by Peron from the Isle de France. Nevertheless the two species resemble one another in some important points, viz. the presence of ten arms, of a central or subcentral mouth, and of an excentric anal tube.

In 1815 Leach[3] rescued the three genera contained in Linck's classis *Crinitæ* from the confusion of the Linnean genus *Asterias*, and united them into one genus, *Alecto*, comprising three species, viz. *Alecto europæa* (=*Decacnemus rosacea*, Linck), *Alecto horrida* (=*Caput-Medusæ*, Linck, or *Asterias multiradiata*, Linn.), and *Alecto carinata* (which seems to have been the same as De Freminville's *Antedon gorgonia*).

Leach defined *Alecto* as having the "os inferius, irregulare," a description which would suit equally well either for the true mouth or for the anal opening, though perhaps more applicable to the former. He seems, however, like his predecessor De Freminville, to have regarded the mouth as situated at the extremity of the anal tube; for in the explanation to Schweigger's figure[4] of Leach's specimen of *Alecto horrida* the latter is described as the "röhrenförmig hervorstehender Mund." It is obvious, therefore, that we cannot make any use for systematic purposes of the definitions of *Antedon* and *Alecto* as given by Leach and De Freminville respectively, as far as the position of the mouth is concerned.

Schweigger's figure of the disk of *Alecto horrida* shows clearly enough that the five trunks of the ambulacral grooves converge towards the centre of the disk, as in *Antedon rosacea* (*Alecto europæa*, Leach), Plate I. fig. 1. Leach's *Alecto horrida* was therefore a true *Antedon* in the modern sense of the term, although belonging to that division of the genus in which the repetition of the bifurcation of the ten primary arms is carried to a great extent.

(§ 4) Leach was apparently unacquainted with the memoir of Freminville; but the same was evidently not the case with Lamarck (1816), who, like Leach in the previous year, united Linck's three genera into one, to which he gave the very appropriate name *Comatula*[5]. His definition of the genus differs but little from that given for *Antedon* five years previously by De Freminville, whose original specimen Lamarck seems to have examined; and it is difficult to see why he did not adopt the name *Antedon* to designate the genus, which, like Leach and De Freminville, he clearly distinguished as belonging to a different type from the Asteridæ, Ophiuridæ, and *Euryale*.

[1] Partie des Vers, pl. 42. fig. 6.

[2] *Tom. cit.* p. 534.

[3] Zoological Miscellanies, vol. ii. p. 61: London, 1815.

[4] Beobacht. auf naturhistorischen Reisen, p. 66, and Taf. iv. fig. 42: Berlin, 1819.

[5] *Tom. cit.* p. 530.

Lamarck included eight species in his new genus *Comatula*. In only three of these is the mouth at or near the centre of the disk, viz. *C. mediterranea* (= *Stella decacnemus rosacea*, Linck), *C. carinata* (= *Antedon gorgonia*, Frem. ?), and *C. adeonæ*.

In all the other five species described by Lamarck, viz. *C. solaris*, *C. brachiolata*, *C. rotalaria*, *C. fimbriata* (= *Stella chinensis*, Petiver), and *C. multiradiata* (= *Caput-Medusæ brunnum*, Linck), the mouth (as I know from examination of the collection of Comatulæ in the Paris Museum, which still contains many of Lamarck's original specimens) is nowhere near the centre of the disk, which is occupied by the anal tube, but is excentric, or even marginal. At the same time the five primary groove-trunks do not converge towards the centre of the disk, as in *Antedon rosacea* (*Com. mediterranea*, Lam.) (Pl. I. fig. 1), but they unite more or less completely into a horseshoe-shaped furrow, at one point of which is situated the excentric mouth (Pl. I. figs. 2–5).

This type will be described further on, under the name of *Actinometra*. Lamarck, who found it in more than half of the species constituted by him, seems to have regarded it as common to all Comatulæ. His description of it is worth quoting, as it is the first notice of a true *Actinometra* that I have been able to find. He says[1]:—"Le disque inférieur ou ventral offre un plateau orbiculaire plus large que le dorsal, entouré de rayons simples, cirreux. Près de la circonférence de ce plateau, on aperçoit un sillon irrégulièrement circulaire qui s'ouvre sur la base des rayons pinnés, et se propage le long de leur face inférieure, aussi que de celle des pinnules. Ce sillon néanmoins, ne s'approche point de la bouche [*i.e.* the anal tube] et ne vient point s'y réunir, comme cela a lieu pour la gouttière des rayons dans les Astéries. Au centre du disque inférieur ou ventral des *Comatules* la bouche, membraneuse, tubuleuse, ou en forme de sac, fait une saillie plus ou moins considérable suivant les espèces."

Although *Antedon* and *Alecto* were both constituted previously to *Comatula*, yet Lamarck's authority was sufficient to establish the latter name, and to bring it into general use, though Cuvier adopted Leach's genus *Alecto*, and used it in preference to *Comatula*. The latter, however, was more generally employed by all subsequent observers (who pointed out Lamarck's error respecting the position of the mouth) thenceforward till the time of Johannes Müller.

(§ 5) During this period the skeleton both of the recent and of the fossil Crinoids was made the subject of careful investigations by Miller[2] and Goldfuss[3]. The latter author divided his class Stellerites into two Orders:—(*a*) Stilasteritæ, or Gestielte Seesterne; and (*b*) Asterites liberi, or Freie Seesterne. The former he again divided into Articulata and Inarticulata, placing in the first group a number of fossil Mesozoic Crinoids, viz. *Eugeniacrinites*, Miller, *Solanocrinites*, Goldf., *Pentacrinites*, *Encrinites*, and *Apiocrinites*.

In his descriptions of these genera he adopted and considerably improved the somewhat inapplicable system of nomenclature, introduced by Miller for the parts of the skeleton of the fossil Crinoids and of *Comatula*.

Portions of his diagnoses of *Eugeniacrinites* and *Solanocrinites* are of considerable interest, both zoologically and morphologically. Of the former, he says[4]:—

[1] *Tom. cit.* p. 532. [2] *Loc. cit.* [3] Petrefacta Germaniæ, i. (Dusseldorf, 1826–35). [4] *Tom. cit.* p. 162.

"Die kurze runde mit einem runden Kanale durchbohrte Säule besteht aus wenigen walzigen verlängerten Gliedern, und nimmt am obern Ende allmälig zu. Ihre Gliederung wird oft nur durch Ringe angedeutet, unten endet sie in starken Wurzeln. Das letzte verdickte Säulenglied vertritt die Stelle des Beckens und articulirt durch eine Gelenkfläche mit den Rippengliedern."

The term "Becken" is here meant to signify the circlet, of basals which, in *Pentacrinus* and other stalked forms, intervenes between the stem and the circlet of first radials, the "Rippenglieder" of Goldfuss.

These basals are also present in *Solanocrinites*, which genus, as Goldfuss well remarks, "hat in verschiedener Hinsicht Aehnlichkeit mit den *Pentacriniten*, und bildet zugleich einen Uebergang zur Gattung *Comatula*."

Its most important characters are as follows[1]:—

"Die Säule ist sehr kurz, beinahe so dick als der Kelch, fünfseitig und an ihrer Basis nicht mit Wurzelsprossen, sondern mit ausstrahlenden Runzeln versehen. Ihre Glieder sind mit einander verwachsen und haben an den Seitenflächen Gelenkhöhlungen für den Ansatz zahlreicher dicker Hülfsarme. Die oberste Gelenkfläche der Säule zeigt fünf strahlenförmige Erhabenheiten, auf welchen das Becken articulirt. Das Becken wird nicht durch das oberste Säulenglied vertreten, sondern es besteht aus fünf Gliedern, welche zwischen die Nähte der fünf Rippenglieder eingefügt sind, oder sie bedecken. Die fünf Glieder des Beckens bilden entweder nur schmale Strahlen, die zwischen die Nähte der Rippenglieder einsenken (*S. costatus, S. scrobiculatus*), oder sie sind breiter, stossen seitlich an einander, und stellen eine tiefe mit 5 Strahlenfurchen ausgehöhlte Gelenkfläche dar (*S. jægeri*)."

The first genus in Goldfuss's order "Asterites liberi" is the *Comatula* of Lamarck, of which he says[2], "Diese Gattung bildet den Uebergang von den Stilasteriten zu den freien Seesternen und steht zunächst mit den Solanocriniten in nächster Verwandtschaft."

Besides describing five fossil species, he gives some account of two recent ones, dwelling more especially upon the structure and composition of the skeleton.

Thus "Bei der *C. mediterranea* besteht die Säule aus drei Gliedern: das Becken fehlt, und die Rippenglieder sitzen unmittelbar auf dem letzten Säulengliede." "Bei der in den Ostindischen Meeren lebenden *C. multiradiata* Lam. hingegen, finden sich Beckenglieder, so dass man berechtigt sein könnte sie als eine eigene Gattung zu betrachten. Ihr Säulenrudiment besteht aus einem einzigen schüsselförmigen Gliede, an dessen Rande fünf schmale dreieckige Beckenglieder ansitzen und mit ihm verwachsen sind. Diese stossen mit ihren Seitenflächen nicht an einander, sondern stehen so weit entfernt dass die ersten Rippenglieder unmittelbar zwischen ihnen auf dem Säulengliede ansitzen, und sie durch einen Abschnitt der unteren Ecke zwischen sich aufnehmen. In der Mitte des innern unteren Randes jedes Beckengliedes entspringt ein zahnförmiger Fortsatz, der sich als knospeliger schmaler Streifen bis zum Mittelpunckte des Säulengliedes verlängert, in welchem er durch eine Rinne aufgenommen ist. Diese Beckenglieder sind also denen der Solanocriniten vollkommen analog."

(§ 6) Goldfuss, who, though acquainted with the name of *Alecto*, yet used *Comatula*

[1] *Tom. cit.* p. 166. [2] *Tom. cit.* p. 202.

in preference to it, paid very little attention to the soft parts of either of the *Comatulæ* which he dissected.

In the following year, however, De Blainville[1] described the visceral mass at some length. Like his predecessors, he adopted Lamarck's genus *Comatula*, making it the only representative of his section, " Les Astérencrinides libres," while at the same time he acknowledged the prior claims of de Freminville's name *Antedon*. He was, of course, acquainted with Lamarck's error respecting the position of the mouth, which he described as " assez antérieure, isolée, membraneuse, au fond d'une étoile formée par cinq sillons bifurqués." The species which he dissected was a foreign one preserved in spirit; it had a large number of arms; and from the not very clear description which he gives of its ventral surface it would seem to have been a true *Actinometra*.

After speaking of the tentacular furrows on the ventral surface of the arms, he says[2], " En suivant ces espèces de sillons dont le nombre est proportionnel à celui des digitations du rayon, on arrive par un sillon unique pour chacun d'eux et qui en occupe la base, au centre d'une sorte d'étoile à bords épais, frangés, et par suite à la bouche qui est au fond. L'étoile formée par la réunion des sillons des rayons n'est pas symétrique, c'est à dire que ses branches sont très-inégales: les unes que j'appellerai les antérieures, étant bien plus courtes que les autres, ou postérieures. Il en est résulté que la bouche n'est pas au centre de l'étoile, mais bien plus proche d'un côté que de l'autre: elle est assez difficile à voir au contraire d'un autre orifice, dont il va être question, et que M. de Lamarck paroît avoir pris pour elle. Elle est profondément enfoncée dans l'étoile des sillons: elle est ronde, sans aucune armature et conduit immédiatement dans l'estomac."

The above description implies, if I rightly understand it, that the mouth of De Blainville's specimen was nearer to one side of the disk than to the other, so that the primary trunks of the ambulacral grooves were of unequal lengths. This will be subsequently seen (section 14) to be the principal distinctive character of the genus *Actinometra*.

De Blainville evidently attached no importance to the position of the mouth as a character of systematic value in the determination of the species of recent *Comatulæ*; and from his definition of it as " assez antérieure," it would almost appear as if he supposed the other species to agree in this respect with the one dissected by him.

This is, in fact, the case in five out of the eight species described by Lamarck, with which De Blainville was probably acquainted, and to which he added no new ones, except that he gave the name of *Comatula barbata* to Linck's third species of *Decacnemus*, the *fimbriata* of Barrelier, or " *barbata* " of Linck. Lamarck had been uncertain to which of his species he should refer it, although, as we have seen above (section 1), it is really only a local variety of his *C. mediterranea*.

Like the other naturalists of his time (1838), Agassiz[3] also adopted *Comatula* in preference to the other generic names of this type, but defined it as having the " bouche centrale enfoncée," and with the five " rayons du disque bifurqués," thus limiting the number of arms in the genus *Comatula* to ten only. At the same time he erected Lamarck's species *C. multiradiata*, with sixty or more arms, into a new genus, *Comaster*, which he defined as

[1] Manuel d'Actinologie, (Paris, 1834) p. 249. [2] *Op. cit*, p. 251.

[3] " Prodrome d'une Monographie des Radiaires ou Échinodermes," Ann. des Scien. Nat. 2e série, Zool. vii. p. 257.

follows:—"Ce genre a la même organisation que le précédent; mais les espèces ont les bras ramifiés au lieu de les avoir simplement fourchus." Agassiz consequently used *Comatula* simply as equivalent to the *Decacnemus* of Linck, while his new genus *Comaster* was Linck's *Caput-Medusæ*, or the *Comatula multiradiata* of Lamarck. Of the seven other species constituted by the last-mentioned naturalist, only two, *C. rotalaria* and *C. fimbriata*, have more than ten arms; in both of these the number of arms is usually twenty, though it may reach twenty-four, or possibly even more. Strictly speaking, therefore, these two species, according to the above definition, should be referred to *Comaster*, and not to *Comatula*.

This character, the number of arms, upon which Agassiz founded a generic distinction, is, in fact, extremely variable, and by no means of generic importance; in fact, as Goldfuss[1] remarked a little later, "Wollte man mit Agassiz die Theilung der Arme als hinreichendes Gattungsmerkmal ansehen, so würde man folgerecht gezwungen sein fast jede Art der Crinoideen als Gattung aufzustellen."

Leach and Lamarck had already recognized this fact in uniting Linck's three genera under a common name; and it is not a little strange that Agassiz should have seen fit to separate them again. His doing so, however, led to somewhat important consequences from a systematic point of view. Turning to the fossil *Comatulæ*, we find that Agassiz erected the *C. pinnata* of Goldfuss into a new genus, *Pterocoma*, and grouped together his other three species, *C. tenella*, *C. pectinata*, and *C. filiformis*, under the generic name *Saccoma*; while he expressed his belief that *Solanocrinus* was really related to the *Comatulæ*, and more especially to the problematical fossil described by Goldfuss under the name of *Glenotremites*, which he rightly recognized as the centrodorsal piece of a free-living Crinoid.

In the year 1840 a new fossil Comatula was described by Hagenow[2] under the name of *Hertha mystica*. The specimen, consisting of the united first radials and hemispherical centrodorsal piece, was somewhat worn; but Hagenow was able to recognize the resemblance between it and the remains of *Solanocrinus*, and the corresponding parts of Goldfuss's *Comatula multiradiata*, except that he was unable to find any trace of the external basals which Goldfuss had described in both the above cases; and though he seems, and (as we now know) correctly, to have suspected "das Vorhandensein etwa verdeckt-liegender Beckenglieder," he was, of course, unable to come to any satisfactory conclusion upon the point.

(§ 7) The year 1840 is a noteworthy one in the history of our knowledge of the Crinoidea; for it marked the appearance of the first of a series of classical memoirs by Johannes Müller, who laid the foundation of nearly all our knowledge of the zoology and morphology of the group: the first[3] of these was devoted to an anatomical account of the recent and very rare genus *Pentacrinus*, together with many observations upon *Comatula*.

[1] "Beitr. z. Petrefactenkunde," N. Acta Acad. Leop.-Carol. Nat.-Cur. xix. A. p. 348.

[2] "Monogr. d. Rügen'schen Kreide-Versteinerungen, II. Abtheil. Radiarien und Annulaten," Neues Jahrb. Mineralogie, 1840, p. 664.

[3] "Ueber den Bau des *Pentacrinus caput-Medusæ*," Abhandl. d. Berlin. Akad. 1843; Abstract in Monatsb. derselben, 1840; also in Wiegmann's Archiv f. Naturgesch. 1840, i. p. 307.

Müller seems at first, not unnaturally, to have supposed that Goldfuss was right in referring the many-armed specimen dissected by him to the *Comatula multiradiata* of Lamarck, for which species he adopted Agassiz's name *Comaster*[1]. But he did not use it precisely in the same sense as Agassiz, who, in his definition of the genus, makes no mention of the external basals, the presence of which was regarded by Goldfuss as the principal character distinguishing *Comaster* from *Comatula*.

Müller adopted *Comaster*[2] in the sense in which Goldfuss used the name; and when he subsequently discovered[3] that the *Comatula multiradiata* or *Comaster* of Goldfuss was not specifically identical with the specimen described as *Comatula multiradiata* by Lamarck, he retained the name *Comaster* for Goldfuss's specimen only, which, like *Solanocrinus*, is remarkable for having "kleine *basalia* zwischen den Insertionen der Kelchradien, oder sogennanten Beckenstücke welche den eigentlichen Comatulen gänzlich fehlen"[4].

At the same time he gave a careful description[5] of Lamarck's original specimen of *Comatula multiradiata*, based upon an examination of it by Troschel; but as he regarded *Comaster* and *Solanocrinus* only as one subgenus of *Comatula*, he gave it a new specific name "*multifida*," on the ground that "die *Comatula multiradiata* Goldfuss, als die zuerst genau beschriebene, den Speciesnamen *multiradiata* behalten muss." Lamarck's specimen was thus restored by Müller to its previous position among the "Comatulen im engern Sinne, nämlich Gattung *Alecto*, Leach (*Comatula*, Lamarck)," which he grouped together with *Comaster* into one family, *Comatulinæ*. The fossil *Solanocrinus* was regarded by him as identical with the latter form, while he referred the *Hertha mystica* of Hagenow, and *Pterocoma*, Ag. (*C. pinnata*, Goldf.), to *Comatula* or *Alecto*; for at that time (1841) he used the two names indifferently, considering them (as, indeed, they originally were) equivalent to one another.

Goldfuss put forward about the same time a somewhat similar classification.[6] In a subsequent abstract (with additions) of his 'Beiträge zur Petrefactenkunde,' [which had been published two years previously (1839)] he speaks of the two species dissected by him as "die Typen der zwei nächst bezeichneten Genera (*Comatula*, *Comaster*), welche daher nebst den zwei zuletzt folgenden (*Solanocrinites, Gasterocoma*) als Verzweigungen des Lamarck'schen weiten Geschlechts *Comatula* zu betrachten sind." He did not, however, agree with Müller in regarding *Solanocrinites* and *Comaster* as identical, partly, apparently, because nothing was known of the arms of the former, and partly because of the differences in the form of the "Knopf," or centrodorsal piece, which he called a short stem—although, as Müller showed, this is not a character of any generic value.

Although Goldfuss had at first supposed[7] that the basals were really absent in *Comatula mediterranea*, and that the first radials therefore rested directly upon the top of the centrodorsal piece, or, as he expressed it, on the last stem-segment, he seems subsequently to have changed his opinion; for in his definition[8] of the genus *Comatula*, given in 1839,

[1] "Beiträge zur Petrefactenkunde," *loc. cit.* p. 349.
[2] Wiegmann's Archiv, 1840, i. p. 309.
[3] "Ueber die Gattungen und Arten der Comatulen," Wiegmann's Archiv, 1841, i. pp. 140, 147.
[4] "Bau des *Pentacrinus*," loc. cit. p. 27.
[5] Wiegmann's Archiv, 1841, i. p. 147.
[6] Neues Jahrbuch für Mineralogie, 1841, p. 818.
[7] Petrefacta Germaniæ, *tom. cit.* pp. 203, 204.
[8] Beiträge, &c. *loc. cit.* p. 349.

he says, "Auf dem letzten Saülengliede ruhen fünf Beckenglieder, und auf jedem derselben ein Rippen- (=second radial) und ein Schulterglied (third or axillary radial), auf welchem zwei einfache Arme eingelenkt sind," from which it is evident that he was wrongly led to regard the first radials as representing the basals of *Comaster* and *Pentacrinus*. This mistake is hardly a surprising one when we consider the remarkable metamorphosis undergone by the embryonic or primitive basals, and their concealed condition in the adult *Comatula mediterranea*.

Müller, who examined a very large number of species of *Comatula*, never found one in which the basals appeared externally, as described and figured by Goldfuss in *Comaster*, and remarked[1]:—"Daraus geht hervor, dass die Gegenwart wirklicher Basalia ohne Zerlegung bei einer lebenden Comatule, auch dann, wenn sie wirklich solche besitzt, schwer zu erkennen sein muss. Die Unterscheidung der *Comaster* und *Comatula* wird daher bei der Ordnung der lebenden Comatulen unpractisch." In fact he appears to have given up the genus *Comaster* altogether; for he adds in a note:—"Kürzlich habe ich die einzige im Museum zu Bonn befindliche *Comatula multiradiata* (nicht das von Goldfuss zerlegte Exemplar, wovon ich nichts mehr vorfand) untersucht. Ich habe daran nichts von Beckenstücken erkennen können. Die Gattung *Comaster* ist daher wohl zu unterdrücken." He seems finally[2] to have thought that it might possibly be identical with the *C. Bennetti* of the Leyden Museum. As, however, *Comaster* has not been seen by any naturalist since the time of Goldfuss, its position must still remain in doubt.

(§ 8) Up to the time of Müller no one paid any attention, from a systematic point of view, to the arrangement of the tentacular furrows on the ventral perisome of the disk of *Comatula*; but Lamarck and De Blainville had, as we have already seen, examined and described, with more or less accuracy, a condition which we now know to differ very considerably from that presented by the *Decacnemus* of Linck, or the *Antedon* of De Freminville. Both these observers seem to have regarded the former condition as the normal one, and as common to all *Comatulæ*. Müller, who does not seem to have been acquainted with their descriptions (for he makes no mention of them), took up the subject systematically, and soon discovered that, using the distribution of the tentacular furrows as a basis of classification, he could distinguish two, as he thought, very distinct types of the genus *Comatula*, which he named *Alecto* and *Actinometra* respectively. In his earlier communications[3] on the subject he described the ordinary *Comatula* and *Pentacrinus* as having a central mouth and symmetrically distributed tentacular furrows; *i. e.* the five main trunks formed by the union of the furrows of the five groups of arms converge directly towards the centre of the disk, being separated by five "interpalmar" areas, one of which, slightly larger than the rest, is occupied by the anal tube, which is therefore excentric in its position (Pl. I. fig. 5, *An.*).

During his visit to Vienna in 1840 Müller had an opportunity of examining an un-

[1] 'Ueber die Gattung *Comatula*, Lam., und ihre Arten,' Separatabdruck aus den Abhandl. Berlin. Akad. 1849, p. 8.

[2] *Ibid.* p. 29.

[3] "Bau des *Pentacrinus*," loc. cit. p. 47, and Wiegm. Archiv, 1840, i. p. 311.

usually large specimen of the *Comatula solaris* of Lamarck—unfortunately, however, only a dry one, which he found to differ so greatly from the other *Comatulæ* then known to him, that he described it under the name of *Actinometra imperialis*[1], "welche generisch von andern durch die Bildung ihres Scheitels verschieden zu sein schien. Auf dem Scheitel der mit blumenartigen Kalkblättchen bedeckt ist, ist keine Spur von den Furchen zu sehen, die bei den Comatulen von den Armen zum Munde führen. Auch ist dort nichts vom Munde zu sehen. Die Mitte der Bauchseite nimmt eine Röhre ein. Die Arme haben die ventrale Furche der Comatulen, die Furchen der zehn Arme münden aber in gleichen Abständen in eine die Scheibe am Rande umziehende Cirkelfurche. Diese eigenthümliche Bildung liesse sich durch eine unsymmetrische Vergrösserung desjenigen Intertentacularfeldes, worin die Afterröhre steht, über den ganzen Scheitel und auf Kosten der anderen Intertentacularfelder erklären, so dass der Mund aus der Mitte des Scheitels ganz an die Seite zwischen je zwei Armen geräth; es ist mir aber nicht gelungen den Mund hier zu finden." (Pl. I. fig. 2.)

In a subsequent visit to Lund, Müller examined two dry specimens of *Comatulæ*, which had been described by Retzius[2] many years previously under the names of *Asterias pectinata*[3] and *Asterias multiradiata*. These he found to belong to the same type as the Vienna specimen, which he had already designated *Actinometra imperialis*, and which he supposed to be distinct from the true *Comatula solaris* of Lamarck. When he visited Paris, however, in 1844, he examined Lamarck's original specimen of this species, and convinced himself of its specific identity with his Vienna *Actinometra*. Consequently he withdrew the specific name "*imperialis*," and described the type simply as *Actinometra solaris*[4]. Müller was unable to determine the position of the mouth in the dry specimens of the Lund and Vienna Museums on which he founded his new genus *Actinometra*; but subsequently he was able to examine many spirit-specimens both of his typical species, *Act. solaris*, and also of other "Comatulen von jener Anordnung der Furchen, sowohl zehnarmige als vielarmige . . . . . . Siehe die beistehende Figur von *Comatula Wahlberghii*[6]" (Pl. I. fig. 3). This last species he describes a few pages further on as *Comatula (Actinometra) Wahlberghii*.

He did not, however, appear to regard the position of the mouth as of any systematic importance; for he goes on to say:—"Der Mund ist bei der in Frage stehenden Ab-

[1] Wiegm. Archiv, 1841, i. p. 141; and "Neue Beitr. z. Kenntniss der Arten der Comutalen," Wiegm. Archiv, 1843, i. p. 132.

[2] Dissertatio sistens species cognitas Asteriarum. Lundæ, 1805.

[3] The specific name "*pectinata*," Linnæus, included both Retzius's specimens and the *Decacnemus* of Linck. These belong, however, to two very different types of the genus *Comatula*, and must be carefully distinguished from one another. The former is, as above mentioned, an *Actinometra*, while the latter was called *Alecto* by Müller, being simply the common *Comatula mediterranea*, Lam. Pennant, Adams, and others naturally employed the Linnean name for this last species; but Dujardin, following Retzius and Müller, applied it also to Retzius's original specimen, which is really an *Actinometra*, and not an *Antedon*, like C. *mediterranea*. This has given rise to much confusion in the synonymy of these two species.

[4] Wiegmann's Archiv, 1843, i. p. 133.

[5] 'Gattung *Comatula*,' pp. 12, 13.

[6] *Ibid.* p. 9.

weichung allerdings vorhanden, er liegt ganz zur Seite, doch ist dies nicht die Ursach des Unterschiedes, es gibt vielmehr auch Comatulen von der gewöhnlichen Anordnung der Furchen, bei denen gleichwohl der Mund seitlich, die Afterröhre central steht. Fig. von *C. multiradiata* (Pl. I. fig. 4). Die fragliche Abweichung beruhrt vielmehr darauf, dass die fünf Furchen nicht symmetrisch für die fünf Gruppen der Arme vertheilt werden, sondern dass von den fünf Furchen einzelne herrschend werden und Aeste an die meisten Arme abgeben. Indem diese Hauptfurchen, nachdem sie die Scheibe umzogen, sich wieder annähern, so entsteht der Schein eines Cirkels. An in Weingeist aufbewahrten Exemplaren sieht man indess, dass es kein geschlossener Cirkel ist;" and further on (p. 10) he says, "Ich werde daher bei den Arten wo fünf centripetale Furchen beobachtet sind, den Namen *Alecto* in Klammer dem Gattungsnamen *Comatula* beifügen, wo aber weniger Furchenstämme den excentrischen Mund erreichen, den Namen *Actinometra* demselben Gattungsnamen *Comatula* folgen lassen. Also z. B. *Comatula* (*Alecto*) *europæa*; *Comatula* (*Actinometra*) *solaris*."

Müller does not appear to have been acquainted with De Freminville's name of *Antedon*; but he distinctly states that Leach's genus *Alecto* was constituted a year earlier than Lamarck's *Comatula*. He had in his earlier communications employed the two indifferently and as equivalent to one another; but when he became acquainted with the type represented by *Comatula solaris* and elevated it into a new genus, or rather subgenus, *Actinometra*, in contradistinction to *Alecto*, he retained Lamarck's name *Comatula*, probably on account of its being so well known, and employed it to designate the genus in which he included the subgenera *Alecto*, *Actinometra*, and *Comaster*.

Thus the sole character by which Müller distinguished the first two of these subgenera from one another was the number of groove-trunks reaching the peristome, irrespective of the position of the mouth. It is therefore easy to understand that, as many of the specimens which he examined were dry, and as in others, although preserved in spirits, the arms were contracted over the disk so as completely to conceal it, he was unable satisfactorily to determine more than three species of *Actinometra*. Two of these, *Act. solaris* and *Act. Wahlberghii*, have been already mentioned; the third was the small *Comatula rotalaria* of Lamarck.

(§ 9) The *Asterias pectinata* of Retzius, which presented the same "Bildung des Scheitels' as *Act. solaris*, resembled it so greatly in other respects, that Müller regarded the two as almost identical, or, at any rate, as presenting only varietal differences[1].

He seems also to have come to the conclusion that the other species described by Retzius, the *Asterias multiradiata*, Linn., had a prior claim to this specific name over either of the similarly named types described by Goldfuss (*Comaster*) or Lamarck (*Comatula multiradiata*); for he described it as "*Comatula* (*Alecto*) *multiradiata* nob."[2]. It is difficult to understand why he called it *Alecto*; for he had already[3] described this

[1] 'Gattung *Comatula*,' p. 52. [2] *Ibid.* p. 25.

[3] Wiegmann's Archiv, 1843, i. p. 133, and 'Gattung *Comatula*,' pp. 9, 10.

Lund specimen as belonging to the type of his new genus *Actinometra*, in which not five, as in *Alecto*, but " weniger Furchenstämme den excentrischen Mund erreichen."

Müller further examined a specimen of the " so-called " *C. multiradiata* in the Bonn Museum; and although he did not actually include it in his type under that name, yet he seems to have been inclined to do so; for he says[1] that " es stimmt durch den Besitz der Syzygien an den Axillaria der Arme mit *Comatula multiradiata* Retz., " but adds, "Maul excentrisch, 5 Furchen der Scheibe sammeln die Furchen der respectiven Arme und kommen am Mund zusammen." (See Pl. I. fig. 4.) Here, again, it is evident that Müller's description of *Alecto* will not hold good; for according to his own descriptions, the Lund and Bonn specimens of *Comatula multiradiata*, Müll., however much alike in other respects, differ so greatly in the distribution of the ambulacra on the disk that one is *Actinometra* and the other *Alecto*.

Müller also referred three specimens contained in the Paris collection to this type; and he was perhaps thinking of the condition of the ambulacra presented by them when he added the following sentence to his previous description of the Lund specimen, and named the type *Alecto*[2]. "Mund excentrisch, aber an Weingeistexemplaren ergibt sich dass die fünf zum Munde führenden Furchen sich ganz symmetrisch für die fünf Gruppen der Arme vertheilen." This arrangement, which he called the "gewöhnliche Anordnung der Furchen," had been already[3] figured by him as occurring in *C. multiradiata*, which, as he says, differs from the ordinary *C. mediterranea* in the excentric position of the mouth (Pl. I. figs. 1, 4).

It is thus evident that, according to Müller's own nomenclature, two types, differing only in the "Bildung des Scheitels," but almost precisely similar in every other respect, viz. the Lund specimen, on the one hand, and the Paris specimens, on the other, were referred by him to the same species, *Alecto multiradiata*, Müller. It will, however, be shown further on that the distinction drawn by Müller between *Alecto* and *Actinometra* is not a real one, and that the Lund and one of the Paris specimens, both of which have an excentric mouth and a central or subcentral anal tube, really belong to one and the same species, *Actinometra multiradiata*.

(§ 10) For a short time after the publication of Müller's *Comatula*-memoirs the genera *Alecto* and *Actinometra* remained as he left them, both being regarded as subordinate types of Lamarck's genus *Comatula*.

A singularly minute fossil species, discovered by Philippi[4] between the valves of an *Isocardia cor* from the Sicilian Tertiaries, was named by him *Alecto alticeps* because of the height of its " Kelchstück," a character found both in *Alecto Eschrichtii* and in *A. phalangium*, as Müller had already pointed out. A few new fossil species of a more or less doubtful nature have been since described, and variously referred either to Müller's family Comatulinæ or to new and distinct types.

The typical genus of this family, *Comatula*, Lam., has undergone numerous changes in its definition. Rœmer, who at first revived Linck's name *Decacnemus*, subsequently

[1] 'Gattung *Comatula*,' p. 29. [2] *Ibid.* p. 26. [3] *Ibid.* p. 9.

[4] " *Alecto alticeps*, n. sp., eine tertiäre Comatula-Art von Palermo," Neues Jahrb. für Mineral. 1844, p. 540.

withdrew it in favour of *Comatula*[1], the "Knopf," or centrodorsal piece of which was described by him as an "Ueberrest der verkümmerten Säule," while, like his predecessors, he mentioned the absence of basals. The existence, however, of external basals, both in *Solanocrinus* and in *Comaster*, led him to regard them, like Müller, as generically identical; and he used the name *Comaster* for this type in preference to *Solanocrinus*, as it "bezieht sich nicht nur auf einen lebend und vollständig bekannten Typus, sondern drückt auch die Verwandtschaft richtig, wie *Solanocrinus* unrichtig, aus." About the same time D'Orbigny[2], and, a few years later Pictet[3], transferred the name *Comatula* to this last-mentioned type, in which the basals appear externally; while they revived Linck's name *Decacnemus* (or, as they named it, *Decameros*) for the *Antedon* of De Freminville and the *Alecto* of Leach. They characterized the genus as only differing from *Comatula*, in their sense, in the total absence of the five basals, so that the radials rest directly upon the centrodorsal piece. Fortunately, however, this peculiar inversion of the nomenclature employed by Müller was not destined to last; for in Bronn's 'Klassen und Ordnungen des Thierreichs'[4], all the above genera are united into one, *Comatula*, which with *Glenotremites* and another doubtful fossil constitute the family Comatulidæ. *Saccocoma* and *Marsupites* are restored to the places originally assigned to them by Müller, in special groups, Costata and Tessellata respectively, among the unstalked Crinoids; while *Eugeniacrinus*, which Goldfuss regarded as nearly related to *Solanocrinus*, is placed with a few similar forms in a family Eugeniacrinidæ, which, together with the Pentacrinidæ and Apiocrinidæ, make up the group Articulata of Müller.

(§ 11) The family Comatulidæ was considerably enlarged a few years later by Dujardin and Hupé[5], who included in it, as D'Orbigny and Pictet had already done, not only the tribes Comatuliens and Saccocomiens, but also the Eugéniacriniens, which both the above authors had ranked among the stalked Crinoids, while *Marsupites*, which they referred to the Comatulidæ on account of its calyx being free, was transferred to the Cyathocrinidæ by Dujardin, who could "ne voir qu'un caractère secondaire dans l'absence d'une tige chez plusieurs de ces Crinoïdes." He distinguishes the three tribes as follows:—"Nos trois tribus seront suffisamment caractérisées: la première, celle des Eugéniacriniens, par son calice adhérent ou pedonculé, jamais libre; les deux autres, dont le calice est libre à l'état adulte, se distinguent parce que celle des Comatuliens porte cirrhes ou rayons dorsaux, dont la dernière, celle des Saccosomiens, est censée dépourvue."

The position of *Eugeniacrinus* does not concern us at present. Let us now investigate the species included by Dujardin in the tribe Comatuliens. Under this head he ranks three genera, viz. *Comatula*, Lam., *Actinometra*, Müll., and *Comaster*, Ag., using the latter name in the sense in which it was employed by Müller and Rœmer, namely as equivalent to *Solanocrinus*. Dujardin's genus *Comatula*, however, is not precisely equivalent to that of Müller, who included in it the two genera or subgenera *Alecto* and

[1] Lethæa geognostica, iii^te Auflage, 1851, Theil iv. p. 133, and Theil v. p. 177.
[2] Cours élement. de Paléontol. et de Géol. stratigraph. 1850–1852, vol. 2, i. pp. 138, 139.
[3] Traité de Paléontol, (Paris, 1857) vol. iv. p. 288.
[4] Band ii. Aktinozoen (1860), p. 233.
[5] Hist. Nat. des Zoophytes, Échinodermes, (Paris, 1862) p. 186.

Actinometra. The latter was erected into a separate genus by Dujardin, who limited the application of the name *Comatula* to those forms only which had been described as *Alecto* by Müller—those, namely, in which five main groove-trunks reach the mouth, irrespective of its position, to which Müller seems to have attached no importance as a character of any systematic value; so that Dujardin, following him, says of the mouth of *Comatula* (i. e. *Alecto*) that it is only "ordinairement au centre"[1].

Further, Dujardin, though really employing the name *Actinometra* in the same sense as Müller did, does not describe it in the same way; he takes no account of the number of groove-trunks reaching the peristome, to which Müller attached so much importance, but simply says[2], "Ce genre ne diffère guère des vraies Comatules que par la position de l'anus au centre et de la bouche au bord du disque. Il en résulte que les gouttières ambulacraires, au lieu de se rendre à la bouche en suivant la direction des bras comme chez les Comatules, s'infléchissent et suivent le contour du disque." Dujardin adds, with perfect truth, that the distinctive characters of *Actinometra* are hardly yet sufficiently established. It will be shown, further on, that his definition of the genus is really the correct one, and that we must refer to it all those forms of *Alecto* (*Comatula*, Dujardin) in which, as described by Müller[3], the anal tube occupies the middle of the disk, "so dass der Mund seitlich gegen den Rand der Scheibe rückt, ohne dass die *Ambulacra* ihre symmetrische Vertheilung auf die 5 Armstämme einbüssen" (Pl. I. fig. 4). As Müller had only employed the names *Alecto* and *Actinometra* to designate subordinate types of the *Comatula* of Lamarck, it is rather unfortunate that Dujardin should have erected the latter into a separate genus, in contradistinction to *Comatula*, and restricted this name to the *Alecto* of Müller; for we now know, as mentioned in section 5, that most of the species described as *Comatula* by Lamarck belong really to *Actinometra*, not only in the somewhat limited sense in which this name was used by Müller, but also in its wider application as employed in this memoir.

Thus, for example, Müller stated expressly[4] that Lamarck's original specimen of *C. solaris* in the Paris Museum is identical with the large Vienna specimen, also bearing the name of *C. solaris*, Lam., which he made the type of his new genus *Actinometra*.

Dujardin, however, paid no attention to this identification of Müller's, and described the two specimens as *C. solaris* and *Act. imperialis* respectively, simply on the basis of Müller's original diagnosis, published before his visit to Paris. Dujardin thus made not only two different species, but also two different genera, out of the same type, while he makes a third species out of the *Asterias pectinata* of the Lund Museum, which Müller regarded as a variety of *Actinometra solaris*.

I have examined a considerable number of specimens of this type, and find it to exhibit an enormous range of variation in minor points, such as the number and relative proportions of the cirrhus-segments, the colouring, the presence or absence of a faint keel on the dorsal side of the arms, &c., and am convinced that none of these can be regarded as of specific value. A number of such varieties group themselves around a

[1] *Op. cit.* p. 194.
[2] *Op. cit.* p. 208.
[3] "Nachtrag zu der Abhandl. über die Comatulen," Monatsb. der Berlin. Akad. 1846, p. 177.
[4] 'Gattung *Comatula*,' p. 13.

type possessing certain definite characters, by which it may be distinguished from other types forming the centres of similar groups of varieties; but the characters above mentioned are usually so excessively variable within each group, that it becomes utterly impossible to make any use of them as specific distinctions, as Dujardin has done.

Dujardin seems to have detected Müller's oversight in classing the *Asterias multiradiata* of Retzius as an *Alecto* after previously describing it as an *Actinometra*; for he transferred it to this genus under the name of *Actinometra multiradiata*, and adopted Müller's specific designation *multifida* for the original specimens described as *Comatula multiradiata* by Lamarck. The third form to which this name has been applied, viz. the *C. multiradiata* of Goldfuss, was regarded by Dujardin as a separate genus on account of its possessing external basals, or, as he called them, "interradials;" and he restored to it the old name of *Comaster*, which had been given up by Müller, including in this genus, as Rœmer had previously done, all the species of *Solanocrinus*.

(§ 12) Müller had, as we have seen above, referred both *Alecto* and *Actinometra* to the one genus *Comatula*, while Dujardin limited the application of the latter name to the species of *Alecto* only, and gave up the name of *Alecto* altogether, as had been previously done by D'Orbigny and Pictet. This was a step in the right direction; for, as Müller had already pointed out, this name had been employed since 1821 to designate a section of the Polyzoa established by Lamouroux. It is a pity, however, that Dujardin, instead of limiting the application of Lamarck's name *Comatula* to the species of Müller's subgenus *Alecto*, did not revert to the old name of *Antedon*, which was proposed by his countryman De Freminville in 1811, and had since received but little notice. This step was taken by Mr. Norman[1] a few years later. He did not, however, use *Antedon* as precisely equivalent to *Alecto*, but applied the name to those forms only in which the mouth is central and the anus lateral; and he has been followed by nearly all the subsequent writers upon the Crinoids.

The etymology of *Antedon* is somewhat obscure. De Freminville described his typical species as *Antedon gorgonia*, which gives no information as to the gender of the name. Mr. Norman, however, arrived at the conclusion that it is masculine, and hence described the common British species as *Antedon rosaceus*. In this respect all the later writers have agreed with him with the exception of Pourtales[2], who employs *Antedon* as a feminine name; and in this step he has since been justified by the result of the recent etymological researches of Mr. Spedding[3].

It will be used in the same manner in the following pages, both because this seems to be etymologically correct, and for the sake of convenience; since, as long as Müller's system of trinomial nomenclature is employed for the *Comatulæ*, it is far simpler to write *Comatula* (*Antedon*) *rosacea* than *Antedon rosaceus*=*Comatula rosacea*. In any case, we are now acquainted with so many different types, *Antedon*, *Actinometra*, *Comaster*, *Phanogenia*, and *Ophiocrinus*, to all of which Lamarck's designation *Comatula*

[1] "On the Genera and Species of the British Echinodermata," Ann. and Mag. Nat. Hist. ser. 3, vol. xv. p. 98.

[2] Bull. of the Mus. of Comp. Zool. vol. i. No. 6, "Contributions to the Fauna of the Gulf Stream at Great Depths," p. 111; and No. 11, "List of the Crinoids obtained on the Coasts of Florida and Cuba in 1867, 1868, 1869," p. 355.

[3] 'Nature,' vol. xv. p. 366.

is equally applicable, that this last can only be used to designate the family, while one of the two names, *Antedon* and *Alecto*, which have precedence over it in point of time, has gradually become more limited in its meaning, and the other has ceased altogether to be applied to the Crinoids.

II. On the Characters of the Genus Actinometra.

(§ 13) We have seen that while the distinction drawn by Müller between *Alecto* and *Actinometra* depended upon the number of groove-trunks reaching the peristome, irrespective of the position of the mouth, the genus *Antedon*, as defined by Mr. Norman, and as subsequently used, is distinguished by having the mouth central and the anus lateral.

There are, however, numerous species of *Alecto* in which, according to Müller[1], "die Afterröhre nimmt die Mitte der Scheibe ein, so dass der Mund seitlich gegen den Rand der Scheibe rückt ohne dass die *Ambulacra* ihre symmetrische Vertheilung auf die fünf Armstämme einbüssen." These forms have obviously no place in the genus *Antedon*, while they were excluded from *Actinometra* by Müller, who goes on to say, "In andern abweichenden Arten geht die gleiche Vertheilung verloren, indem der excentrisch liegende Mund weniger als fünf Furchen der *ambulacra* aufnimmt, dann werden einzelne dieser Furchen herrschend und verästeln sich, indem sie einen grossen oder den grössten Theil der Scheibe umziehen, auf mehreren Armstämmen zugleich, so dass die Scheibe von einem Furchenkreis umgeben ist, der jedoch an einer Stelle nicht geschlossen ist (*Actinometra*) (Pl. I. figs. 2, 3, 5).

In Pl. I. figs. 6–16 is represented the distribution of the groove-trunks or ambulacra on the disks of the eleven specimens of *Act. polymorpha* which I have been able to examine. A glance at these, no two of which are alike, will suffice to show that within the limits of one and the same species there may occur individuals, some of which would have been referred by Müller to *Alecto*, some to *Actinometra*, and some which, strictly speaking, have no place in either of these genera.

Thus, for example, the specimen represented in fig. 16 would probably have been classed as *Alecto* by Müller; but although five groove-trunks leave the peristome, their branches are by no means equally and symmetrically distributed to the different arms. On the contrary, one of them gives off far more branches than any of the others, supplying *all* the arms borne by two radii (D_1–E_2), together with half of those of another radius (A_1); while another trunk running straight out from the peristome bifurcates but once, and only supplies two of the arms of one radius (B_2). Again, in fig. 15, only four groove-trunks leave the peristome, one of which gives off a large number of branches, as in fig. 16, also supplying all the arms of two radii (D_1–E_2). According to Müller's system, therefore, this individual is an *Actinometra*.

In all the other nine specimens of this species which I have examined, however, there are invariably more than five groove-trunks running out from the excentric peristome (Pl. I. figs. 6–14). Even in the small specimen with thirteen arms, represented in fig. 6, there are six groove-trunks, while in fig. 11 there are eight, and in all the other figures

[1] Berlin Monatsberichte, 1846, p. 177.

either six or seven. In no case are there only five with their branches so regularly distributed as Müller figured them in *Alecto multiradiata* (Pl. I. fig. 4); nor in the single individual with only four primary trunks (fig. 15) is the distribution so regular and symmetrical as in Müller's figure of *Actinometra Wahlberghii* (fig. 3). Further, the distribution of the ambulacra on the disk of the specimen of *Act. solaris,* represented in Pl. I. fig. 5, is by no means so symmetrical as Müller found it to be in the large Vienna specimen which he made the type of his new genus *Actinometra* (fig. 2). It can hardly be said of fig. 5 that the "Furchen der zehn Arme münden in gleichen Abständen in eine die Scheibe umziehende Cirkelfurche."

The above instances, which could be multiplied indefinitely, suffice to show the impossibility of classifying the *Comatulæ* according to the distribution of the ambulacra on the disk. We have already seen (sect. 9) that Müller found the Lund and Paris specimens of his species *Com. multiradiata* to agree in every respect but this; so that, had he adhered strictly to his own system of classification, he would have had to refer the former to *Actinometra* and the latter to *Alecto.* In this case, however, as in all the specimens represented (Pl. I. figs. 2–16), there is one point of agreement, viz. the relative positions of the mouth and anal tube. In the Paris, Bonn (fig. 4), and Lund specimens of *C. multiradiata,* Müll., in both the specimens of *Act. solaris,* represented in Pl. I. figs. 2, 5, in *A. Walhberghii* (fig. 3), and, lastly, in all the eleven specimens of *A. polymorpha* (figs. 6–16), the centre of the disk is occupied by the anal tube, and the mouth is situated excentrically, either close to the margin of the disk (fig. 11), or at some point rather nearer to the centre.

(§ 14) After arriving at the conclusion that in this character, the central or excentric position of the mouth, lies the real distinction between *Antedon* and *Actinometra,* and that the number of groove-trunks reaching the peristome is a character of very minor importance, I wrote to Dr. Lütken, of the University Museum, Copenhagen, upon the subject, and was not surprised to learn that he had held this opinion for some time past. With his usual kindness he has permitted me to make use of the following extract from an unpublished MS. of his, containing descriptions of some new species of recent *Comatulæ*:—

"One of the reasons why it is so difficult to identify Müller's species is, that he does not always mention the positions of the mouth and anal tube, and the direction of the ambulacra on the disk, but has evidently established a somewhat unnatural distinction between the differences which may occur in these characters. Two cases may occur: in the one the mouth is subcentral ('quite central' probably never occurs), and the ambulacral furrows converging from the arms unite into five trunks, which all run directly towards the mouth along the shortest line; they differ, therefore, but slightly in length; and the 'interpalmar' areas defined by them are of almost equal size, that containing the anal tube having sometimes, however, a slight preponderance in size, especially when the anal tube is placed close to the mouth, almost centrally. In the other case the mouth is removed towards the margin of the disk; and of the ambulacra, those only which come from the arms nearest to the mouth run directly towards that orifice, while the others, and especially the two enclosing the anal area, are obliged to make a large deviation, and reach the mouth, after a circuitous course, parallel to the margin of the disk. It is often difficult to state the number of ambulacral furrows abutting on the mouth, as they frequently unite immediately before reaching it; in different species, and in different specimens of the same species, I have counted 4, 5, 6, 7, 10 stems originating from the mouth; this difference, therefore, is of no importance at all. The anal tube in all these species [*Actinometra*, mihi] has a central or subcentral position, and the anal area occupies the larger portion of the disk. Using this difference as 'fundamentum divisionis,' I have never encountered a doubt whether any type should be referred to *Antedon* or to *Actinometra*, although I have examined a great number of specimens and species. Moreover the lower or oral pinnules of *Actinometra* are always very different from the others, being flagelliform and presenting a more or less distinct serrature or comb (pinnulæ orales prehensiles); while in *Antedon* they are only slightly differentiated from the others, or are transformed into strong rigid spines, forming a protective covering over the disk [*A. protectus*, mihi]. It will, perhaps, be thought improper to elevate these sections into genera, as the fossil *Antedons* would usually not be generically determinable[1]; but they are at least very good subgenera for the distribution of the numerous species. The mode of classification here proposed is concerned with the main point of that established by Müller, but is evidently an amelioration of it. In *Actinometra* he describes the five ambulacra as partially uniting before reaching the mouth, so that their number becomes reduced to three or four [*C. solaris*, Pl. I. figs. 2, 5, and *A. Wahlberghii*, Pl. I. fig. 3], while he refers to *Alecto* all those specimens in which five ambulacra separately reach the mouth, even though this orifice be quite excentric and marginal, and the length of the ambulacra therefore exceedingly different, as in *Alecto multiradiata* [Pl. I. fig. 4]. This mode of distinction used by Müller is, however, very unnatural, and often quite arbitrary or illusory. It is the marginal or subcentral position of the mouth that is of importance; and this character is never ambiguous. *C. multiradiata* [Pl. I. fig. 4] is not less a true *Actinometra* than *A. solaris* [Pl. I. figs. 2, 5] and *A. Wahlberghii* [Pl. I. fig. 3]."

It will be seen from the above note that Dr. Lütken considers *Antedon* and *Actinometra* as two subgenera of *Comatula*, *Antedon* having a subcentral mouth and but slightly differentiated oral pinnules, while in *Actinometra* the mouth is excentric and the oral pinnules bear a terminal comb (Pl. III. figs. 1–3). At the time I received Dr. Lütken's note I had had no opportunity of examining any large collection of *Comatulæ*; and his statement that the oral pinnules of all *Actinometræ* were marked by a terminal comb was therefore new to me. I have since been able to examine a considerable number of *Comatulæ*, and, like Dr. Lütken, have never had the least difficulty in determining to which type any given specimen should be referred, while at the same time I have always[2] found that in *Actinometræ*, or *Comatulæ* with an excentric mouth, the oral pinnules bear

[1] It will be shown further on that there are very decided differences in the shape of the calyx in the two genera *Antedon* and *Actinometra*. These render the determination of fossil *Comatulæ* (and also of recent specimens from which the disk is lost) less impracticable than Dr. Lütken supposes.

[2] The above passage was written early in 1877. Since then I have examined the large collection of *Comatulæ* brought home by the 'Challenger.' Out of nearly fifty species with an eccentric mouth, all but two have a terminal comb on the oral pinnules.

a terminal comb. These two characters, however, do not always coexist; for Pourtales[1] describes *Antedon meridionalis*, A. Ag., as having an excentric mouth, while he says nothing about the first pinnule, except that it is "rather long, the first five or six joints webbed by the perisome."

Again, in many of the *Comatulæ* with an excentric mouth which I have examined, the terminal comb is not limited to the oral pinnules only, but may occur at intervals on different pinnules till near the end of the arms, although it is never so well developed as it is on their basal or oral pinnules, fewer of the terminal segments bearing the processes which go to make up the comb.

Lovén[2] has found the same to be the case in the new *Comatula* which he has described under the name of *Phanogenia typica*. Speaking of the pinnules, he says, on p. 232:—"In nonnullis (omnibus ?) articuli 8 l. 9 ultimi convoluti, pectinati, margine cujusvis externo in laminam lanceolatam magnam erectam producto;" but he goes on to say (p. 233), "Os centrale. Tubus analis crassus in media area interradiali. Sulci tentaculiferi fere quales in *Antedone*."

Here, therefore, a terminal comb on the pinnules coexists with a central mouth; so that all the four possible variations may occur of these two characters, viz. the position of the mouth and the condition of the terminal segments of the pinnules.

Thus *Antedon rosacea* &c. have a central mouth and no comb.
,, *Phanogenia typica* has a central ,, and comb.
,, *Actinometra solaris* &c. have an excentric ,, and comb.
,, *Comatula meridionalis* has an excentric ,, and no comb.

Leaving *Phanogenia* out of consideration for the present, as it was unknown to Johannes Müller, the following scheme will represent the relations of *Antedon* and *Actinometra* as used by Dr. Lütken and myself, to *Alecto* and *Actinometra* as used by Müller:—

Alecto.	Ambulacra symmetrically distributed on the disk.	mouth central.	*Antedon.*	Oral pinnules not specially distinguished.
		mouth excentric.		
Actinometra.	Ambulacra unsymmetrically distributed on the disk.	mouth excentric.	*Actinometra.*	Oral pinnules nearly always have a terminal comb.

(§ 15) We are now in a position to investigate which species of the numerous *Comatulæ* described by Müller can be referred to *Actinometra* under its new definition, and what further subdivisions of the genus are possible according to the principles of classification introduced by Müller. Before doing so, however, it will be advisable to devote a little time to a consideration of the descriptive terminology which he employed, and of the manner in which it has been modified by later writers.

In *Pentacrinus* and *Comatula* Müller regarded the arms as starting directly from the five radial axillaries. The two primary arms borne by each of these might either remain

[1] *Loc. cit.* No. 11, p. 355. Pourtales here evidently uses *Antedon* as equivalent to *Alecto*, and not in the sense in which it was employed by Mr. Norman, viz. to designate those forms only in which the mouth is central (or nearly so) and the anus lateral. To avoid confusion, I shall speak of this species simply as *Comatula meridionalis*.

[2] "Phanogenia, ett hittills okändt slägte af fria Crinoideer," Öfver. af Kongl. Vetensk.-Akad. Förhandl. 1866, No. 9, p. 223.

simple, as in *Ant. rosacea*, or divide more or less frequently into secondary, tertiary, &c. arms, as in *Act. multiradiata* and in *Pentacrinus*; and every segment, like the radial axillary, preceding a bifurcation, was called by Müller a "brachial axillary."

In some of the Tessellate Crinoids, however, the arms do not become free at the radial axillary, but "der Kelch setzt sich noch weiter fort; die Radien zerfallen dann in zwei Distichalradien mit *radialia distichalia*, die jedes mit einem *distichale axillare* enden, wie bei *Actinocrinus moniliformis* und *Eucalyptocrinus*" [1]. In this case the distichal radii represent the primary arms of *Comatula* and *Pentacrinus*, though Müller never used the name "distichals" in his descriptions of the species of *Comatula*; for, as in the Tessellata the segments composing two adjacent distichal radii are united laterally with one another by intermediate plates, he regarded them as forming a part of the calyx, and considered the arms of this group as starting from the distichal axillary, and not from the radial axillary, as in the Articulate Crinoids.

The two primary arms, or distichal radii, borne upon a single radial axillary, were called by Müller a "*distichium*;" and the interval between two successive distichia dorsally between the calcareous segments, or ventrally between the corresponding grooves on the disk, was spoken of by him as "*inter*palmar," while the interval between the two primary arms or distichal radii borne by the same radial axillary, or, as Müller called it, "die Kluft eines Distichiums," was "interbrachial" or "intrapalmar."

The words "interambulacral," "interradial," and "intertentacular," have been also used by Müller and others to designate the interpalmar areas on the disk of *Comatula*. Either of these is preferable to "interpalmar," for reasons which will presently appear, though "intertentacular" is not universally applicable, as in certain *Actinometræ* the posterior ambulacral grooves bounding the large area in which the anal tube is situated are not provided with tentacles at their sides.

The term "interbrachial" is decidedly preferable to "intrapalmar," which was used by Müller to designate the small areas on the disk, bounded by the two branches of each of the five primary groove-trunks. "Intrapalmar" does not convey any clear idea of the relation of these areas to the divisions of the skeleton, while "interbrachial" distinctly indicates that they correspond to the intervals between the two primary arms borne by every axillary radial.

Rœmer [2] adopted Müller's nomenclature for the fossil Crinoids, and, like him, considered that the distichal radii, when present and united laterally to one another, formed a part of the calyx; so that the arms were regarded by him as commencing from the axillary distichals, while he distinguished their different divisions simply as rami of the first, second, and third order. De Koninck and Le Hon [3], however, regarded the arms as commencing from the first bifurcation, *i. e.* from the axillary radial, whether they become free at once or whether they remain united with the calyx for a longer or shorter distance. Nevertheless they distinguished the arm-segments by different names in the two cases, using the expression "pièces brachiales" for the distichals of Müller, *i. e.* for those segments which are immovably united with the calyx, while they gave the name "articles brachiaux" to the movable segments, the brachials of Müller.

[1] Bau des *Pentacrinus*, p. 31. [2] Lethæa geognostica, Band i. Theil 2, pp. 210, 215.

[3] Recherches sur les Crinoïdes du Terrain Carbonifère de la Belgique, (Bruxelles, 1854) p. 69.

This view, although unquestionably correct in the case of the Articulate Crinoids (*Comatula, Pentacrinus,* &c.), is, as Rœmer has pointed out, beset with some difficulties in its application to the fossil Tessellata; and Schultze[1] accordingly reverted to the original view of Müller, saying, "Die Arme (brachia) beginnen unveränderlich da, wo eine deutliche Gelenkfacette eines festen Kelchstückes, ihren Ursprung anzeigt." In describing the divisions of the arms, he speaks of the brachial axillaries of the first, second, and third order, without giving them any special names. These are perhaps scarcely necessary when the number of segments between each division varies so much in different specimens and in different arms of the same specimen as it does in many fossil Crinoids, and in *Pentacrinus.* Among the *Comatulæ,* however, the number and character of the segments between the successive divisions of the arms exhibit variations which are to a certain extent constant in different species, and thus give us the means of classifying them into larger or smaller groups.

Müller has availed himself of this character to a certain extent in the scheme which he gives[2] of a classification of the *Comatulæ* according to the presence or absence of syzygia in the various brachial axillaries; but though, in his descriptions of the different species, he furnishes the material for carrying this classification much further, and for separating species which, in his scheme, stand very near to one another, he never made any use of it, simply classifying the *Comatulæ* in the groups which he had constituted, according to the number of their arms—10, 20, 40, or more. Under these circumstances he would have been puzzled where to place *Act. polymorpha,* in which I have found the number of arms to vary from 13 to 39.

(§ 16) It has been already stated that the arms proper of *Comatula* begin from the radial axillaries. In many cases they are united by perisome as far as their second or third division; and in *Act. multifida* this perisome contains numerous small calcareous plates, which render the union of the arms with one another and with the calyx somewhat firmer than usual; but they are never so united as to be immovable, as their various segments are connected with one another, except, of course, at the syzygia, by muscles and ligaments. There is one point about the nature of this union which has not, I think, received sufficient attention; and as it shows clearly that the arms of *Comatula* and *Pentacrinus* begin from the radial axillaries, it is worth considering here. It is this: the first and second segments beyond every axillary, whether radial or brachial, are nearly always united together in the same manner as the second and third (axillary) radials.

Thus, for example, in *Act. solaris,* and in the forms allied to it, the second and third radials are united by a syzygy. The same is the case with the first and second brachials. In *Ant. rosacea,* and in the various species which are closely allied to it, there are no muscles between the second and third radials; but their opposed articular faces present a vertical and not a transverse ridge, and are so united by ligament that the two segments are only capable of a lateral movement upon one another, and cannot take part in any movements of flexion or extension, in which they act as a single segment only. The first and second brachials are united in precisely the same manner.

[1] Monographie der Echinodermen des Eifler Kalks, (Wien, 1866) p. 5.

[2] Gattung *Comatula,* p. 11.

In both these groups the primary arms do not subdivide; so that the total number of arms is limited to ten; and we are as yet unacquainted with any *Comatula* in which the second and third radials are united by a syzygy and there are more than ten arms[1]. This is, however, the case in *Pentacrinus Mülleri*, in which, in like manner, the first and second segments beyond every brachial axillary are also united by a syzygy[2]. On the other hand, *Pentacrinus asteria*, L. (=*P. caput-Medusæ*, Müller), is remarkable for having muscles between the second and third radials as well as between the first and second[3]. In the same manner the first and second segments beyond every axillary are united by muscles, and the syzygium is between the second and third segments[4].

In nearly all the *Comatulæ* with which we are acquainted, with the exception of *Act. solaris* and the species most nearly allied to it, the second and third radials are united by ligament only, as in *Ant. rosacea*, their opposed faces being marked by a vertical articular ridge (Pl. VII. figs. 2 b, 3 a, 5 b, 6 a, *i*). In almost all of these species which have more than ten arms, the first and second segments beyond every axillary are united by ligament only, just like the second and third radials[5]. Thus in *Ant. Savignii* every third segment, so long as the division lasts, is an axillary, and the first and second segments beyond each axillary are united by ligament only. But in *Ant. palmata* only two segments follow each bifurcation, the second of which is again axillary; it is nevertheless united to the first one by ligaments only. I have found these same two conditions to occur together in *Act. polymorpha* (Pl. II. fig. 8), in which the normal number of segments between every two points of division is three (Pl. II. figs. 7, 9, 10), of which the third is axillary with a syzygium, as in *Ant. Savignii*, while the second is united to the first by ligament only. In exceptional instances, however (Pl. II. figs. 8, 11), the second segment may be axillary, and united to the first by ligaments only, as in *Ant. palmata*.

In every case, after the division has ceased, the union of the first and second brachials

[1] There are three *Comatulæ* in the 'Challenger' collection which answer to this description. In two of them the first and second distichals and the first and second brachials are united by syzygies, like the second and third radials. But in the third species there is a curious exception to the rule. The rays may divide eight times; and in the primary divisions there are three distichal joints, the first two of which are united by ligaments and not by syzygy. But in all the subsequent divisions the first two joints beyond each axillary form a syzygy, like the second and third radials.

[2] This agreement between the mode of union of the second and third radials, and of the first and second brachials respectively, is seen also in *Encrinus moniliformis*, in which these segments are united by syzygia as in *P. Mülleri*. See 'Petref. Germ.' Taf. liv. figs. F, G. The same is the case in *Rhizocrinus* (Sars, 'Crinoïdes vivants,' pp. 15, 22).

[3] Bau des *Pentacrinus*, p. 30, and Taf. ii. fig. 8.

[4] This does not appear, however, to be always the case; for Müller described the syzygium as uniting the first and second arm-segments in the specimen examined by him, while I have found the same to be the case in a specimen of this species contained in the Zoological Museum of the University of Würzburg, in which there is certainly no syzygial union between the second and third radials. In *Pentacrinus* the opposed faces of two elements, which are united by a syzygium, are simple, and not radially striated as in *Antedon*. Sars has found this to be the case in *Rhizocrinus* also; but in its predecessor, *Apiocrinus obconicus*, Goldfuss, the radial striation of the syzygial surfaces is very distinct (Petref. Germ. Taf. lvii. fig. 5).

[5] The 'Challenger' collection includes two very abnormal species which present a singular exception to the rule. The rays divide three times; and the first two segments (distichals) of each of the ten primary arms are united by ligaments only, like the second and third radials. So far the rule holds good; but with the next arm-division there is a new point of departure. The third or axillary distichal bears the secondary arms, which consist of one axillary segment only. But this segment is itself primitively double, *i. e.* it consists of two parts united by a syzygy; and the first joints of each of the ultimate arms borne by tis axillary a gree with it in being syzygial segments.

of the free and undivided secondary or tertiary arms is of precisely the same nature as the union of the first and second segments of the primary arms borne by the radial axillary. In fact, it is not at all uncommon for one of the primary arms to remain simple and the other to divide, as in Pl. II. fig. 9, C, D, E, which shows that the arms taken in the strict sense of the word, cannot be regarded as commencing from any point but the axillary radials.

(§ 17) In practice, however, it is more convenient to regard the arms of *Comatula* as beginning from the last bifurcation, *i. e.* from that axillary the two branches borne by which do not further divide, but remain composed of a series of simple brachial segments (b_1, b_2), &c. In the ten-armed *Comatulæ* the brachials are, of course, borne directly by the radial axillary. But in those forms, such as *Act. multiradiata*, in which the subdivision of the ten primary arms is carried to a very great extent, it is most convenient to regard as brachials only the segments of the ultimate branches borne by the last axillaries, and to give special names to the segments composing the primary and secondary arms; for we have already seen that the number of the segments composing these arms, *i. e.* between every two successive axillaries, varies in different species, and it consequently becomes desirable to have some system of nomenclature by which these differences can be briefly indicated. Under these circumstances, therefore, the term *distichals* may be applied to the segments composing the ramified primary arms of e Articulate as well as of the Tessellate[1] Crinoids, but only on the distinct understanding that they are really arm-segments and do not enter into the formation of the calyx, as in the Tessellata; so that the name is purely a conventional one, employed for greater convenience in the description of species.

Supposing the secondary arms borne by the distichal axillaries to divide again, we may consider them as composed of two, three, or four palmar[2] segments, of which the last is a "palmar axillary" (figs. 10, 11, *p.a.*), and bears two tertiary arms. These may either remain simple and composed of brachial segments, or they may continue to divide more or less frequently. The latter case, however, is somewhat rare; for if complete series of distichals and palmars be developed on each radius, the total number of arms rises from 10 to 40; and there are not many *Comatulæ* in which this number is exceeded.

If we apply this nomenclature to the species of which mention has already been made, we should describe *Antedon Savignii* with 20 arms, as characterized by the presence of three distichals composing each primary arm and bearing the brachials directly, while in *Antedon palmata*, with 30 or 40 arms, there are only two distichals, which are followed by two palmars in the secondary arms. *Act. polymorpha*, again, normally has three distichals and three palmars (Pl. II. figs. 7, 10), while *Act. multiradiata*, Müll., has

[1] *l. c.* As understood by MM. de Koninck and Le Hon.

[2] I have been accustomed for some years past to use the term "palmar" to designate the secondary arms of the Crinoids. Professor Huxley, in whose lectures I first heard it used in this sense, informs me that he believes it to have been so employed by Müller; but I have searched in vain through Müller's works for any definition of the term. In his description of the Tessellate Crinoids, however, he describes the plates which continue the series of interradials and interaxillaries in a peripheral direction as "interpalmaria;" and as these partially correspond to the intervals between the secondary arms, when such are developed, the latter may perhaps be not incorrectly regarded as composed of "palmar" segments. It will now be apparent why "interpalmar" is not a very suitable designation for the strictly "interradial" areas on the disk of *Comatula*, as was remarked in section 15.

only two palmars in each secondary arm, although the number of distichal segments in the primary arms is usually three. Another proof, if proof were wanted, that the arms proper of the articulate Crinoids begin from the axillary radial is seen in the fact that whenever there are three segments in a distichal or palmar series, the second of these, which is united to the first by ligament only, always bears a pinnule, while the third, or axillary, is a double segment, *i. e.* it consists of two primitive segments united by a syzygium. This is in precise accordance with what we find in all the ten-armed *Comatulæ*, even in those forms in which, as in *Act. solaris*, the first and second brachials are united by a syzygium like the second and third radials. In these the second brachial or the epizygial element of the syzygium bears a pinnule, while the next segment is also a double one, and corresponds with the compound third brachial of *Ant. rosacea* and of the ordinary ten-armed *Comatulæ*. In these last the second brachial is laterally movable upon the first, and bears a pinnule as in *Act. solaris*, while the third has a syzygium (*i. e.* is a double segment). This is exactly what we find to be the case in those primary and secondary arms of the multiradiate *Comatulæ* which consist of more than two segments.

(§ 18) The principal character of the genus *Actinometra* is, as we have seen in sect. 14, that the mouth is situated excentrically, while the centre of the disk is occupied by the anal tube. The position of the mouth relatively to the radii or ambulacra, however, is not the same in all *Actinometræ*; thus in *Act. solaris* (Pl. I. figs. 2, 5) the mouth lies in a radial or ambulacral plane, while in *Act. Wahlberghii* and many other species (Pl. I. figs. 3, 4, 6–16) it is interradial or interambulacral. If we place the disk of an ordinary *Antedon* in such a position that the interradial area containing the anal tube is nearest to us (Pl. I. fig. 1), the odd ambulacrum lies in front of the mouth. Let us designate this as ambulacrum or radius A, and the two branches of its groove-trunk corresponding to the two primary arms as A_1 and A_2 respectively, A_1 being that on the left of the mouth. Proceeding round the disk in the direction of the hands of a watch, we may call the other four ambulacra B, C, D, E respectively, and their primary divisions B_1 B_2 . . . . E_1 E_2. The anal area is then bounded by the two postero-lateral ambulacra C, D; and a plane passing through the mouth and anus, so as to divide the disk into two symmetrical halves, passes along the odd ambulacrum or radius A, in front of the mouth, which may therefore be regarded as radial in position.

In *Act. solaris* the same is the case, as may be seen in Müller's somewhat diagrammatic figure (Pl. I. fig. 2)[1], and still better in Pl. I. fig. 5, which was drawn from a spirit-specimen, and not from a dry one like Müller's figure. Here, as in *Antedon*, the odd ambulacrum is in front of the mouth, which, although excentric in position, lies in the radial half of a plane which passes through the mouth and anus, so as to divide the disk into two symmetrical halves. The same is the case in a new *Actinometra* from the

[1] It is not usual to meet with specimens of *Actinometra* in which the branches of the ambulacral grooves are distributed with such symmetry as is represented in Müller's diagrams (Pl. I. figs. 2–4) and in Pl. II. fig. 1. Thus, for example, Müller's figure of *Act. solaris* (Pl. I. fig. 2) is remarkably regular, much more so than that represented in fig. 5; and I have examined other specimens with more than 20 arms and a radial mouth, in which the regularity is by no means so distinct as in Pl. II. fig. 1. A great range of variation in this respect is seen in Pl. I. figs. 6–16, which represent the disks of eleven different individuals of *Act. polymorpha*, no two of which are alike; the position of the mouth, however, is constant in all individuals of the same species.

Philippines (Pl. II. fig. 1) with 23 arms. In both these species the dividing plane passes in front of the mouth between the two primary divisions, A_1 A_2 of the odd anterior ambulacrum A, while behind the mouth it is interradial, and separates the two postero-lateral ambulacra C, D.

In *Act. Wahlberghii* (Pl. I. fig. 3), *Act. multiradiata* (fig. 4), and *Act. polymorpha* (figs. 6–16) the case is different. If, as in *Antedon*, we designate the two ambulacra bounding the anal area as C and D respectively, we find that the latter is the odd ambulacrum, and that a plane cutting the mouth and anus is radial behind the mouth, in front of which it passes between the two ambulacra A and B; so that if the centre of the disk be regarded as the centre of radiation, the mouth lies in an interradial or inter-ambulacral plane. This is clearly seen when we turn to the dorsal side of the disk, in which the radii converge to a central point, and not to an excentric one, like the ambulacra of the ventral side. Thus in Pl. II. figs. 9–11, the position of the mouth relatively to the radii is indicated by a ×, which in each case is between the two anterior radii A and B, or interradial.

So far as my experience goes, this type of *Actinometra*, in which the mouth is interradial and the odd ambulacrum lies behind it, is slightly more common than the simpler type, in which the mouth is radial and the odd ambulacrum anterior, as in *Antedon* [1].

(§ 19) We are now in a position to investigate which of the numerous species of *Comatulæ* described by Müller belong to the type of *Antedon*, and which to *Actinometra*, and into what groups the latter may be divided according to the principles of classification discussed in the last four sections. Müller's specific descriptions afford very little information in this respect; for though he says that the mouth, in some instances, is excentric, and that in others the oral pinnules have a terminal comb, he does not always do so; and he makes no use whatever of these two characters in his distinction between *Alecto* and *Actinometra*. In some cases he simply designates a species as *Comatula*, without attemping to name it more exactly. This is often, no doubt, simply due to the fact that, in the specimens which he examined, the arms were so closed over the disk that he was unable to investigate the distribution of the ambulacra. This, however, is not the case in the *C. trichoptera* of the Paris Museum, the disk of which can be readily examined; and I believe that Müller did not define this species more precisely because he was unable to decide whether it should be referred to *Alecto* or to *Actinometra*; for in one of the two Paris specimens five groove-trunks start from the excentric peristome, while in the other there are only four. This example alone suffices to show the unsatisfactory nature of the only distinctive character established by Müller between his genera *Alecto* and *Actinometra*. The Paris Museum [2] contains a very large majority of the

[1] Since the above was written, I have examined three large *Comatula*-collections:—(1) that of the 'Challenger;' (2) that made by Prof. Semper in the Philippines; and (3), thanks to the kindness of Dr. Günther, that in the British Museum.

I have been able to determine the position of the mouth in 80 species of *Actinometra*. In 45 of these it is interradial, as in *Act. polymorpha*; while in the remainig 35 it is radial, as in *Antedon* and in *Act. solaris*.

[2] I would here express my most hearty thanks to Mons. Edmond Perrier, Assistant-Naturalist at the Museum of Natural History, Jardin des Plantes, who has charge of the Echinoderm collection, and also to his two Assistants, for the kindness which they showed me during my stay in Paris, and for the readiness with which they afforded me every possible facility in the prosecution of my work.

species of *Comatula* described by Müller, who personally examined this collection. Last autumn (1876) I was also able to examine it for myself, and thus to determine which species should be removed from Müller's genus *Alecto* and transferred to *Actinometra*, in the sense in which this name is understood by Dr. Lütken and myself.

In the following scheme all those species to which no note of interrogation and the name of no authority is attached, have been determined by myself as *Actinometræ*, *i. e.* as having an excentric mouth and a terminal comb on the oral pinnules.

Actinometra.

- With 10 arms.
  - Second and third radials united by a syzygy. Mouth radial.
    - *Act. solaris*, Müll.
    - *Act. pectinata*, Müll.
    - *Act. brachiolata.*
    - *Com. purpurea* ? 1.
    - *Com. rosea* ?
    - *Act. robusta*, Lütken.
  - Second and third radials united by ligaments only. Mouth ?
    - *Com. echinoptera* ? 2.
    - *Com. meridionalis*? 3.
- With more than 10 arms. Second and third radials united by ligaments only.
  - 2 Distichals. Axillary has no syzygy.
    - 3 palmars. Axillary has a syzygy. .... *Act. rotalaria*, Müll. 4.
  - 3 Distichals. Axillary has a syzygy.
    - No palmars.
      - Mouth interradial.
        - *Act. polymorpha.*
        - *Act. trichoptera.*
        - *Act. Wahlberghii*, Müll.
      - Mouth radial .... *Act. fimbriata.* 5.
    - Mouth interradial.
      - 2 palmars. Axillary has no syzygy.
        - *Act. multifida.* 6.
      - 2 palmars. Axillary has a syzygy.
        - *Act. multiradiata.*
      - 3 palmars. axillary has a syzygy.
        - *Act. parvicirra.* 7.
        - *Act. polymorpha.* 8.
        - *Act. Bennettii*, Böhlsche. 9.

Remarks.

1. I have not personally examined either *C. purpurea* or *C. rosea*. Müller seemed to think that the former might be a young condition of *Act. solaris*[1]; so that it is most probably a true *Actinometra*. *C. rosea*, however, presents a difficulty; for Müller says expressly[2] that the first pinnules are not specially distinguished; but, except in this point, he regarded it as very closely related to *C. brachiolata*, which is a true *Actinometra*.

[1] 'Gattung *Comatula*,' p. 13.

[2] *Ibid.* p. 14.

2. *C. echinoptera*, on the other hand, has, according to Müller[1], a very marked comb on the oral pinnules. He says nothing, however, about the position of the mouth; and I have unfortunately not been able to examine the species for myself.

3. According to Pourtales[2] the mouth is excentric in *Com. meridionalis*; but he makes no mention of a comb on the oral pinnules. If it should be absent in this species, and also in *Com. rosea*, while it is present in *Phanogenia*, in which the mouth is central, it becomes obvious that the only external character, besides the shape of the calyx, on which we can rely with any certainty in the determination of the generic position of any *Comatula*, is the nearly central or the excentric position of the mouth.

4. According to Müller[3] there are only two radials in *Act. rotalaria* which are united by a syzygium, while they bear the distichal axillaries directly; and these are also syzygial segments. Although, like Müller, I examined Lamarck's original specimen of this species, I cannot confirm the above statement. It is true that only two radials are visible externally; but this is often the case in *Comatulæ*, with a wide centrodorsal piece; and I was quite unable to satisfy myself that they are united by a syzygium, as Müller describes, and as is the case with the second and third radials of *Act. solaris*, while I was equally unable to determine a syzygial union between the two segments of which the distichal series is composed. Lamarck's original specimen of this species in the Paris Museum is wrongly labelled *C. brevicirra*, Troschel.

5. The dry specimen of *Act. fimbriata* in the Paris Museum, from the voyage of Peron and Lesueur, is labelled *C. multiradiata*, Lam.; while Reynaud's original specimens from the Strait of Soude are labelled *C. brevicirra*, Trosch., together with *Act. rotalaria* and the Vavas variety of Müller's *C. parvicirra*.

6. In *Act. multifida* the tertiary arms borne by the palmar axillaries may divide again several times. In every case there are only two segments between each division, and all the successive axillaries, like the palmar axillaries, have no syzygia. Although Müller mentions this in his description of the species, it is placed in his scheme in a group in which the axillaries of the arms have syzygia. In reality, however, this is the case with the distichal axillaries only.

7. The type specimen of this last species does not exist in the Paris Museum under that name, nor even under *C. brevicirra*, Troschel, which seems to have been used as an equivalent for it; but I believe that three small spirit-specimens from the voyage of Peron and Lesueur in 1803, which are classed, with two specimens of *Act. pectinata*, under the name of *C. simplex*, are really those which were described by Müller as *C. parvicirra*.

8. It will be noticed that *Act. polymorpha* has already appeared higher in the list as a species in which palmars are not developed. In some individuals but few of the 10 primary arms bear axillaries; so that the total number of arms is less than 20 (Pl. II. fig. 9); while in others all the primary arms divide again, and so do the resulting secondary arms, so that the total number is little short of 40 (Pl. II. figs. 10, 11). This is very unusual; for I only know of two other species which present the same kind of

[1] 'Gattung *Comatula*,' p. 14. [2] *Loc. cit.* No. 11, p. 355.

[3] 'Gattung *Comatula*,' p. 20.

irregularity. As a general rule all the individuals of a species agree in the presence or absence of distichals and palmars.

9. In *Act. Bennettii* there are more than 70 arms; but all the axillaries are like the first one (distichal), and not different from it, as in *Act. multifida.* According to Müller[1], every fourth segment is an axillary without a syzygium; but Böhlsche[2] has found this to be incorrect. There are, indeed, four segments between every two points of division; but the last two are united by a syzygium; so that the formula becomes three distichals, palmars, &c., of which the axillary has a syzygium. Böhlsche's figure of the disk of his specimen is noteworthy; for though five groove-trunks leave the excentric peristome, as in *Alecto*, yet their distribution to the arms is not by any means symmetrical, so that he seems to have decided upon calling it *Actinometra.* Müller named it simply *Comatula.*

(§ 20) In the above scheme are included all the species of *Comatula* which have been determined by myself or by others[3], as far as I know, to belong to the type *Actinometra.* Fourteen of these were known to Müller; and of the remaining 23 species described by him I have been able to refer 16 to *Antedon*, viz.:—

Ant. adeonæ.	*Ant. macrocnema.*	*Ant. phalangium.*
Ant. articulata.	*Ant. Milberti.*	*Ant. Philiberti.*
Ant. carinata.	*Ant. Milleri.*	*Ant. Reynaudii.*
Ant. Eschrichtii.	*Ant. palmata.*	*Ant. rosacea.*
Ant. Jacquinoti.	*Ant. petasus.*	*Ant. Sarsii.*
	Ant. Savignii.	

To these must be added

Ant. armata, Pourt.	*Ant. cubensis,* Pourt.	*Ant. Hagenii,* Pourt.
Ant. bicolor, Mus. Paris.	*Ant. dividua,* Mus. Paris.	*Ant. polyactinis,* Mus. Paris.
Ant. celtica, Barrett.	*Ant. Dubenii,* Bölsche.	*Ant. rubiginosa,* Pourt.

The following list contains the seven remaining species of *Comatula* described by Müller which I have not been able to examine, and of which I know no descriptions from which it is possible to obtain any information as to the position of the mouth or the character of the oral pinnules.

C. Cumingii.	*C. elongata.*	*C. flagellata.*
C. japonica.	*C. novæ Guineæ.*	*C. tessellata,*

and *C. timorensis.* To which must be added *C. brevipinna,* Pourt.

III. External Characters of Act. polymorpha, and Specific Diagnosis of the Type.

(§ 21) In *Act. polymorpha*, as in all *Actinometræ*, the mouth (Pl. I. figs. 6–16, *m*)

[1] 'Gattung *Comatula*,' p. 28.

[2] "Ueber *Actinometra Bennettii* und eine neue *Comatula*-Art (*Antedon Dubenii*)," Wiegm. Archiv, 1866, i. p. 90.

[3] Dr. Lütken has named several new species of *Actinometra* besides *Act. robusta*—for example, *Act. tenax* and *Act. trachygaster.* But his descriptions have not, as far as I know, been published; and I have had no opportunity of examining any specimens of his new species except *Act. robusta*; so that I am unable to place them in the classification given in the previous section.

Grube has described a new *Actinometra* from Borneo, and two new species of what he calls *Comatula.* His descriptions (Jahresber. d. Schlesisch. Gesellsch. 1875, Nat.-Hist. Sect. pp. 54, 55) are, unfortunately for me, not to be obtained in this country.

does not occupy a central or subcentral position on the ventral surface of the visceral mass as it does in *Antedon*, but is placed more or less excentrically, and may be sometimes almost marginal (Pl. I. fig. 11). It occupies the centre of the peristome, P, and is bounded by two lips, a large anterior and a smaller posterior one; so that its opening is very inconspicuous, and usually so much extended in a direction transverse to the antero-posterior diameter of the disk, that it presents the appearance of a simple slit, as is well seen in Pl. II. fig. 2.

The circumoral portion of the peristome, or the peristome proper, is a more or less oval depression in the ventral perisome of the disk, which completely surrounds the oral opening, and gives origin to the ambulacral grooves or, more shortly, the ambulacra. Beneath this depression lies the water-vascular ring which gives off a trunk under each of the ambulacra radiating from it. The number and distribution of these are very variable, as is seen in Pl. I. figs. 6–16. This principally depends upon the way in which the ambulacra divide, so as to give rise to the groove-trunks corresponding to the ten primary arms. As a general rule, the two ambulacra corresponding to the radii D and E unite into one large posterior trunk, from which the branches are distributed to the various arms into which these radii divide (Pl. I. figs. 8–10, 12–16). In other cases the left lateral ambulacrum, E, leaves the peristome alone (figs. 6, 11); while in others it is partially united with the posterior ambulacrum, D, its anterior division, E_2, leaving the peristome by a separate trunk, while its posterior division, E_1, unites with the posterior ambulacrum (fig. 7).

As a general rule, the right lateral ambulacrum, C, leaves the peristome alone, and supplies the arms of the corresponding radius; but in figs. 9 & 15 it is seen to unite with the posterior division, B_2, of the right anterior ambulacrum, B.

The mode of division of the two anterior ambulacra is excessively variable. As a general rule there are no principal trunks corresponding to the two radii A and B, and the primary divisions, A_1, A_2, B_1, B_2, start directly from the peristome. In the specimens with but few arms, however, each pair may be united for a longer or shorter distance (Pl. I. figs. 6, 7), as in *Antedon* (fig. 1). Not unfrequently the posterior divisions A_1, B_2, of these two anterior ambulacra unite for a longer or shorter distance with the two large aboral groove-trunks, to form an open horseshoe-shaped curve bounding the anal area (figs. 12, 15, 16). The position of the anal tube in this area, and also with regard to the whole surface of the disk, varies somewhat with the position of the mouth; it is rarely, if ever, absolutely central. Its appearance differs very much according as it is full or empty: sometimes its aperture is so completely closed as to be scarcely discernible, though the tube below is widely distended; and sometimes the aperture is patent with its edges everted and crenate, and the tube leading to it quite shrunk and flaccid (Pl. II. fig. 2).

(§ 22) In *Antedon* the median line of the ventral perisome of all the arms is occupied by an ambulacral groove, with a floor of ciliated epithelium. This groove extends also on to all the pinnules, with the exception of those borne by the second distichals and second palmars, &c. (when present), and by the lowest brachial segments. Beneath it lie the radial water-vascular and blood-vascular trunks, between which last and the ciliated epithelium of the floor of the groove lies a fibrillar structure, to which I have given the name of the "subepithelial band"[1], and to which a nervous character has been attributed by myself and by all the other observers who have described it. Each side of the ambulacral groove is bounded by an elevated fold of perisome, the edge of which is not straight, but cut out into a series of minute valvules, the crescentic or respiratory leaves (Wyv. Thomson), or "Saumläppchen" of the German authors.

At the base of each leaf, and to some extent protected by it, is a group of three tentacles, one of which, the more distal one, is larger than the other two. This trifid group of tentacles and the cavity of the respiratory leaf adjacent to them receive a common branch from the radial water-vessel. These groups of tentacles alternate on the opposite sides of the ambulacral groove from the base to the tip of each arm, and are distributed in the same manner at the sides of the ambulacra of the disk, though they are not so markedly developed, especially near the peristome, where every lateral branch of the water-vessel supplies only one tentacle. The crescentic leaves at the sides of the groove are also far less distinct than in the arms, the edges of the folds of perisome bounding the groove being only marked by a faint wavy line, and not distinctly cut out into "Saumläppchen."

In many *Actinometræ*, however, the above description only applies to the arms of the two anterior radii, A, B (Pl. II. figs. 2, 4), and to more or fewer of the antero-lateral arms, C_1 and E_2. The arms of the posterior radius, D, and of the posterior divisions of the lateral radii, C_2 and E_1, are often entirely devoid of tentacles; and in many of them the ventral perisome not only exhibits no ambulacral groove, but is, on the contrary, *convex*, as in the oral pinnules of *Antedon* (Pl. II. figs. 5, 6).

We have just seen that in *Act. polymorpha*, as in all *Actinometræ* with an interradial mouth, the anal area is bounded by two large aboral groove-trunks, which start from the posterior angles of the peristome, and form a horseshoe-shaped curve, the limbs of which are unequal in size (Pl. II. fig. 2). The smaller right limb is formed by the right lateral ambulacrum, C; while the larger left limb represents the posterior ambulacrum, D, combined with part or the whole of the left lateral ambulacrum, E. In neither of these limbs are the tentacular groups and crescentic leaves so well developed as they are in the two anterior ambulacra. After the branches to the two antero-lateral primary arms, C_1 and E_2, have been given off, or sometimes even sooner (Pl. I. figs. 13, 15), the tentacles at the sides of the two aboral groove-trunks become more and more insignificant, and finally disappear altogether, while the position of the crescentic leaves is only indicated by a very faint wavy line at the edge of each groove.

In small specimens with but few arms (Pl. I. figs. 6, 9) the grooves of the posterior (D) and postero-lateral arms (C_2, E_1) may remain in this condition; but in larger specimens with many arms all trace of the crescentic leaves disappears, and the two edges of the groove meet and unite so as to produce the condition represented in Pl. II. figs. 5 & 6, where the ventral surface of the arms and pinnules is convex, and does not show the least trace of a groove of any description.

[1] "Remarks on the Anatomy of the Arms of the Crinoids. Part I.," Journ. of Anat. and Physiol. vol. x. p. 579.

The position of the point at which the two folds of perisome bounding the sides of the original ambulacral groove meet and unite, varies extremely. The fusion may, though rarely, take place on the disk; sometimes it is at the base of the arms, and sometimes not till near their middle or terminal portions. In any case, however, the fusion, whenever it occurs, is so complete that all trace of the original ambulacral groove is entirely obliterated.

(§ 23) The bearings of this fact upon the different views advanced by Greeff[1] and Ludwig[2] respecting the homologies of the ambulacral grooves of the Crinoids will be best discussed at a later period, when the changes undergone by the various structures underlying the grooves are described and illustrated. One point, however, must be noticed here on account of its importance with respect to the two views now entertained regarding the nervous system of *Comatula*.

As long ago as 1865 it was stated by Dr. Carpenter[3] that the cord which traverses the length of the arms between the subtentacular and cœliac canals, "and which was regarded by Professor Müller as a nerve, really belongs to the reproductive apparatus. But it will also be shown that a regular system of branching fibres proceeding from the solid cord (described by Professor Müller as a vessel) that traverses the axial canal of each calcareous segment of the rays and arms, is traceable on the extremities of the muscular bundles; and reasons will be given for regarding these fibres as probably having the function of nerves, though not exhibiting their characteristic structure." During his residence in the Philippine Islands, Professor Semper had also discovered that the arm-nerve of Müller is really a part of the generative system; and in a short paper[4] published some time after his return he announced this fact, and suggested at the same time, "dass der bisher immer als Gefäss aufgefasste Strang im innern des Kalkskelettes ein Nervenstrang sei, und dann wäre wohl das im Kelch liegende sogenannte Herz als ein Ganglion anzusehen."

These observations of Dr. Carpenter's and Professor Semper's were unfortunately overlooked for many years, so that even as late as 1874 Müller's erroneous statements with regard to the nervous system of *Comatula* were repeated in the valuable text-book of Gegenbaur[5] and in many smaller works. At the commencement of 1876, however, two very different views respecting the nervous system were put forward nearly simultaneously by Greeff and by Dr. Carpenter. The former[6] described the whole floor of the ambulacral grooves on the arms and disk of *Ant. rosacea* as constituting a radial nervous system, starting from an oral nervous ring in the peristome, and corresponding

[1] "Ueber den Bau der Echinodermen. III. Mittheilung," Sitzungsb. der Gesell. z. Beförder. d. gesamm. Naturwiss. zu Marburg, 1872, No. 11, p. 155.

[2] "Beitr. z. Anat. der Crinoideen," Nachrichten von der Königl. Gesells. der Wissens. u. der G. A. Universität zu Göttingen, 1876, No. 5, pp. 107, 108.

[3] "Researches on the Structure, Physiology, and Development of *Antedon rosaceus*. Part I.," Philos. Trans. vol. clvi. p. 705.

[4] "Kurze anatom. Bemerk. über *Comatula*," Arbeit. aus d. zool.-zootom. Inst. zu Würzburg, Band i. (1874), p. 262.

[5] Grundriss der vergleich. Anat. p. 222.

[6] "Ueber den Bau der Crinoideen," Marburg. Sitzungsb. 1876, No. 1, Jan. 13, p. 21.

in position and histological structure with the typical Echinoderm nerves. At the same time he denied the nervous nature of both the structures described as nerves by Müller and Dr. Carpenter respectively, viz. the genital cord, the so-called "rachis," on the one hand, and the axial cords in the centre of the calcareous segments on the other.

A week after the publication of Greeff's views, Dr. Carpenter[1] announced his belief that a complicated apparatus, "consisting of the outer cylinder of the Crinoidal stem, of the five-chambered central organ formed by the dilatation of that axis within the centro-dorsal basin, and of the cords proceeding from it to the arms and cirrhi," should be regarded as the central portion of a nervous system. This view was based both upon anatomical and upon physiological considerations:—

(*a*) That while a single arm may be made to coil up by irritating one of its pinnules, the whole circlet of arms closes together when an irritation is applied to the pinnules, which arch over the mouth—an act which affords a strong indication of the "inter-nuncial" action of a definite nervous system.

(*b*) That stimulation of the central quinquelocular organ ("heart" of Müller and Greeff) contained in the calyx, with which the axial cords of the arms are in connexion, is followed by sudden and simultaneous flexion of all the arms.

(*c*) That these axial cords give off successive pairs of branches, which ramify upon the muscles connecting the arm-segments.

Shortly after the announcement of these views on the part of Dr. Carpenter, Ludwig[2] described a *ventral* nervous system as existing in *Comatula* in common with all the other Echinoderms. He attributed a nervous character, not to the whole epithelial floor of the ambulacral grooves, as was done by Greeff, with whose researches he was unacquainted, but to a fibrillar layer beneath it, and more or less distinctly separated from it. This layer, which was also discovered independently by myself[3] and Teuscher[4], and was regarded by us both as of a nervous nature, is the "subepithelial band" mentioned in sect. 22. Ludwig, like Greeff before him, denied the nervous character of the dorsal axial cords of the arms; Teuscher discussed it as possible, but hesitated to accept it on account of the morphological difficulties involved in such a view.

Baudelot[5], who seems to have been unacquainted with Dr. Carpenter's earlier statements, was apparently struck with the nature of these cords, though he could not regard them as nervous. After describing their structure and their union in the calyx to form the pentagonal commissure, he adds, "Ainsi donc chez les Comatules il existe des parties qui *évidemment n'appartiennent point au système nerveux* (!), et qui dans leur disposition aussi bien que dans leur structure offrent une analogie presque complète avec les cordons nerveux des autres Échinodermes." It must be remembered that Baudelot wrote before the discovery of the so-called "ventral nerve" of *Comatula*; but, in any case, I do not quite see the force of his "évidemment."

[1] "On the Structure, Physiology, and Development of *Antedon rosaceus*," Proc. Roy. Soc. no. 166, Jan. 20th, 1876, pp. 219–226.

[2] Göttingen Nachrichten, no. 5, Feb. 23rd, 1876, p. 106.

[3] Journ. Anat. Phys. x. p. 578.

[4] "Beitr. z. Anat. der Echinodermen, I. *Comatula mediterranea*," Jenais. Zeitsch. B. x. p. 253.

[5] "Contribution à l'histoire du système nerveux des Échinodermes," Arch. de Zool. Exp. et Gén. i. p. 211.

In the centre of every segment of the skeleton of *Act. polymorpha* and of all the other *Comatulæ* which I have examined, from the first radials to the ends of the arms and pinnules, and also in the cirrhus-segments, these axial cords increase considerably in size, and give off four principal branches. Two of these run towards the ventral side, and in the calyx disappear in the neighbourhood of the muscles connecting the segments, though I must confess that I have never been able to trace them any further (Pl. VIII. fig. 3, *n'*). In the arm-segments, however, they continue their course towards the ventral surface and break up into numerous branches, some of which, as I have already described[1], extend to the tips of the crescentic leaflets at the sides of the tentacular furrow. The two inferior or dorsal trunks run towards the surface of the skeleton; and while some of their branches are lost in the plexus of tissue forming its organic basis, others seem to become connected with epidermic structures in a manner which will be described at length further on.

Not one of the German observers makes any mention of these branches, although two of them at least have examined *Antedon Eschrichtii*, while they have all cut sections of the arms of species of *Actinometra*, in which genus I find them to be particularly distinct. It is obvious that the facts above stated strongly support the view expressed by Dr. Carpenter and by myself, that the axial cords of the arms are of a nervous nature; and the experiments made by Dr. Carpenter[2] at Naples have shown conclusively :—

1. That the quinquelocular organ is the instrument of the perfect coordination of the swimming movements of the arms, which involve the conjoint contraction of several hundred pairs of muscles.

2. That nothing contained in the visceral mass is essential to the perfect coordination of the swimming-movements, and that therefore the subepithelial band or ambulacral nerve of the German authors has no immediate relation to those movements, even if it be a nerve at all.

3. That section of the subepithelial band in an arm does not prevent its playing its usual part in the regular swimming-movements.

4. That destruction of the axial cord of an arm by the application of acid causes the arm to become rigidly stretched out, while all the others work as usual.

Since the publication of these experiments Greeff seems to admit the nervous nature of the axial cords, and of the yellowish fibrillar envelope (Pl. VIII. figs. 1–3, N) of the quinquelocular organ from which they proceed. Ludwig[3], however, while allowing their force, cannot admit the existence in the Crinoids of an antiambulacral nervous system, of which we know as yet no homologue in the other Echinoderms, but sees no difficulty in regarding the quinquelocular organ, its fibrillar envelope, and the axial cords proceeding from it, as parts of a blood-vascular system, like that of the other Echinoderms, although he admits (p. 87) that "ihnen vergleichbare Gebilde sind bis jetzt bei anderen Echinodermen nicht bekannt geworden." The axial cords of the

[1] Journ. Anat. Phys. x. p. 584.

[2] "Supplemental Note to a Paper on the Structure, Physiol. and Develop. of *Antedon rosaceus*," Proc. Roy. Soc. no. 169, 1876.

[3] "Beitr. zur Anat. der Crinoideen," Sep.-Abdruck aus der Zeitsch. f. wissensch. Zool. B. xxviii. Heft 3, p. 81.

calcareous segments are regarded by him (pp. 80, 86) as "unverkalkt gebliebene Theile der bindegewebigen Grundlage der Kalkglieder, deren Aufgabe es ist, aus dem Blutgefässsystem, genauer aus den fünf Kammern die kernnährende Flüssigkeit aufzunehmen und den Arm- und Pinnulagliedern zuzuführen."

Without going into the question as to how far the organic basis of the calcareous skeleton can be regarded as of a connective-tissue nature, I would only remark that it is difficult to see why the axial cords, which Ludwig supposes to consist of uncalcified connective-tissue fibres, should give off branches the terminations of which are entirely outside the skeleton, as is the case with those which reach the crescentic leaves at the sides of the tentacular groove, and which therefore cannot take any part in the nutrition of the tissue forming the organic basis of the skeleton.

(§ 24) This is not the place for a full discussion of Ludwig's views on the nervous system of *Comatula*; but one point must be briefly referred to. I have already[1] stated that in some arms, and in most of the pinnules, of many *Actinometræ*, the subepithelial band or nerve of Ludwig is entirely absent, and also that "if the axial cords are not nerves, and if the subepithelial bands are to be regarded as the only nervous structures in the whole Crinoid organization, the difficulty presents itself that the oral pinnules of the European Crinoids, and more than half the arms, with the majority of the pinnules of some forms of *Actinometra*, are entirely devoid of a nervous supply.

"The oral pinnules of *Antedon* have been shown by Dr. Carpenter[2] to be extremely susceptible of irritation; when they are touched in the living animal, the whole circlet of arms is suddenly and simultaneously coiled up over the disk, while irritation of one of the ordinary pinnules is simply followed by flexion of the arm which bears it.

"The structure of these oral pinnules, which are borne in *Antedon rosacea* by the second brachials, differs very considerably from that of the pinnules borne by the other brachial segments; for not only are they sterile, but they have neither tentacular apparatus nor ambulacral groove, their ventral surface being slightly convex instead of being concave as in the ordinary arms and pinnules. This has been mentioned by Teuscher[3]; but he has omitted to state that the ordinary ciliated epithelium of the ambulacral groove, with its subjacent nervous layer and nerve-vessel, are also absent." Ludwig entirely ignores this argument, although he confirms the above statement concerning the oral pinnules of *Antedon*; in the text he is obliged to confess that "Fraglich est mir geblieben ob die oralen Pinnulæ einen Zweig des radiären Nerven besitzen oder nicht" (p. 75); while his figure of a section of an oral pinnule (pl. xvii. fig. 55) entirely confirms the statement quoted above, to which, however, he makes no reference.

This condition, which is limited in *Ant. rosacea* to the oral pinnules, sometimes exists in whole arms and in all the pinnules borne by them in many species of *Actinometra*. Even in the arms which come off from the anterior or oral side of the disk the ambulacral groove does not give off regular branches to the pinnules borne by the third and successive brachial segments; but a variable number of these first pinnules (sometimes only

[1] "Remarks on the Anatomy of the Arms of the Crinoids, part ii.," Journ. of Anat. and Physiol. vol. xi. October, 1876, p. 89.

[2] Proc. Roy. Soc. no. 166, p. 226.

[3] Jenaische Zeitschrift, x. p. 249.

three or four, sometimes as many as forty) resemble in this respect the oral pinnules, their ventral surface being convex, and devoid of any ciliated epithelium or subepithelial band; while their water-vessel is simple, without any lateral extensions to respiratory leaves and tentacles. In these oral arms, however, branches of the ambulacral groove enter the pinnules sooner or later, so that the terminal ones are always provided with a distinct tentacular apparatus, while the floor of their median groove is of the usual character, consisting of a ciliated epithelium and a subepithelial fibrillar band.

We have seen in sect. 22 that in many cases the ambulacral grooves going to the aboral arms become less and less distinct as they get further and further from the peristome, and that their tentacles diminish and finally disappear. At the same time the floor of the groove becomes very much reduced in extent, its epithelial layer thinner and thinner, and the subepithelial band almost invisible, until, in those cases in which the two sides of the groove meet and unite, the ciliated epithelium and subepithelial band disappear altogether. Consequently, when this union takes place on the disk, whole arms are entirely devoid of any nervous supply, if we suppose, with Ludwig, that the anti-ambulacral axial cords are not of a nervous nature, and that the "subepithelial bands" are the only nervous structures in the arms. In such cases it would naturally be expected that these arms would be incapable of performing the regular swimming-movements like those in which there is an open ambulacral groove and a subjacent "ambulacral nerve;" but Professor Semper, who has kept *Actinometræ* in his aquaria for weeks together, informs me that he never saw the least trace of any irregularity in the alternating movement of their arms while swimming.

The gradual obliteration of the ambulacral grooves by the approximation and fusion of the elevated folds of perisome at their sides, which may occur to so great an extent in *Actinometra*, is found also at the ends of the arms and pinnules of *Antedon Eschrichtii*. Ludwig states (p. 75) that their terminal segments have no ambulacral groove or tentacles; and he gives a figure of a section through the end of a pinnule (pl. xiii. fig. 12), the ventral surface of which is convex, while there is no ciliated epithelium or subepithelial band (ambulacral nerve), although in the text Ludwig makes no mention of their absence. I have found the gradual obliteration of the groove in these cases to take place in precisely the same manner as in *Actinometra*, the only difference being that the point at which the sides of the groove meet and fuse is much further from the disk in the one case than in the other.

If we suppose, with Ludwig, that the subepithelial band is the sole structure of a nervous nature in the whole Crinoid organization, it is difficult to understand the fact, which Ludwig himself admits (p. 10), that it gives off no branches except those which go to the tentacles. It is true that in the Ophiuridea the ambulacral nerve does give off branches which go to the muscles, besides those proceeding to the tentacles, as described by Lange[1], Teuscher[2], and Simroth[3]; but the researches of the first-mentioned observer render it very doubtful whether the representative in the Ophiuridea of the

[1] "Beitr. z. Anat. und Histiol. d. Asterien und Ophiuren," Morphol. Jahrb. ii. Heft 2, p. 241.
[2] "Beitr. &c., II. Ophiuridæ," Jenais. Zeitsch. x. p. 274.
[3] "Anat. und Schizogonie der *Ophiactis virens*, Sars," Zeitsch. f. wissensch. Zool. xxvii. p. 473

subepithelial band of *Comatula* takes any part in the formation of these branches. Ludwig further admits that he has been quite unable to find any sense-organs at the ends of the arms or pinnules of *Comatula* like those which exist in the Asteridea, and, in discussing the views of Greeff, expresses it as his opinion (p. 78) that "die subepitheliale Faserlage, welche durchsetzt wird von fadenförmigen Verlängerungen des darüber gelegenen Epithels allein den Nerven darstellt." There can, I think, be little doubt that this subepithelial band is of the same nature in the Crinoids and Asterids; and it is therefore very interesting that the nervous nature of this structure in the Asterids has recently been disputed by Lange[1], who regards as nervous only some cellular masses separated from the subepithelial band by a lamella of connective tissue, and projecting into the lumen of the two nerve-canals. He believes these cell masses to swell into a large ganglionic mass beneath the pigment-spot; while, in his opinion, the subepithelial band, together with the ciliated epithelium and the cuticula, constitutes a protecting integumentary layer. Lange finds a corresponding condition in *Ophiura texturata*, in which the radial nervous system is better developed than in the Asterids, and consists of a series of paired ganglionic masses, connected with one another by transverse and longitudinal commissures. On the ventral side of this ganglionated cord is a longitudinal band, which Lange regards as the homologue of the protecting integumentary layer forming the floor of the ambulacral groove of the Asterids, and which, as is universally admitted, corresponds to the subepithelial band, epithelium, and cuticula of the ambulacral grooves of the Crinoids.

Lange's views have been partially accepted by Simroth[2]; but the correctness of them is altogether denied by Teuscher[3], who regards Lange's nervous cell-masses in the Asterids simply as the "geschichtetes Epithel" on the wall of the nerve-canals; while the terminal ganglionic mass under the eye-spot described by Lange is represented by Teuscher (pl. xix. fig. 22) simply as a "bindegewebiges Polster." Ludwig[4], too, speaks of the nervous cell masses as local thickenings of the epithelium of the nerve-canals, which are not present in every species. This is naturally a very strong argument against Lange's views; but Ludwig omits to apply similar reasoning to his own opinions regarding the Crinoid nerves. The subepithelial bands (*his* nerves) are not constant in every arm of many species of *Actimometra*. Still less do Teuscher and Lange agree about the nervous system of the Ophiurids; Lange's ganglionic masses are described as artificial by Teuscher, who, as in the Asterids, regards as the nerve only the fibrillar structure representing the subepithelial band of *Comatula*.

The question is still an open one; and it is therefore of no slight interest to learn that the supposed ambulacral nerve, or subepithelial fibrillar band, is not always present in the arms of *Comatula*, and that even when it exists it is certainly not motor in function, even if it be a nerve at all[5].

[1] Morph. Jahrb. ii. 274.

[2] Zeitsch. f. wiss. Zool. xxvii. pp. 556–560.

[3] "Beitr. &c., III. Asteriden," Jen. ertsch. x. p. 513.

[4] "Beiträge zur Anatomie der Asteriden," Zeitschr. für wiss. Zool. xxx. p. 191.

[5] It is worth noticing here that the "ambulacral nerve" of *Comatula* must be derived either from the mesoblast or from the hypoblast of the embryo. It is developed immediately beneath the tentacular atrium of the pentacrinoid larva, which Götte has shown to be the most anterior portion of the left peritoneal sac. This is lined by hypoblast,

(§ 25) We have seen in sect. 22 that in certain of the arms of *Actinometra* the water-vessels are simple tubes, like the integumentary water-vessels of the *Molpadidæ*, and are not in connexion with any tentacular apparatus. Whether the mouth be radial or interradial, the non-tentaculiferous arms are invariably the aboral ones; so that in the latter case they belong to the trivium (Pl. I. figs. 6–15), and in the former to the bivium (Pl. I. fig. 5)[1]. This last, however, is not always the case; for I have a specimen of *Act. solaris* in which an anterior arm (C_1) of one of the two ambulacra of the bivium is tentaculiferous, while a posterior arm (E_1) in the trivium has no tentacles; it is nevertheless aboral in position, as may be seen from Pl. I. figs. 2, 5.

In only one individual of *Act. polymorpha* (Pl. I. fig. 15) have I found a non-tentaculiferous arm on one of the two anterior radii (A, B.); but this was a very remarkable case. Out of 31 arms, 19 were entirely devoid of a tentacular apparatus; and in 15 of these the fusion of the two sides of the ambulacral grooves had taken place either on the disk or in the basal arm-segments, so that an "ambulacral nerve" was wanting in nearly half the total number of arms. In the other four non-tentaculiferous arms the groove remained open for a short distance, and then closed in the manner above described. Three of these four arms constituted the anterior division (E_2) of the left lateral ambulacrum; but the fourth was the first arm of the left anterior ambulacrum (A_1), and was borne upon the same palmar axillary as a well-developed ordinary tentaculiferous arm. Pieces of the middle portions of these two arms are represented in Pl. II. figs. 3 and 5, and their terminations in figs. 4 and 6. With this exception, I have invariably found the non-tentaculiferous arms on the aboral side of the disk; their number and distribution, however, vary extremely, not only in different species but in different individuals of the same species.

Thus in *Act. polymorpha*, in Plate II. fig. 8, the former is as low as $\frac{6}{20}$ of the total number of arms, while in fig. 15 it reaches $\frac{19}{31}$. Even in two individuals with the same number of arms it may be different; thus in figs. 8 and 9 it is $\frac{6}{20}$ and $\frac{11}{20}$ respectively, and in figs. 12, 13 it is $\frac{10}{28}$ and $\frac{15}{28}$. The individual represented in fig. 12 was also remarkable for the fact that one of its aboral arms belonging to the posterior division of the left lateral ambulacrum (E_1) was tentaculiferous, while those on either side of it were not so.

In all the specimens of the type of *Act. polymorpha* which I have examined, and in three of its varieties, of which I have, unfortunately, only single specimens, more or

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and appears to be separated from the hypoblastic epithelium lining the water-vascular ring by a remnant of the mesoblastic tissue which occupied the blastocœl of the Echinopædium. One or other of these two layers, the hypoblast lining the atrium, or the mesoblast between it and the epithelium of the water-vascular ring, must give rise to the "ambulacral nerve," which cannot be in any way derived from the epiblast. I am inclined to believe that the "nerve" is most probably of mesoblastic origin, and that the remainder of the mesoblast (in this position) is converted into the muscular layer of the ventral wall of the water-vascular ring; while the blood-vascular ring is a remnant of the primitive blastocœl. Huxley ('Anatomy of Invertebrata,' p. 559) has suggested a similar origin for the nerve-canals (perihæmal canals, Ludwig) of the Asterids.

[1] In all these figures (Pl. I. figs. 5–16) the tentaculiferous ambulacra are indicated by dark lines, and the non-tentaculiferous grooves by fainter lines.

fewer of the arms have no tentacular apparatus; but in the fourth variety (Pl. I. fig. 16) all the arms are of the usual character, with open ambulacral grooves fringed with crescentic leaves and groups of tentacles. I have found the same variation to occur also in *Act. solaris*. In this case the number of arms is limited to ten, which may be all tentaculiferous, or from one to four of the aboral arms may have no tentacular apparatus.

[*Note.* February 1879.—No less than 23 out of 48 species of *Actinometra* brought home by the 'Challenger' have more or fewer grooveless arms. I have cut sections of these arms in two species, and have obtained the same results as with *Act. polymorpha* and *Act. solaris*. The "ventral nerve" and ambulacral epithelium are conspicuous by their absence, while the axial cords in the skeleton give off branches freely in the centre of each arm-joint, as I have already described for other species, both of *Antedon* and of *Actinometra*. Two points are noteworthy. In one species one of the posterior ambulacra stops quite abruptly on the disk, and the two arms to which it would naturally have gone, with its "nerve," tentacles, &c., receive no branches from any of the adjacent grooves to supply the deficiency. Again, in one of the largest *Comatulæ* I have ever seen (a 'Challenger' specimen from the Philippines) there are more than 100 arms, many of which are both grooveless and nerveless, as I have found from sections. But these abnormal arms are not limited to the hinder part of the disk as is usually the case; for there are several on each radius.]

The distribution of the non-tentaculiferous arms in *Act. polymorpha* varies, like their number, to a very great extent. In any case they always occur on the odd posterior radius, D (Pl. I. fig. 8); when more are developed they may occur on the posterior divisons, C_2 and E_1, of the two lateral radii, C, E; and they may then be called postero-lateral (Pl. I. figs. 6, 12–14); and when the proportion of non-tentaculiferous to tentaculiferous arms becomes very great, more or fewer of the antero-lateral arms, C_1, E_2, belong to the former class (Pl. I. figs. 7, 9–11, 13), while in exceptional cases non-tentaculiferous arms may occur even on the anterior radii (fig. 15, A).

(§ 26) The condition of the ambulacral groove and of the tentacular apparatus is not the only point in which the anterior or oral may differ from the posterior or aboral arms. The former taper very slowly, contain far more segments, and are much longer than the latter, while the form of their terminal portions and of the pinnules which these bear is altogether different (Pl. I. figs. 4, 6). When viewed from the dorsal side (Pl. II. fig. 7) the basal portions of the two kinds of arms are precisely similar; they widen slightly between the first and second syzygia, *i. e.* from the third to the tenth brachial, remaining uniform till the third syzygium on the fourteenth brachial, after which they begin to taper. Up to about the twenty-fifth or thirtieth segment the oral and the aboral arms decrease in width at about the same rate; but from this point onwards there is a great difference between them. The arms borne by the two anterior radii, A and B, taper very slowly, the length of their segments increasing considerably, while the breadth only diminishes very gradually; at the same time the middle and terminal pinnules, in which no genital glands are developed, become very long and filiform, and remain so until the last few segments, when their length suddenly diminishes very considerably (Pl. II. fig. 4).

I have never been able to ascertain what is the precise mode of termination of these anterior arms; even when the arm ends in such a manner that there is no reason to suppose that its terminal segments have been broken off, its few last pinnules appear simply as immature, and the last pair are separated by a delicate prolongation of the arm-stem, on which no pinnules have been as yet developed. Dr. Carpenter[1] has found the same "growing-points" at the ends of the arms of *Ant. rosacea*, all of which are of the same character as the oral tentaculiferous arms of *Actinometra*; and he was never able satisfactorily to determine the normal mode of termination of the arms.

With the posterior arms of *Actinometra*, however, the case is different. From the twenty-fifth segment onwards they taper very rapidly, and instead of reaching a length of 145 millims., as the anterior arms with some 150 segments may do, they have only some 80 segments, and rarely attain a greater length than 60–70 millims.

At the same time their terminal pinnules are little, if at all, longer than those of the middle portion of the arm (Pl. II. figs. 5, 6); and the centre of the dorsal half of each of their segments is occupied by a dark-brown egg-shaped body, of a peculiar cellular nature, which I have reasons for believing to be a sense-organ[2] (Pl. II. fig. 6, *o.b*). These bodies commence to appear in the pinnules at about the beginning of the second third of the length of the posterior arms, and are continued to their extremities. The pinnules of the last few segments decrease very slowly in size; and the arm ends in an axillary segment which bears *two* pinnules of the ordinary character, each provided with the brown ovoid bodies or "sense-organs" (Pl. II. fig. 6, *o.b*).

These bodies, which may occur, though but rarely, on one or more of the anterior tentaculiferous arms, do not exist in all the specimens of *Act. polymorpha* which I have examined. In three out of my eight specimens of the type they are entirely wanting; and they are also absent in all the single specimens of the four varietal forms which I have investigated. I have also failed to find them in the non-tentaculiferous arms of *Act. solaris*[3].

Between these two kinds of arms, the long anterior ones on the radii A, B, with a wide ambulacral groove and a well-developed respiratory apparatus, and the short posterior ones of the radius D with a closed groove and no external respiratory apparatus, all possible forms of transition may occur. As a general rule, more or fewer of the antero-lateral arms, C_1 and E_2, are tentaculiferous; but they never reach such a great length as the anterior arms, and their terminal pinnules are by no means so long and slender. At the same time the postero-lateral arms, C_2 and E_1, although generally non-tentaculiferous, have, except in rare cases, a more or less open groove for the greater part of their length, which, while greater than that of the posterior arms of the radius D, is less than that of the antero-lateral arms of C_1 and E_2; and their pinnules increase slightly in length from the middle till near the end of the arm.

[1] Phil. Trans. 1865, p. 723, plate xxxviii. fig. 4.

[2] Journ. Anat. & Phys. vols. x. xi. *locc. citt.*

[3] Sense organs occur in two of the 'Challenger' species—one from Banda (which is probably the young of *Act. polymorpha*), and one (a new species) from the Admiralty Islands. In both cases they are limited to the hinder arms, some of which are grooved and others not.

The arms of *Act. polymorpha* may thus be roughly classified as follows :—

Anterior, on radii A and B, 120–150 segments. Pinnules increasing in length to the terminal ones, which are very long and slender. Tentaculiferous.

Anterolateral, on C_1 and E_2, 100–120 segments. Terminal pinnules long and slender. Tentaculiferous.

Posterolateral, on C_2 and E_1, 80–100 segments. Terminal pinnules stout, and rather longer than the median ones. Usually have "sense-organs" and narrow ambulacral grooves, but are non-tentaculiferous.

Posterior, on radius D, 60–80 segments. Terminal pinnules stout, but shorter than median ones. Sense-organs. Usually no grooves. Non-tentaculiferous.

Another difference between the anterior and posterior arms is that the genital glands in the latter are far more developed than in the former. Not only is their number greater, although the total number of pinnules on a posterior arm may not be much more than half that of an anterior arm, but they also attain a very much greater size; the basal and median pinnules of an anterior arm being very much less swollen than the corresponding pinnules of a posterior arm. A similar inequality in the development of the genital glands has been noticed by Alex. Agassiz[1] as occurring in the Echini. This difference in length in the anterior and posterior arms of *Act. polymorpha,* and in the character of their terminal pinnules, seems to be to a certain extent dependent upon the condition of the respiratory apparatus occupying their ventral surface. When this is well developed the arm seems to have the power of indefinite growth; for in the single specimen (Pl. I. fig. 16) in which all the thirty-three arms were normal and tentaculiferous as in *Antedon,* there was no very appreciable difference in the lengths of the anterior and posterior arms[2]. The shape of the terminal pinnules, however, was of a slightly different character in the two cases, though the development of the genital glands was about the same; and we have just seen that those arms are the shortest in which the ambulacral groove entirely closes, and the water-vessel is reduced to a simple tube without any lateral tentacular branches, while it is in these arms only that any definite mode of termination is known. This may occur before half the number of segments have been developed which are commonly met with in an anterior tentaculiferous arm.

(§ 27) The ventral surface of some of my specimens of *Act. polymorpha* is marked by small calcareous concretions, somewhat resembling the " blumenartige Knötchen mit mehreren blattartigen Fortsätzen" described by Müller[3] in the Vienna specimen of *Act. solaris.* When present, they are usually scattered around the peristome, and

[1] 'Revision of the Echini,' part iv. pp. 680, 681.

[2] Not only are the arms of different lengths in the 'Challenger' species of *Actinometra,* which have ungrooved hinder arms, but there are three species in which the anterior arms are longest, although all, anterior and posterior alike, are grooved and bear tentacles. In another species the arms are all grooved and all equal in length, but the distribution of the syzygia is quite different in the anterior and posterior arms.

[3] 'Gattung *Comatula,*' p. 12.

disposed along the edges of the primary groove-trunks proceeding from it, and there are generally some upon the sides of the anal tube. They are particularly well developed in the dark variety from Ubay, in which all the arms are tentaculiferous.

(§ 28) The "oral pinnules" of *Act. polymorpha*, those, namely, which arch over the disk so as to protect it, are borne by the second distichals and second palmars when these are present, but in any case upon the second brachials, those of the distichals and palmars being the longest. They are all very long and slender, consisting of some 30 or 40 segments; and their terminal portions exhibit the peculiar characteristic comb made up of processes which rise from the outer margin of the ventral surface of each calcareous segment (Pl. III. fig. 2), just as in *Act. solaris* and *Act. pectinata* (Pl. III. fig. 1). The number of segments on which these processes may be developed varies from 10–12 on a distichal pinnule, to 6–8 on a brachial pinnule; but in cases in which no second distichals or palmars are developed, so that the pinnule on the second brachial is the first of the series, it is much longer than usual, and more of its terminal segments bear the comb-like processes.

The oral pinnules of the dark Ubay variety of *Act. polymorpha* differ considerably from those of the type and of other *Actinometræ*; not only are they much stouter, but their terminal comb is differently constituted (Pl. III. fig. 3). As is usually the case, the lower processes gradually develope themselves from the outer margin of the ventral surface of each calcareous segment; but towards the end of the pinnule they gradually come to rise less and less from the outer margin, and more and more from the median portion of the ventral surface of each segment, until finally, on the last two or three segments, they are developed from the inner margin. Consequently the comb, when viewed from above, is seen not to lie altogether on the outer side of the pinnule, as is usually the case, but to start from the outer side, cross its ventral surface, and finally come to lie on the inner side of each pinnule, *i. e.* on the one nearest the arm.

Both in the type of *Act. polymorpha* and in all the four varieties, the pinnules diminish in length from that of the second distichal (when present) to those borne by the fourth and fifth brachials; that of the sixth brachial is longer, and usually contains well-developed genital gland, so that it is slightly swollen. From this point onwards the pinnules increase in length till about the thirtieth brachial, after which their length and character vary according as the arm is tentaculiferous or non-tentaculiferous.

(§ 29) The dorsal aspect of *Act. polymorpha* differs from that of most *Antedons*, and especially from that of *Ant. rosacea*, in the fact that the plane of the second and third radials, like that of the first, is parallel to the vertical axis of the calyx, and not inclined to it, as in *Antedon*; so that the dorsal surfaces of the whole of the pieces of the calyx lie in one horizontal plane. The centrodorsal piece is circular (Pl. II. figs. 9, 10, *c d*), or pentagonal (fig. 11), and conceals a large portion of the pentagon formed by the first radials, less in young specimens with but a few arms (fig. 9) than in large and full-grown specimens with many arms (Pl. II. figs. 10, 11 & Pl. VI. fig. 2). It is usually a flattened plate with a slight concavity in the centre of its outer surface; and around its margins are disposed some 20 or 25 cirrhi in one row, but with occasional traces of a second, in which the cirrhi alternate in position with those of the first row. The number of segments in each cirrhus is normally from 11 to 14, of which the last forms a recurved claw, while a more or less distinct spine is usually visible upon the dorsal edge of each of the three or four penultimate segments (Pl. III. figs. 8–11).

In Pl. II. fig. 8, is seen an abnormal condition of the centrodorsal piece, which is of an irregular oval form, and so extended as to conceal large portions even of the second radials. These last are usually more or less completely united with one another laterally. The amount of their union is to a certain extent dependent upon the number of arms developed. Thus in the small specimen with only 13 arms, represented in Pl. II. fig. 9, the second radials are not united laterally for more than half their length; in fig. 10 (26 arms) the union is somewhat more complete, and even more so in fig. 8 (28 arms), while in the variety with 39 arms, represented in fig. 11, the second radials are completely and closely united with one another all round. This rule, however, appears to be only a specific one, and not generally applicable to all *Comatulæ*; for in the 80-armed *Phanogenia* the second radials, as figured by Lovén[1], do not appear to be united with one another any more closely than they are in the small 13-armed specimen of *Act. polymorpha* (Pl. II. fig. 9).

In *Act. polymorpha* the two segments (first distichals, palmars, or brachials) borne by any axillary are united to one another laterally to about very much the same extent as the second radials are; *i. e.* when the number of arms is small, their first segments, whether primary, secondary, or tertiary, are not laterally united in pairs with such completeness as when the division of the ten primary arms is carried to any considerable extent (Pl. II. figs. 8–11, d_1, p_1, b_1).

When the arm-division is unequal it is generally carried further in the trivium or posterior radii, C, D, E, than in the two anterior radii, A, B, which form the bivium. This is well seen in Pl. II. fig. 9, in which no distichals are developed on either of the two anterior radii; and again in fig. 10, in which, while distichals are developed all round, the division is carried no further in one of the anterior radii, while in each of the others from one to three palmar series may be developed. In only four normal cases have I found an anterior radius to bear more arms than a posterior one. In each of these the total number of arms was considerable, and one at least of the two posterior radii bore the same number of arms as the abnormal anterior one. Thus, for example, in Pl. II. fig. 11, each of the radii bears eight arms, with the exception of the posterior one (D), on which only seven are developed. This, however, is an abnormal case of fracture of the whole radius between its second and third segments. The new portion is considerably smaller than the old, the proximal articular face of the new axillary being far less wide than the corresponding distal face of the old second radial; while both the distichal series which it bears are imperfect and abnormal, so that the absence of a further division in one of the secondary arms is not particularly remarkable.

(§ 30) The number of arms that may be developed in *Act. polymorpha* is a character

[1] "*Phanogenia*," loc. cit. p. 230.

of extreme variability. In the specimens I have examined it varies from 13 to 39; so that, with one remarkable exception (Pl. II. fig. 8), the ten primary arms do not, at the most, divide more than twice, while in two specimens with 18 and 13 arms respectively two and seven of the primary arms remain undivided. I believe, however, that, as a general rule, an axillary is developed on each primary arm, and that the amount of further division is variable, but that a tertiary division is probably exceptional, so that the number of arms in this species will be found rarely to exceed 40.

It will have been already apparent from the position assigned to *Act. polymorpha* in the classification given in sect. 20, that I consider the typical number of distichals and palmars in this species to be three, of which the second (d_2) bears a long pinnule, while the third or axillary segment ($d\,a$) consists of two primitive segments united by a syzygium. A typical specimen of this condition is seen in Pl. II. fig. 10. Out of the twelve specimens of this species which I have examined, but four others resemble this one in having all their distichal and palmar series regularly developed. In each of the other seven specimens one or more of the distichal or palmar series is irregular, consisting only of two segments, the second of which is axillary without a syzygium. In one very remarkable case, represented in Pl. II. fig. 8, one of the palmar series is reduced to a single segment placed on the distichal axillary, being also itself an axillary bearing the brachials directly on one of its articular surfaces, while on the other are two segments which may be called suprapalmar, of which the second (*sp.a*) is an axillary without a syzygium, and bears two arms.

Excluding this remarkable case, the comparative frequency of the usual variations in the distichal and palmar series in the twelve specimens of *Act. polymorpha* examined by me is seen in the accompanying Table. From this it appears that out of 111 distichal

TABLE I.—Showing the Variations in the Distichal and Palmar Series.

Specimen.	Total number of Arms.	Distichal Series.			Palmar Series.				
						On two distichals.		On three distichals.	
		Total number.	Of three segments.	Of two segments.	Total number.	Of two segments.	Of three segments.	Of two segments.	Of three segments.
I.	13	3	3						
II.	18	8	4	4					
III.	20	10	5	5					
IV.	25	10	10	..	5	..	..	3	2
V.	26	10	10	..	6	..	..	..	6
VI.	28	10	7	3	5	..	..	..	5
VII.	28	10	10	..	8	..	..	1	7
VIII.	31	10	10	..	11	..	..	..	11
Var. 1	20	10	10						
2	29	10	10	..	9	..	..	..	9
3	39	10	8	2	19	2	1	2	14
4	33	10	9	1	13	..	1	1	11
Total....	310	111	96	15	76	2	2	7	65

series 96 were normal, and that out of 76 palmar series 65 were normal, *i. e.* consisted of three segments, of which the second bore a long pinnule, while the third was axillary, with a syzygium. The three forms of variation exhibited by the abnormal palmar series are of considerable interest, because some of them, at least, represent the normal condition of the palmars in other groups of *Actinometræ*. Thus the most frequent one, two palmars on three distichals, is typical for *Act. multifida*, while that of three palmars on two distichals is typical for *Act. rotalaria*. The third variation, two palmars on two distichals, occurs in *Act. tenax*, Ltk., and in a few new 'Challenger' species; and it is typical in several species of *Antedon*—for example, in *Ant. palmata* and *Ant. articulata.* Specimens Nos. II. and III. are remarkable for the fact that the numbers of regular and irregular distichal series are in each case equal to one another; so that a specific diagnosis based upon either of these specimens alone, would, as is evident from the above Table, have been entirely incorrect.

The amount of variation in these characters is so enormously great that only after examination of a considerable number of specimens is it possible to draw conclusions of any value respecting the use which may be made of these characters for systematic purposes. The above Table, however, will, I think, show clearly that I am justified in assuming the normal number of both distichal and palmar segments in this species to be three, of which the second bears a long pinnule, and the third is axillary with a syzygium.

(§ 31) The same variability occurs in the position and distribution of the syzygia in the arms, but, as might be expected from the nature of the case, to an infinitely greater extent. In most of his specific diagnoses Müller gives the position of the first syzygium on the arm and the average number of segments which occur between every two successive syzygia throughout the rest of the arm. Only in a very few cases does he make mention of the position of the second syzygium, which I believe to be a character of nearly or quite as great systematic value as the position of the first; and, owing to its greater constancy, of considerably greater value than the number of segments between every two successive syzygia, which I will call the "syzygial interval." It will be seen from Table I. that the total number of arms in the 12 specimens of *Act. polymorpha* at my disposal reached 310: 11 of these were broken below the third segment; but of the remaining 299, the first syzygium was on the third brachial in 283 cases; and in 156 of these the second syzygium was on the tenth brachial. The irregularities in the position of the first syzygium were limited to three specimens, and, as will be seen from Table II., nearly all confined to one variety.

TABLE II.—Showing Irregularities in the Position of the first Syzygium.

No.	Irregular series of Syzygia.	Type.		Variety. 4.
		III.	VI.	
	Brachials.			
1.	On 4, 9, 13.	..	..	1
2.	4, 10, 14.	..	..	2
3.	5, 13, 16.	1		
4.	6, 10, 14.	..	..	1
5.	9, 13, 17.	..	..	2
6.	10, 14, 16.	..	..	1
7.	10, 14, 18.	1	4	2
8.	10, 14, 19.	..	..	1
	Total	2	4	10=16

In nearly every case the irregularity appears to have been the result of regeneration, the arm having been broken, either in the distichal or in the palmar series, or between the third brachial and the preceding axillary, and a new one developed with an irregular syzygial series; although in many cases similarly regenerated arms of other specimens exhibit perfectly normal series of syzygia. One of these unusual cases, in which there is no syzygium on the third brachial (b_3) and the first syzygium occurs on the tenth segment (b_{10}), which is usually the position of the second syzygium, is seen in Pl. II. fig. 8.

We have seen that when the first syzygium is on the third brachial, the position of the second is in the great majority of cases on the tenth brachial; that is to say, the first syzygial interval is six simple segments, while the second and all the subsequent intervals are, as a general rule, only three simple segments, though the range of variation on either side of this number is very great.

Table III. shows the variations in the positions of the second and third syzygia in all those 283 arms in which the first syzygium is on the third brachial. From the last column of this Table it is evident that in *Act. polymorpha* and its varieties the normal position of the second syzygium is on the tenth brachial, and that in those cases in which it does not occupy this position it is much oftener on the eleventh or twelfth segment than on the eighth and ninth; *i.e.* that variation, when it occurs, is in the direction of increase rather than of decrease in the length of the first interval. This is more clearly seen in Table IV., which shows the number of segments intervening between the first and second syzygia in all the above cases.

TABLE III.—Showing the Variations in the Positions of the second and third Syzygia in the Arms of twelve specimens of *Act. polymorpha.*

No.	Positions of the first three Syzygia.	Type.	Var. 1.	Var. 2.	Var. 3.	Var. 4.	Total.	No. of Variations in the first interval.
	Brachials.							
1.	On 3, 4, 5.	..	..	1	..	..	1	
2.	3, 4, 9.	..	..	..	1	..	1	3
3.	3, 4, 10.	..	..	..	1	..	1	
4.	3, 5, 10.	2	..	..	..	..	2	2
5.	3, 6, 11.	1	..	..	..	..	1	1
6.	3, 7, 11.	..	..	..	2	..	2	2
7.	3, 8, 11.	1	..	..	..	..	1	
8.	3, 8, 12.	1	..	..	2	2	5	8
9.	3, 8, 13.	1	..	..	..	..	1	
10.	3, 8, 14.	1	..	..	..	..	1	
11.	3, 9, 11.	1	..	..	..	..	1	
12.	3, 9, 12.	1	..	..	..	..	1	23
13.	3, 9, 13.	10	..	..	7	3	20	
14.	3, 9, 14.	1	..	..	..	..	1	
15.	3, 10, 12.	1	..	..	..	..	1	
16.	3, 10, 13.	3	1	..	4	..	8	
17.	3, 10, 14.	76	10	23	16	13	138	
18.	3, 10, 15.	..	..	..	1	..	1	156
19.	3, 10, 16.	1	..	1	..	1	3	
20.	3, 10, 17.	..	3	..	1	..	4	
21.	3, 10, 19.	..	..	1	..	..	1	
22.	3, 11, 14.	3	..	..	..	1	4	
23.	3, 11, 15.	33	4	1	3	2	43	50
24.	3, 11, 16.	3	..	..	..	..	3	
25.	3, 12, 14.	1	..	..	..	..	1	
26.	3, 12, 16.	30	1	1	..	..	32	34
27.	3, 12, 18.	1	..	..	..	..	1	
28.	3, 13, 16.	1	..	..	..	..	1	
29.	3, 13, 17.	..	..	..	..	1	1	2
30.	3, 14, 18.	1	1	..	..	..	2	2
	Total number of variations ..	174	20	28	38	23	283	283

TABLE IV.—Showing the Variation in the number of Segments in the first Interval.

No. of Segments.	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	Total.
Type	..	2	1	..	4	13	81	39	32	1	1	174
Var. 1 ...	..	..	..	..	..	..	14	4	1	..	1	20
2 ...	1	..	..	..	..	..	25	1	1	..	..	28
3 ...	2	..	..	2	2	7	22	3	..	..	..	38
4 ...	..	..	..	..	2	3	14	3	..	1	..	23
Total	3	2	1	2	8	23	156	50	34	2	2	283

It is also seen in Table III. that even when the second syzygium is abnormally placed, it is usually the case that the interval between it and the third is the normal one of three simple segments, so that series like 3, 9, 13; 3, 11, 15; and 3, 12, 16, are very common. This is well seen in Table V., which shows clearly that the length of the second interval is normally three segments; that, like the first, it tends to vary in the direction of excess rather than of defect, and that the range of variation in both directions is greater in the varieties than in the type of *Act. polymorpha.*

TABLE V.—Showing the Variation in the number of Segments in the second Interval.

No. of Segments.	0.	1.	2.	3.	4.	5.	6.	8.	Total number of Arms.
Type	..	3	9	151	8	3	..	..	174
Var. 1	..	..	1	16	..	..	3	..	20
2	1	..	..	25	..	1	..	1	28
3	..	..	4	30	2	1	1	..	38
4	..	..	1	21	..	1	..	..	23
Total	1	3	15	243	10	6	4	1	283

After the fourteenth brachial a syzygium usually occurs on every fourth segment; so that the number of segments composing the syzygial interval is normally three. It is, however, very unusual to meet with an arm in which this interval is constant throughout its whole length and does not vary to a greater or less extent. In only seven arms out of the whole number which I have examined have I found this to be the case, together with normal first and second intervals, although twenty-three other arms were regular from the second syzygium onwards. These thirty arms were distributed among five out of the eight specimens of the type, while in none of the other three was the syzygial interval constant throughout the length of any of the arms; the same was the case with the four varietal specimens.

TABLE VI.—Showing the Variations in the Syzygial interval (usually 3 segments) in the Arms of twelve specimens of *Act. polymorpha.*

	Number of Segments in each interval.	Type.	Var. 1.	Var. 2.	Var. 3.	Var. 4.	Total Cases.
1.	0.	7	..	..	..	1	8
2.	0, 0, 0.	3	..	..	..	..	3
3.	0, 2.	1	..	..	..	..	1
4.	1.	11	..	..	..	1	12
5.	1, 1.	2	..	..	..	..	2
6.	1, 1, 2.	1	..	..	..	..	1
7.	1, 1, 5.	1	..	..	..	..	1
8.	1, 2.	5	..	..	..	..	5
9.	1, 2, 2.	2	..	..	..	..	2
10.	1, 4.	1	1	..	1	..	3
11.	1, 11.	..	..	..	1	..	1
12.	2.	109	3	13	10	11	146
13.	2, 0.	1	..	..	1	..	2
14.	2, 1.	3	..	..	..	..	3
15.	2, 1, 1, 2, 2.	1	..	..	..	..	1
16.	2, 1, 4, 2.	1	..	..	..	..	1
17.	2, 2.	31	1	..	..	..	32
18.	2, 2, 0, 2.	1	..	..	..	..	1
19.	2, 2, 2.	11	..	..	..	..	11
20.	2, 2, 2, 2.	4	..	..	..	..	4
21.	2, 2, 2, 2, 2.	4	..	..	..	..	4
22.	2, 2, 2, 2, 2, 2, 2.	1	..	..	..	..	1
23.	2, 4.	2	..	..	1	..	3
24.	2, 4, 2.	1	..	..	..	..	1
25.	2, 4, 5, 1.	..	..	..	..	1	1
26.	2, 5.	..	1	..	..	..	1
27.	2, 6.	..	..	..	..	1	1
28.	4.	18	18	15	7	24	82
29.	4, 1, 2, 4.	1	..	..	..	..	1
30.	4, 2.	2	..	..	1	..	3
31.	4, 2, 0.	..	..	..	..	1	1
32.	4, 2, 2, 1, 2.	1	..	..	..	..	1
33.	4, 4.	..	1	..	..	..	1
34.	4, 4, 1, 2.	1	..	..	..	..	1
35.	4, 4, 4.	..	..	..	..	1	1
36.	5.	3	2	1	..	2	8
37.	5, 2.	2	..	..	..	..	2
38.	5, 2, 1.	1	..	..	..	..	1
39.	6.	3	1	..	..	1	5
40.	6, 4.	..	1	..	..	..	1
41.	7.	..	..	1	1	..	2
42.	10.	..	1	..	..	..	1

As might be expected from the nature of the case, the range of variation of the syzygial interval for the whole length of the arms is considerably greater than that of the second interval alone. In the type and in variety 3 it differs also in a tendency to a decrease rather than an increase in the length of the interval, which is more often two segments than four, as is seen from Table VI.; while in the other three varietal specimens the tendency of the variation is to increase in the length of the interval, four segments occurring much more commonly than two. With respect to these varieties, however, it must be remembered that these conclusions are all based upon an examination of single specimens, which, as already mentioned, may in some instances be very misleading.

(§ 32) The colour of *Act. polymorpha* is usually (in spirit-specimens) a yellowish brown, which is much darker in the soft parts of the body than in the elements of the skeleton. In variety 4, from Ubay, the colour is the same as that of the type, but considerably darker, so that the disk appears almost black. In varieties 1 and 2 the colour is rather a greyish brown, which is considerably lighter on the ventral surface of the disk and arms than on the dorsal skeleton; and in variety 3 it is a somewhat reddish brown.

In varieties 2, 3, and 4 the dorsal surface of the skeleton is marked by a median white line, with more or less defined dark borders, which commences on the radials, and extends for some distance onto the arms. Its distinctness varies in different specimens and in different arms of the same specimen; but it is especially well marked in the darkly coloured var. 4, as is seen in Pl. II. fig. 7.

In an adult specimen of *Act. polymorpha* the total diameter, including the arms, is about 200 or 220 millimetres, of which about 20 millims. represents the diameter of the disk alone; but in one young specimen I found these two diameters to measure only 105 and 7 millims. respectively. The three specimens of varieties 2, 3, and 4 were of about the same size as the type, but the single specimen of variety 1 was considerably smaller, its longer diameter being only about 100 millims., and its shorter (that of the disk) about 8 millims. This specimen, however, was, I believe, full-grown; for it had very large and well-developed genital glands; while in the young and small specimen of the type mentioned above, the size of which was about the same as that of variety 1, the genital glands were scarcely developed at all.

(§ 33) The manuscript name of *Act. armata* has been given to the type of *Actinometra* here described, by Professor Semper, on account of the small spines with which the segments of the arms and pinnules are fringed, more especially upon their dorsal and aboral margins. As, however, this character is a very general one among the *Comatulæ*, and as it is by no means so well developed in this type as in many others, I have thought it advisable not to adopt Professor Semper's specific name, "*armata*," more especially as it has been already employed by Pourtales to designate a new American *Antedon*. Under these circumstances, I propose to designate this type as *Act. polymorpha*, having regard to the enormous amount of variation which I have found to exist in nearly all its characters.

I believe it to be very closely allied to, if not actually identical with, the type described as *Alecto parvicirra* by Müller[1], who gave this name to three small spirit-specimens in the Paris Museum, from the voyage of Péron and Lesueur in 1803, which I recently found there under the name of *Comatula simplex*, Mus. Müller's diagnosis of *Alecto parvicirra* was based upon his examination of the three Paris specimens, which all have an excentric mouth and a terminal comb on the oral pinnules, and is exactly applicable to *Act. polymorpha*, except that he describes the pinnules as "ziemlich gleichförmig." In their yellow colour and smaller size (about 100 millims.) these also differ slightly from the type of *Act. polymorpha*; but without a very much closer examination of them than I was able to make, it would be impossible to arrive at a definite conclusion as to the identity or difference of these two species.

The Vavao variety of *Alecto parvicirra* described by Müller occurs in the Paris Museum under the name of *Comatula brevicirra*, Troschel. This specimen differs from *Act. polymorpha* in many subordinate characters, and is not absolutely identical either with the type or with either of the four varietal specimens which I have examined; and I cannot but regard it as representing another of the slight and probably very numerous modifications of this type, of which I think it most likely that Müller's original species, *Alecto parvicirra*, is also a varietal form.

(§ 34) The following diagnosis will, I believe, be found sufficient for the future identification of *Act. polymorpha* and of the four varieties here referred to.

Actinometra polymorpha, n. sp.

Centrodorsal piece. A circular or irregularly pentagonal disk almost completely concealing the first radials. Surface flattened, and slightly concave in the centre.

Cirrhi marginal, 15–25, of 11–14 segments, of which the fifth and sixth are the longest; basal ones thick, and wider than long; remainder taper gradually, and terminal ones are laterally compressed; the last 5 or 6 segments have a small dorsal spine, increasing in distinctness up to the penultimate segment, which bears the terminal claw.

Radials 3, of which the first are barely visible; the second are short, and in the middle of the same height as the first, but somewhat lower at the sides, for nearly the whole length of which they are united to one another in pairs.

Axillary radial pentagonal, about twice as wide as the second, to which it is united by ligaments only.

Arms from 13–40; rays may divide three times. First segments borne by each axillary in contact for nearly their whole side.

Distichals and Palmars. When present, 3; second bears a long pinnule, and is united to the first by ligamentous articulation only. Axillary has a syzygium.

Syzygia. First on third brachial, then an interval of 6 segments to the next, and then a general interval of 3 throughout the arm, variable from 0–6, but usually varying to < 3.

Arms. Anterior arms much longer than the posterior, which are usually non-tentaculiferous. Width increases from 3rd to 10th segment, remains uniform till about the 14th, and then decreases, slowly in the long anterior arms, and rapidly in the short posterior ones. Arm-segments wedge-shaped, slightly overlapping one another, and fringed at the borders with short spines.

Pinnules. The second distichal and the second palmar, when present, bear long pinnules, of which the palmar bears the shorter one; the next is on the second brachial, and still shorter, and the length

[1] 'Gattung *Comatula*,' p. 24.

gradually diminishes to the pinnules of the fourth and fifth brachials, which are the shortest on the whole arm. From the sixth brachial onwards the pinnules are long and stout, gradually increasing in length and thickness to near the middle of the arm; the thickness is greatest in the short posterior arms, in which both length and thickness rapidly decrease from the middle to the end of the arm, while in the long anterior arms the thickness slowly diminishes and the length slightly increases, so that the terminal pinnules are long and slender.

Comb. The last six or eight segments of the distichal, palmar, and first eight or ten brachial pinnules have the outer ventral margin of each calcareous segment produced into a small lancet-shaped process which bends over towards the ventral side, so that the end of the pinnule has a comb-like appearance. Many of the other pinnules till near the end of the arm have similar processes upon their four or five terminal segments.

Disk. Mouth excentric and interradial; posterior ambulacra very indistinct, and often nearly obliterated. Small calcareous concretions occasionally present in the neighbourhood of the peristome and anal tube.

Colour. Yellowish brown to dark brown.

Diameter. About 20 centimetres.

Locality. Bohol.

The following are the points in which the varieties differ from the type as described above:—

Variety 1.

Cirrhi. 25, of 13–15 segments, with terminal claw; spines on dorsal face of terminal segments not very distinct, but the segments are laterally compressed.

Radials. Second radials completely united with one another in pairs.

Arms. 20.

Syzygial interval. Usually 3, but varying from 1–10 segments; generally to >3.

Comb. From 2nd distichal to 6th brachial pinnules, and then, at intervals, to about 20th brachial but no further.

The basal pinnules of the arms have a faint dorsal keel, and the distal ends of their segments are rather wider than the proximal ends.

Diameter. 105 millims.

Colour. Greyish brown.

Locality. Ubay.

Variety 2.

Centrodorsal piece. Small, but rather thick.

Cirrhi. 10, of 11 or 12 segments, with a terminal claw; the fourth and fifth are longest; the spines on the dorsal border begin from the middle segments, and the opposing process on the penultimate segment is well marked.

Radials. Second radials only incompletely united; second and third very convex, and much higher than the first; median dorsal line of skeleton marked by a white line with dark borders, which is lost about the middle of the arms.

Arms. 29.

Syzygial interval. Usually 3, but varying from 1–10 segments; generally to >3.

Comb. Limited to distichal, palmar, and first five brachial pinnules; those of the 6th and next succeeding brachials have a dorsal keel, and the distal ends of their segments are much wider than the proximal ones.

Colour. Greyish brown.

Locality. Cabulan.

Variety 3.

Centrodorsal piece large and thick, with only 3 cirrhus-scars.

Radials. Second radials completely united all round. Centre of dorsal surface of the skeleton, from the centrodorsal till near the end of the arms, marked by a faint white line with dark borders.

Arms. 39.

Syzygial interval. Usually 3, but varying from 1–7 segments; generally to <3.

Comb. On second distichal, palmar, and brachial pinnules, and occasionally also on those of the 3rd–5th brachials, but on no others.

Colour. Reddish brown.

Locality. Bohol.

Variety 4.

Centrodorsal piece large and thick, with only 3 cirrhus-scars.

Radials. Second radials closely united all round. Median white line on dorsal surface of skeleton very marked.

Arms. 33, all tentaculiferous, and tolerably uniform in length and in the character of their pinnules.

Syzygial interval. Usually 3, but varying from 0–6 segments; generally to >3.

Pinnules. Oral pinnules much stouter than in the type; that of third brachial but little shorter than that of second. Comb limited to these and to the distichal and palmar pinnules, and the processes forming it gradually come to rise from the ventral surfaces of the calcareous segments instead of from their outer margins.

Colour. Blackish brown.

Locality. Ubay.

IV. The Skeleton.

(i.) *The Skeleton generally with its Ligaments and Muscles.*

(§ 35) The general structure of the skeleton of *Actinometra*, and of the ligaments and muscles which connect its component pieces, is precisely the same as in *Antedon*; and as this has been already described by Dr. Carpenter[1], there is no need to repeat it here: a few points, however, must be treated somewhat more in detail. The component pieces of the skeleton of *Actinometra*, as of all the other Echinoderms, consist of a calcareous reticulation formed by the calcification of an organic basis of a protoplasmic nature, in which numerous nuclei and pigment-granules are imbedded. This "nuclear tissue," as Simroth[2] has called it, is in the form of a network, around the meshes of which the calcareous material is deposited.

The character of the calcareous reticulation varies greatly in different parts of the skeleton, being much closer at the synostoses and syzygia and at the articular surfaces than in the interior of the segments; and in correspondence with this greater compactness of the calcareous tissue, the organic plexus which forms its basis becomes remarkably modified at these points, as will be seen further on. The various modes of union of the different pieces of the Crinoid skeleton have been closely investigated by Müller and by Dr. Carpenter. The former[3] described the stem-segments of *Pentacrinus* as united to one another in two different ways—(1) by the tendons which traverse the whole

[1] Phil. Trans. *loc. cit.* p. 702. [2] *Op. cit.* p. 433. [3] Bau des *Pentacrinus*, pp. 17–20.

length of the stem, passing through the substance of its various segments, and (2) by the "elastic interarticular substance" between the individual segments.

The substance of these tendons consists of a white fibrillar tissue very like the tendinous tissue of the higher animals; but Müller supposed the elastic interarticular substance to be of a totally different nature, consisting of "lauter senkrecht stehenden Fasersäulchen, die durch Reihen bogenförmiger Schlingen einfacher Fasern verbunden sind," and "diese Schlingen gehen mit den regelmässigsten Arkaden in ganz gleichen Abständen aus einem Fasersäulchen in das andere über." This substance fills up the whole space between the successive stem-segments which is not occupied by the tendons, and is connected in the closest possible manner with the opposed surfaces of every pair of segments, even extending for a short distance into their superficial calcareous tissue. Each of the arcades above mentioned consists of a single primitive fibre, the terminations of which are lost in the "Fasersäulchen;" and the passage of these fibres in loops from one fibrous column to another gives an elasticity to the whole tissue, viz. a power of contraction after lateral displacement, and of extension after vertical compression, although the individual fibres are not elastic in the ordinary sense of the word.

Müller described the basals of *Pentacrinus* as united with the top stem-segments in the same manner as the successive stem-segments with one another, namely, by this elastic interarticular substance, while their sides simply "stossen an einander" (p. 25). This mode of union between the stem-segments was generally called by him a "Nath," or suture; but he sometimes spoke of it as an articulation, though he usually employed this last term only in those cases in which two segments are movable on one another through the intervention of muscles and ligaments which pass between them.

He further described the union between the first radials and the basals of *Pentacrinus* and between the first radials and the centrodorsal piece of *Comatula* as a suture, which name he also gave to the lateral union of the five first radials with one another (pp. 28, 29); but he does not seem to have supposed that in these cases the various elements were connected by the elastic interarticular substance which he found between the likewise suturally united stem-segments. In fact, in speaking of the syzygia, which he called an immovable sutural union of two segments, he said expressly that not only the muscles but also the elastic interarticular substance was absent. On the other hand, the latter is to be found between the segments which are capable of motion upon one another, whether ligaments and muscles be present, as between the first and second radials and between most of the brachials, or ligaments only, as between the first and second brachials and the second and third radials; for Müller described the ligaments connecting two mutually movable segments as having essentially the same structure as the elastic interarticular substance of the stem, except that their surface is plain and not "krausenartig gefaltet" (pp. 30–38).

In those more common cases in which there is a muscular union between two segments, such as the first and second radials, in contact by transverse articular ridges upon their opposed faces (Pl. VII. figs. 1 *b*, 2 *a*, 4 *b*, 5 *a*; *i*), Müller drew no distinction between the pair of ligamentous bundles on the ventral side of the articular ridge, and the single mass which occupies the whole space between the opposed faces on the dorsal side of this ridge, describing them as alike consisting of elastic interarticular substance, the function of which is extensor and antagonistic to the flexor action of the muscles. Dr. Carpenter [1], however, regards the former as interarticular, with the special function of holding the pieces together, but allowing a certain amount of movement between them, while he describes the single dorsal mass as elastic, and as antagonizing by its extensile powers the action of the flexor muscles. Histologically he finds no difference between them, both consisting of minute, straight, and nearly parallel fibres, very much, in fact, like those which Müller described as composing the tendons of the stem of *Pentacrinus*. At their points of attachment to the pieces of the skeleton these fibres pass into their basis substance and become incorporated with it.

The union of the first radials with one another and with the centrodorsal piece, which had been spoken of as sutural by Müller, is described by Dr. Carpenter as "an adhesion of expanded surfaces closely fitted together, and held together by the continuity of their sarcodic basis substance" (p. 704); so that the different elements are cemented together by a "thin layer of sarcodic substance, continuous with that which occupies the meshwork of their own calcareous reticulation." This mode of union may be conveniently described by the word "synostosis," which has been employed by Simroth to designate the mode of union of two faces which "verkitten sich" in the skeleton of the *Ophiuridæ*. It is essentially the same as the syzygial union which occurs between certain pairs of the primitive arm-segments, although differing from it in points of detail.

(§ 36) We have seen that Müller regarded the tendinous tissue of the stem of *Pentacrinus*, and the fibrous ligamentous bundles, or, as he called it, the elastic interarticular substance uniting the movable elements of the skeleton both of *Pentacrinus* and of *Comatula*, as distinct from one another. I believe, however, that they are fundamentally identical, not only with one another, but also with the so-called "cement-substance" between two segments which are united by synostosis. This last consists, in the *Ophiuridæ*, according to Simroth [2], of connective-tissue fibres which lose themselves in the organic basis of the skeleton, and are of the same nature as the substance of the masses of connective tissue uniting two articulating surfaces, both tissues staining deeply with picro-carmine. I find the same to be the case in *Comatula* and *Pentacrinus*. The tendons of the stem of the latter genus, the ligamentous bundles, composed, according to Müller, of elastic interarticular substance, which connect every pair of movable arm-segments, and, lastly, the "cement-substance," uniting the first radials to one another and to the centrodorsal piece, all stain very deeply with picro-carmine, and are of essentially the same histological structure.

Fig. 4, on Plate III., represents a portion of a horizontal section through the suture, or, as I prefer to call it, the synostosis of two of the first radials of *Pentacrinus*. In the immediate neighbourhood of their apposed lateral faces there are none of the nuclei nor pigment-granules which are imbedded so abundantly in the more internal portions of their protoplasmic ground-substance, and the threads of the plexus of which it is composed

[1] Phil. Trans. *loc. cit.* pp. 703–714. [2] *Op. cit.* p. 435.

become excessively attenuated and disposed with great regularity almost parallel to one another. At the same time the meshes of this organic plexus become greatly elongated in the intervals between the parallel threads or fibres, which are connected with one another by very delicate fibrils passing in the form of loops from one fibre to another. These loops, which forcibly recall Müller's description of the arcades connecting the fibrous columns of the elastic interarticular substance in the stem of *Pentacrinus*, are simply the expression of the ends of elongated meshes of the protoplasmic plexus forming the organic basis of the skeleton. In the neighbourhood of each of the two opposed surfaces the fibrous elements of this plexus assume the character of closely placed parallel connective-tissue fibres, with no pigment-granules nor nuclei imbedded in them, but staining deeply with picro-carmine, while the normal protoplasmic basis of the interior part of the calcareous segments is but little affected by this reagent. These fibres pass from the organic basis of the one segment into that of the other so that the two are firmly united, and the superficial denser layer of calcareous tissue is deposited around their ends, which corresponds with Müller's description of the elastic interarticular substance of the stem of *Pentacrinus* as extending for a short distance into the calcareous substance of the opposed faces of the segments. The superficial layer of calcareous reticulation which occupies the small intervals between the ends of the fibres thus becomes extremely close and compact; but the central portion of the fibrous tissue (Pl. III. fig. 4, *L*) does not calcify, remaining as a thin layer of fibrous cement-substance between the two opposed surfaces, precisely like the interarticular substance in the stem of *Pentacrinus*, with which I believe it to be identical. It is, at any rate, of the same nature as the substance of the ligaments connecting the first and second radials, which Müller described as identical with that connecting the stem-segments; for at the angles of the radial pentagon the fibres of the cement-substance connecting the adjacent first radials with one another in pairs pass directly into the fibres of the ligamentous bundles between the first and second radials. These, which are of precisely the same character as the ligamentous bundles between the successive brachial segments, also stain deeply with picro-carmine, and only differ from the cement-substance in the greater length of their fibrous element.

At the points of attachment of the ligaments to the pieces of the skeleton, the meshes of the organic plexus become greatly elongated, and its fibrous bars regularly disposed and connected with one another by loops, as above described. As, however, the distance between the two articulating faces is very much greater than in a synostosis, several of these minute primitive fibrils unite to form one of the larger fibres composing the ligamentous bundle, at the other attachment of which these primitive fibres again separate, become connected with one another by transverse loops, and finally pass into the bars of the protoplasmic plexus forming the ground-substance of the next segment.

(§ 37) I have found the fibres composing the ligamentous bundles between the arm-segments of *Antedon* to terminate in the manner above described for *Pentacrinus*; but in *Act. polymorpha* they do not pass so directly into the organic basis of the segment. At the ends of the ligamentous bundles, where their component fibres begin to break up into primitive fibrils, the latter cross one another in all directions, very much as described by Simroth[1] in *Ophiactis virens*, so as to form a network of delicate threads without any imbedded nuclei, although it may contain pigment-granules; and this network passes very gradually into the nucleated protoplasmic plexus forming the organic basis of the brachial segments (Pl. III. fig. 7, L_1).

The tendons of the stem of *Pentacrinus* are, I believe, of precisely the same character as the ligamentous bundles between the arm-segments, although, of course, enormously longer. They stain deeply with picro-carmine, and are composed of parallel fibres, which may be teased out into very much finer ones, and their upper ends pass into the organic ground-substance of the five basals, precisely in the same manner as the fibres of the arm-ligaments pass into the protoplasmic network composing the organic basis of the successive segments.

In *Pentacrinus Wyville-Thomsoni*, in which the five basals are completely in contact with one another in pairs, the two elements of every pair are united by a synostosis, and the union of the basals with the radial pentagon above them is of the same character. The first radials of *Comatula* are connected with one another and with the centrodorsal piece in the same manner, as is seen in Pl. III. figs. 5, 6, where *L, l* represent the tracts of fibrous tissue connecting the first radials with one another and with the centrodorsal piece respectively. The terminal portions of this fibrous tissue become calcified to form the compact superficial layers of calcareous substance on the apposed faces, while the middle portion remains as the fibrous cement-substance uniting the two calcareous segments, which is thus essentially of a connective-tissue nature.

The mode of union of the segments of the calyx of the Tesselate Crinoids, none of which are connected with one another by a muscular articulation like the first and second radials of *Pentacrinus* and *Comatula*, was most probably a synostosis of the same nature as those just described. The immovable sutural unions between certain of the brachial segments to which Müller gave the name of "syzygia," are, in *Pentacrinus*, of precisely the same nature as the synostoses between the segments of the calyx, the organic basis of the one segment being continuous with that of the other through the fibrous cement-substance, which forms a thin layer between the whole of the two simple opposed surfaces. This was described by Müller[2] as a very delicate membrane, of a different nature from the elastic interarticular substance between the likewise suturally united stem-segments.

In *Comatula*, however, the apposed surfaces of the two elements united by a syzygium are not plain and simple, as in *Pentacrinus* and *Rhizocrinus*[3], but marked by a series of radiating ridges, as in *Apiocrinus obconicus*, Goldf.[4] The ridges of the two surfaces correspond in position, and when the surfaces are in contact are closely applied to one another, and united by fibrous cement-substance as in an ordinary synostosis. The fibrils are very numerous and placed very close to one another, so that the calcareous reticulation forming the ridges is remarkably dense and compact, being formed around the ends of these fibrils where they pass into the organic basis of the segments; and these ridges thus correspond to the whole of the syzygial surfaces in *Pentacrinus* and *Rhizo-*

[1] *Op. cit.* p. 435. [2] Bau des *Pentacrinus*, p. 29. [3] Sars, *loc. cit.* p. 22. [4] Petref. German. Taf. lvii. fig. 5.

crinus. In the intervals between them the organic basis of the one segment is directly continuous with that of the other, little or no fibrous tissue being interposed.

The muscular fibres of *Actinometra* correspond very closely with those of *Antedon*, as described by Dr. Carpenter[1] and Ludwig[2]; their expanded terminations are simply applied to the surfaces of the calcareous segments to which they are attached, not passing into their substance as the ligamentous fibres do (Pl. III. fig. 7, $b\,m_2$), and there is no trace either of a sarcolemma or of transverse striation.

(ii.) *The Dorsal Cirrhi.*

(§ 38) The Dorsal Cirrhi of *Actinometra* do not appear, so far, at least, as my observations have extended, to be developed over such a large surface of the centrodorsal piece as is the case in *Antedon*. In all the specimens which I have examined the cirrhi are limited to its margin, while its central portion is entirely free from them and usually slightly concave. There is generally only one row of these appendages; but small and rudimentary ones may occasionally be found interposed between the large and full-grown ones at the extreme circumference of the plate, thus forming the commencement of a second row. The number of cirrhi existing at any one time upon the plate-like centrodorsal piece of *Act. polymorpha* varies, I believe, between 15 and 20. Three or, in large specimens (Pl. VI. figs. 1, 2), four are attached on each side of its more or less distinctly pentagonal margin, while in var. 1 (Pl. VI. fig. 14), and in one specimen of the type (fig. 7), the total number reached 25. In var. 2 (fig. 16) there are only 10; while in vars. 3 (fig. 20) and 4 there is no evidence, in the single specimens which I have examined, of the existence of more than three perfect cirrhi in the adult state, as there are no sockets around the margins of the centrodorsal plate for the attachment of a larger number; though there may be minute openings here and there, which appear to have corresponded with the central canals of lost cirrhi, the sockets of which have been obliterated by a later calcareous deposit.

It is not a little singular that the dorsal cirrhi of *Act. polymorpha*, like the centrodorsal piece which bears them, should exhibit such a very slight range of variation, not only in size but also in number (the three varieties just mentioned of course excepted); for in nearly every other part of the skeleton the range of variation is very great. In *Antedon rosacea* the reverse appears to be the case; for the composition of the skeleton is fairly constant in its simplicity, but the cirrhi vary considerably both in number and in size.

In a fully developed cirrhus of *Act. polymorpha* (Pl. III. fig. 8 a) the number of segments varies from 11–14, being usually 12 or 13, the last of which is in the form of a strong sharp claw. This is attached by simple suture to the penultimate segment, which is prolonged at the base of the claw into a short opposing process on its concave or aboral margin.

The diameter of the basal segment somewhat exceeds its length; but in the second and third segments this disproportion between the length and breadth is reduced, and in the fourth it becomes reversed, the length of this segment being slightly greater than its

[1] Phil. Trans. *loc. cit.* p. 704. [2] Beiträge &c. *loc. cit.* p. 40.

diameter. In the fifth and sixth the proportion between the length and breadth reaches 3 : 2; and a very slight degree of lateral compression is visible in the latter segment, while the fifth, like the four basal segments, is cylindrical, or nearly so. These are the two longest segments of the cirrhus; and from this point onwards the length of the segments gradually decreases, until in the tenth and following segments it becomes again less than the dorso-ventral diameter. At the same time the transverse diameter, which in the first five cylindrical segments is equal to the dorso-ventral diameter, undergoes in the seventh and eighth segments a sudden decrease. A faint indication of this is seen in the sixth segment, and it is continued on to the end of the cirrhus, so that its terminal portion exhibits a considerable degree of lateral compression. In correspondence with this, a small spine gradually developes itself on the dorsal margins of the sixth and successive segments, on which it becomes progressively more and more marked, until in the penultimate segment, *i. e.* the last one before the claw, it becomes the short pointed opposing process above mentioned. This series of small spines, like the single penultimate opposing process of the cirrhi of *Ant. rosacea*, seems to be characteristic of those cirrhi only which have reached their full development; for scarcely any trace of it is visible in the still immature cirrhus represented in Pl. III. fig. 8 c. Although its penultimate segment shows a faint indication of an opposing process, the dorsal margins of the segments immediately preceding it are almost, if not quite, even.

The segments of this cirrhus, although of the normal proportions, are not so large as those of an adult cirrhus, and (counting the terminal claw) are 14 in number, the first seven of which precisely resemble those of the cirrhus represented in Pl. III. fig. 8 a, with 12 segments and a claw, so that the extra one in the former case would appear to be interpolated between the middle and end of the cirrhus. As in *Ant. rosacea*, and for precisely the same reason, greater facility of flexure, the ligamentous substance between the terminal segments is thicker on the aboral side than on the oral (Pl. III. fig. 9 b), while in the more cylindrical segments of the basal half of the cirrhus the ligamentous substance is tolerably equally developed on both sides (fig. 9 a). In correspondence with this, the canal (*c c′*) which occupies the centre, or nearly so, of the circular opposed faces of the basal segments (fig. 9 a), lies in the laterally compressed terminal segments much nearer to the oral side of the oval articular faces, more than half of which is occupied by the large fossa for the lodgment of the aboral interarticular ligament (fig. 9 b). The opening of the central canal (*c c′*) is surrounded in each case by a more or less prominent articular surface.

(§ 39) Both the single specimens of Varieties 3 and 4 of *Act. polymorpha* which I have been able to examine had unfortunately lost all their few cirrhi; but in Var. 1 twenty-five still remained attached to the centro-dorsal piece; most of these are fully developed, and present some slight differences from those of the type (Pl. III. fig. 11). Not only is the number of segments greater, varying usually from 13 to 15, besides the terminal claw, but they also differ considerably in their relative proportions; for in the type the fifth and sixth segments are the longest, while in Var. 1 there is less difference between them and the fourth and seventh in this respect. The lateral compression, which is not visible till the eighth segment, becomes somewhat marked towards the end of the cirrhus, which is more distinctly flattened than in the type, although the small opposing spines on the dorsal margins do not appear at all until the three or four penultimate segments; and even on these they are but slightly developed.

In Var. 2 there are only ten cirrhus-sockets around the margin of the pentagonal centrodorsal plate, two on each of its sides, and placed close to the angles (Pl. VI. fig. 16). The number of segments in each cirrhus is eleven or twelve besides the terminal claw (Pl. III. fig. 10), and the width of the two basal segments somewhat exceeds their length. In the third the length and breadth are nearly equal, but in the fourth and fifth, which are the two longest segments of the cirrhus, the proportion between them is as about 4 to 3. The sixth segment is slightly shorter than the fourth, and from this point to the end of the cirrhus the length of the segments gradually decreases, while at the same time they exhibit a slight degree of lateral compression. The dorsal spine, the first indication of which is seen in the fifth and sixth segments, becomes very marked indeed towards the end of the cirrhus, and develops in the penultimate segment into a stout opposing process.

(§ 40) The development of the cirrhi of *Act. polymorpha* seems to take place somewhat differently from their development in *Ant. rosacea* as described by Dr. Carpenter [1]. In the latter species the individual segments usually present all the characters of maturity from a very early date, viz. the relative proportions in the length and breadth of the segments, the bevelling off of the opposed faces on the aboral side, and the development of the opposing process on the penultimate segment. But in some rare cases, even after the cirrhus has attained a considerable size and has the normal number of segments, the latter are of a very rudimentary character; their basal segments are the longest, and the following ones rapidly decrease in diameter, so that the whole cirrhus tapers considerably from its base to its point. This condition gradually becomes less and less marked as the segments increase in size, and their opposed faces become bevelled off towards the aboral side, so that the cirrhus ultimately acquires all the characters of maturity.

This mode of development, which is the exception in *Ant. rosacea*, seems to be the rule in *Act. polymorpha*. All the very young cirrhi, both of the type and of Varieties 1 and 2, which I have met with, taper rapidly from the base to the apex; and while the four or five basal segments exhibit from a very early period the same proportion between length and diameter as is seen in a completely developed cirrhus, the following ones are still in a very rudimentary condition. The sixth segment, instead of being as long as the fifth, is much shorter; the seventh is still shorter and more slender, while the terminal segments are little more than a succession of small disks ending in a small and very rudimentary claw (Pl. III. fig. 8 b). They are thus not only of the smallest dimensions, but have a much more immature appearance than the basal segments; and it would therefore seem that the augmentation in the number of segments is effected by the interpolation of new segments, not at the base, as is usually the case in *Ant rosacea*, but between the middle segments and the terminal claw.

[1] Phil. Trans. *loc. cit.* p. 711.

The fact already mentioned (sect. 38), that in two cirrhi in which the number of segments is different, the character of the first six or seven is the same, would seem to point to the same conclusion.

(iii.) *The Centrodorsal Plate.*

(§ 41) In all the *Actinometræ* with which I am acquainted, the external appearance of the "Knopf," or centrodorsal piece, is very characteristic. Like the cirrhi which it bears, it is far more constant throughout a considerable range of species from very various localities, than it appears to be in the individual members of a single species, both of the European and of some of the foreign *Antedons*, even when existing in the same locality.

Thus, for example, the centrodorsal piece of *Ant. celtica* may either be very shallow, flattened, and bluntly rounded off at the base, where it was originally united to the joint of the stem next beneath it, with only two rows of sockets (*U*) for the attachment of the cirrhi (Pl. IV. fig. 1); or it may be deep and nearly hemispherical, with three or four alternating rows of cirrhus-sockets, and terminating inferiorly in a flattened circular or rudely pentagonal base (fig. 6); or, finally, it may have the form of a five-sided pyramid, the apex of which is directed downwards and very slightly truncated, while the sides bear three or four alternating rows of indistinct cirrhus-sockets (Pl. IV. fig. 8). This last character indicates that the animal had attained a considerable age; and as all the specimens of this kind which I have seen have been smaller than normal specimens of *Ant. celtica*, and exhibit slight differences from them in the characters of other parts of the skeleton, I am disposed to regard them as dwarfed varietal forms rather than as young and incompletely developed individuals of the ordinary type.

Again, of the two specimens of *Ant. macrocnema*, Val., in the Paris Museum, both of which were brought from New Holland by Quoy and Gaimard in 1829, one has a large and hemispherical centrodorsal piece, while in the other it is a short pentagonal or nearly circular column, on which the cirrhi are disposed in three or four alternating rows.

These instances, which might be greatly multiplied, suffice to show that the centrodorsal piece of *Antedon* may vary very considerably in its external appearance. In *Actinometra*, so far as my experience goes, it is almost invariably a flattened circular, or rudely pentagonal disk, somewhat hollowed in the centre of its dorsal surface, and with low sloping sides marked out into distinct sockets for the articulation of the cirrhi (Pl. V. figs. 1, 6, 15, and Pl. VI. figs. 1, 2, 7, 14, 16, 20). It generally conceals more or less of the first radials which rest upon it (Pl. II. figs. 9–11, *c d*), but it may sometimes be very irregularly extended so as to conceal a considerable part of one or more of the second radials (Pl. II. fig. 8, *c d*).

As a general rule, only one row of cirrhus-sockets can be traced; but in the large *Act. robusta* (Pl. V. fig. 15) I have found two alternating rows of sockets to be distinctly visible, and even traces of a third row, so that the dorsal surface of the plate becomes slightly convex, though by no means to the same extent as in most *Antedons*. In fact, the flattened plate-like condition of the centrodorsal piece, and the existence upon it of only one or two whorls of marginal cirrhi, seem to be very characteristic of *Actinometra*; and it would be almost possible to distinguish the *Antedons* from the *Actinometræ* among the *Comatulæ* described in Müller's memoir, by simply referring to his descriptions of the "Knopf."

When the centrodorsal is viewed *in situ*, with all the cirrhi attached around its sides, its central flattened surface appears almost circular; but when the cirrhi are removed, so as to expose the low and more or less sloping sides to which they are attached, the outer margin of the plate is seen to have a distinctly pentagonal form. This is well seen in the large *Act. robusta* (Pl. V. fig. 15), with its three rows of cirrhus-sockets; but in *Act. solaris* (Pl. V. fig. 1) the angles of the pentagon are more rounded off, and there is only one row, a complete one, however, of cirrhus-sockets, while the plate itself is of a considerable diameter, so as entirely to conceal the first radials.

In a variety of this species, which I believe to be identical with the *Act. pectinata* of Retzius and Müller, the diameter of the centrodorsal (Pl. V. fig. 6) is very slight, so that the greater part of the superjacent radial pentagon is visible outside its pentagonal margin; and there are only ten distinct cirrhus-sockets, two at each angle, though one of the angles (the upper one in the figure) is marked by the presence of a third socket, which either indicates the commencement of a second row of cirrhi, or, and more probably, the incomplete obliteration of a pre-existing row.

In *Act. polymorpha* the angles of the pentagonal centrodorsal plate, the diameter of which varies from 3 to 5 millims., are sharp and distinct (Pl. VI. fig. 2); in varieties 3 (fig. 20) and 4, the dorsal and ventral surfaces almost meet at the edge of the plate, which is very slightly truncated, and marked in three places by the large sockets (*U*) for the attachment of the few remaining cirrhi, while other small openings indicate the former existence of others which have been since lost.

In var. 2 (Pl. VI. fig. 16) the diameter of the centrodorsal plate is very small, as in *Act. pectinata* (Pl. V. fig. 6); and, also as in this species, it normally bears ten cirrhi, two at each angle. The sockets for the cirrhi are, however, but slightly marked, so that the edge of the plate is but little truncated, and it can hardly be said to have distinct sides as in *Act. solaris* (Pl. V. fig. 1).

In the type, on the other hand (Pl. VI. figs. 1, 2, 7), and more especially in var. 1 (fig. 14), in which there are 25 cirrhi, the edge of the plate where the dorsal surface passes over into the ventral is obliquely truncated, so that the plate has distinct sides, which are marked by numerous cirrhus-sockets, as in *Act. solaris* (Pl. V. fig. 1). Towards the ventral surface the angles of the pentagonal margin of the plate are prolonged into five short processes (Pl. VI. fig. 14, *t*), each situated between a pair of cirrhus-sockets (*U*). Their distinctness varies in different individuals; they are especially marked in var. 1 (fig. 14), and in that specimen of the type which resembles it in having 25 cirrhi (Pl. VI. fig. 7), and they are best seen after removal of the centrodorsal plate from the radial pentagon which rests upon it. They exist also in the other varieties of *Act. polymorpha* (Pl. VI. figs. 16, 20), though they are not so distinctly visible externally, owing to the greater extension of the dorsal surface of the plate than is found in the type and in var. 1, since it is not reduced in size by the truncation of its edges, as is the case in these forms.

(§ 42) The meaning of these processes becomes apparent when we examine the ventral or superior surface of the centrodorsal plate which bears the superjacent radial pentagon. Its condition in *Act. polymorpha* is rather complicated, and will be better understood after an examination of the simpler forms of this surface presented by other species of *Comatula*.

In the large variety of *Ant. celtica*, the cavity of the centrodorsal piece (Pl. IV. fig. 2, *cd.c*) is very deep, and its opening on the flattened ventral surface has a circular or somewhat pentagonal form. Between the angles of this internal pentagon and those of the outer more distinctly pentagonal margin of the piece run five slight ridges or elevations (*i.e*). In the intervening radial areas (*r.ar*), between these ridges the surface is somewhat depressed, so as to receive the convexities of the dorsal surfaces of the first radials that rest upon it, while the five ridges correspond with five slight furrows marking the lines of junction of these surfaces on the dorsal aspect of the radial pentagon (Pl. IV. fig. 3), and are therefore interradial in position.

In *Ant. celtica* these ridges are tolerably uniform in width throughout their whole course; but in *Ant. rosacea* (Pl. IV. fig. 15) they are considerably wider at their internal or central ends than they are towards the external pentagonal margin of the piece, so that they have an elongated triangular form. From the base of each triangle a shallow depression extends a little way towards its apex, cut out along the median line of the ridge; but it soon becomes obliterated by the gradual approximation of its two sides, which meet and form a simple ridge, like that of *Ant. celtica* (Pl. IV. fig. 2), extending outwards to the margin of the plate.

The central ends of the radial areas into which the ventral surface of the plate is divided are marked in *Ant. rosacea* by five shallow depressions (Pl. IV. fig. 15, *q*), placed close to the margin of the internal cavity, which bends somewhat inwards at these points. These depressions correspond in position with five large radial openings on the dorsal surface of the pentagonal base of the calyx (Pl. IV. fig. 16, *Q*), and receive the blind ends of five diverticula of the body-cavity, which are enclosed between the five radial spout-like processes of the rosette (Pl. IV. figs. 13, 16, *p*) and the internal faces of the first radials. They are, however, occasionally absent in *Ant. rosacea*, while, on the other hand, traces of them may occur in *Ant. celtica*. In fact, the differences which I have described above in the appearance of the ventral surface of the centrodorsal piece of these two species must not be regarded as representing more than two extreme variations of one and the same type.

(§ 43) We shall now be able to understand the meaning of the short processes (*t*) above mentioned, which are seen projecting from the angles of the centrodorsal plate of *Act. polymorpha*, when viewed from below. It will be best to begin with the examination of the ventral surface of the centrodorsal piece of variety 1 (Pl. VI. fig. 15), in which they are more distinctly marked than in the type. This surface rises slightly from the circumference towards the centre, which is occupied by the opening of a shallow cavity, the centrodorsal cœlom (*cd.c*), the diameter of which is rather less than one third of the total diameter of the plate. The floor of this cavity is marked by minute punctations (*u*), which are the internal orifices of canals proceeding from it towards the dorsal surface of the plate. They originally opened externally on the summits of the small tubercles occupying the centres of the sockets for the articulation of the first developed cirrhi in the young animal; but their openings have gradually become obliterated by the deposit of new material upon the central portion of the external surface of the plate, as described by Dr. Carpenter[1] in *Antedon rosacea*. This is accompanied by the continual removal of old material from the internal surface, so that the minute openings (Pl. IV. fig. 15, *u*) seen on the central part of the floor of the internal cavity of the centrodorsal piece are the original external openings of the first developed canals, which have subsequently become closed externally by the new material deposited upon the central part of the dorsal surface. The internal openings of the canals proceeding to the last developed cirrhi are much larger, and placed more towards the periphery of the floor of the cavity. Similarly in *Actinometra polymorpha*, the internal openings of the canals proceeding to the existing marginal cirrhi on the plate-like centrodorsal piece are placed under its projecting rim, so as not to be visible from above. There are usually one or two large openings under the central margins of each of the radial areas (Pl. VI. figs. 3, 8, 10, 15, 17, 21, *r.ar*), and the canals which proceed outwards from these internal openings break up into five branches, one of which reaches the summit of each of the small tubercles occupying the centres of the five cirrhus-sockets, which are placed along the outer or peripheral margin of each of the corresponding radial areas (Pl. VI. figs. 1, 2, 7, 14, 16, 20, *U*). These canals enclose the axial cords of the cirrhi (Pl. VIII. figs. 1, 3, 4, 5, 6, 8, *n.c*), which proceed from the fibrillar envelope of the quinquelocular organ contained in the cavity of the centrodorsal plate (Pl. VIII. figs. 1, 2, 3, 7, *N*), and surround the cirrhus vessels arising from its chambers (figs. 2, 3, 7, *ch*), from each of which there arises a single trunk[2], dividing, sooner or later, into branches for the individual cirrhi. In the specimen of var. 1 represented in Pl. VI. fig. 15, the division is not completed within the cavity of the centrodorsal plate, as two or, sometimes, even only one aperture can be seen under the inner margin of each of the radial areas, so that the primary trunk enters the substance of the plate, and there divides into the five branches for the cirrhi placed on the outer margin of each radial area.

The rim of the cavity of the centrodorsal plate of *Actinometra polymorpha*, var. 1 (Pl. VI. fig. 15, *cd.c*), is ten-sided, or nearly circular, and is not marked by shallow radial depressions, like those described above in *Ant. rosacea* (Pl. IV. fig. 15, *q*). The radial areas rise very slightly from their peripheral to their central margins, and are marked by various indistinct ridges and furrows. Their sides rise towards the five inter-radial elevations, which, though not very much raised above the general surface of the plate, are nevertheless very distinct; for they are wide and marked by shallow grooves

[1] Phil. Trans. *loc. cit.* pp. 742, 743.

[2] This is in precise accordance with the origin of the vessels proceeding to the cirrhi which are borne on the stem of *Pentacrinus*. At every nodal segment the five chambers which are placed radially around the central axis of the stem enlarge slightly, and each gives off a single vessel to one of the five cirrhi.

(Pl. VI. fig. 15, *b.g*), which occupy the greater part of their width, so that the simple ridge, as seen in *Ant. celtica* (Pl. IV. fig. 2, *i.e*), is here represented by the two sides of the groove which is cut out along its median line. In *Ant. rosacea* (Pl. IV. fig. 15), as we have already seen, these sides meet at a very short distance from the central end of the groove so as to obliterate it. In this form, however, they approach one another very gradually, and only just meet within the margin of the plate; but the ridge formed by their fusion does not end here as in *Ant. rosacea*, for it is continued a short distance beyond the general surface of the plate, so as to appear as a short process (*t*) extending outwards from the angle between two sides of its external pentagonal margin. Consequently these five short processes appear on the dorsal aspect of the plate, prolonging its angles outwards, as we have seen in sect. 41 (Pl. VI. fig. 14, *t*).

(§ 44) The grooves (*b.g*) which are thus cut out along the median line of the interradial elevations on the ventral surface of the centrodorsal plate of *Actinometra* are of no little importance; for there lie in them, as will be seen further on, the five rays of the basal star (Pl. VI. fig. 13, *S*), which is in close connexion with the dorsal surface of the radial pentagon; they may therefore be called the "basal grooves" (*b.g*).

As a general rule, these interradial elevations and the basal grooves are, like the rays of the basal star, entirely devoid of pigment, which is, however, very abundant in the organic basis of the calcareous reticulation composing the rest of the ventral surface of the plate; so that when this is first exposed by the removal of the centrodorsal from the dorsal surface of the radial pentagon which rests upon it, five white rays are visible on a dark background. Unless the plate is immediately removed from the alkaline solution used to effect its separation, this distinction in colour between the radial and the interradial portions of its ventral surface rapidly disappears, owing to the destruction of the pigments contained in the former.

The development of these basal grooves is not only different in the type and in all the varieties of *Act. polymorpha*, but it differs in different individuals of the type, and even to a certain extent in the same individual.

In the specimen of the type represented in Pl. VI. figs. 7, 8, which, like variety 1, had 25 cirrhi, two only of the basal grooves are seen; for the other three are occupied by the rays of the basal star (fig. 8, *S*), which have become detached from the rest of the star and from the first radials with which they were connected. But even these two grooves do not resemble one another; one extends almost to the margin of the plate, beyond which the interradial ridge formed by the union of its sides is continued as a short process (*t*), just as in var. 1 (fig. 15). The other open groove, however, terminates very soon, as its sides, widely separated at its central end, bend sharply towards one another, and meet some distance within the margin of the plate, to which the ridge formed by their union does not extend, for it terminates abruptly in a blind and rounded extremity.

In variety 1 (Pl. VI. fig. 15) the basal grooves (*b.g*) are narrow, and after increasing a little at first, diminish gradually in width from their central to their peripheral ends; but in the specimen of the type (fig. 8) they are much wider in proportion to their length, and the width increases slightly from their base to about the middle of their course, so as to give a leaf-like appearance to the rays of the non-pigmented interradial star on the ventral surface of the centrodorsal plate.

In another specimen of the type, however (Pl. VI. fig. 3), the sides of the narrow basal grooves are almost parallel, and in every case meet at some distance within the margin of the plate, while the interradial ridges resulting from their union scarcely extend at all beyond the angles of the external pentagon.

Lastly, in the monstrosity represented in Pl. VI. fig. 10, the dorsal aspect of which is seen in Pl. II. fig. 8, both ridges and grooves are extremely indistinct, and in no case reach the outer margin of the plate; while the margin of the internal cavity is markedly pentagonal in form, and not ten-sided nor circular, as is the case where there are five distinct interradial elevations alternating with the five radial areas (Pl. VI. figs. 3, 8, 15); and it does not project inwards so far as to conceal all the openings (*u*) of the canals leading to the marginal cirrhus-sockets, as is the case in the other two specimens of the type (figs. 3, 8) and in var. 1 (fig. 15).

In all these three specimens of the type the ventral surface of the centrodorsal plate is not nearly so flattened as in var. 1, but rises very distinctly between its external and its internal margins, while the radial areas are marked in the same way by various indistinctly marked radiating ridges and furrows; though as the floor of the central cavity is also somewhat thicker, its depth is but little if at all greater. The same is the case in the other three varieties, in each of which the basal grooves differ slightly in form from one another and from the type. In every case they are widest about the middle of their length, as in one of the specimens of the type (Pl. VI. fig. 8, *b.g*); this is most marked in var. 3 (fig. 21), and least in var. 2 (fig. 17). They reach almost, if not quite, to the margin of the plate, though the ridges formed by the union of their sides extend but little if at all beyond it, except in var. 3 (figs. 20 & 21), in which two of the angles of the external pentagon are marked by traces of the small processes (*t*) so distinctly seen in var. 1 (figs. 14, 15). In this variety the course of the interradial ridges is indistinctly visible on the dorsal surface of the plate (fig. 20), which is slightly hollowed in the centre. The floor of the central cavity is, however, very thick and solid, and its middle portion presents no trace whatever of any perforations for the canals of preexisting cirrhi, though those proceeding to the three marginal cirrhus-sockets are just visible under the projecting lip (fig. 21, *u*), which conceals several others. These indicate that more cirrhi either have been or would have been developed had the animal lived longer, their external openings having been obliterated in the former case (the more probable one) and not yet formed in the latter.

(§ 45) In *Act. solaris* (Pl. V. fig. 2) the ventral surface of the plate-like centrodorsal piece is very nearly flat, as in *Ant. rosacea* (Pl. IV. fig. 15) and in *Act. polymorpha*, var. 1 (Pl. VI. fig. 15), rising but slightly from the circumference towards the centre, and marked by five interradial elevations, along the top of each of which runs a long and narrow basal groove (*b.g*). Its width is tolerably uniform from its base until near its end, where its sides suddenly approach one another, and meet at a little distance within the margin of the plate, where the ridge formed by their union also ceases without extending outwards beyond the general surface of the plate. The same is the case in the large *Act. robusta* (Pl. V. fig. 14), in which three of the basal furrows are widest at their central ends, and consequently triangular, while the others are somewhat irregular in shape.

In both these specimens numerous small openings are visible on the floor of the central cavity of the centrodorsal piece, but the principal ones leading to the marginal cirrhus-sockets are concealed under its projecting lip. In the small centrodorsal piece of *Act. pectinata*, however, these last are very distinct (Pl. V. fig. 7, *u*) and correspond in number to the eleven external cirrhus-sockets (Pl. V. fig. 6, *U*), so that the five principal cirrhus-vessels leaving the quinquelocular organ would seem to divide at once within the cavity of the centrodorsal piece, and not within the substance of its walls, as is the case in *Act. polymorpha*. The ventral surface of the centrodorsal plate of *Act. pectinata* (Pl. V. fig. 7) is by no means so flattened as in the closely allied *Act. solaris* (fig. 2), but rises considerably from the circumference towards the centre, and the interradial ridges are well marked. The basal grooves (*b.g*) are narrow and parallel-sided, and terminate within the margins of the plate, beyond which the interradial ridges are not continued, so that there are none of the small processes extending outwards from the angles as in some forms of *Act. polymorpha*. The median line of each of the radial areas is occupied by a deep depression, which is particularly distinct at its central end. A similar depression, though developed to a less extent, exists also in *Act. polymorpha*, Var. 2 (Pl. VI. fig. 17, *r.ar*).

(§ 46) Nearly all the observers who have studied *Comatula* have regarded the "Knopf," or centrodorsal piece, as of essentially the same nature as the stem of the stalked Crinoids. The first author who put forward this opinion was Schweigger[1]; and Miller's views[2], published two years later, were fundamentally the same, though somewhat modified in form; for the centrodorsal piece was regarded by Miller as composed of two separate pieces, one forming the floor of the cavity and the other its sides and rim. The former was described by him as a pentagonal unperforated plate, "analogous in situation to the first columnar joint of the Crinoidea; but as it is not required to transmit the passage to the alimentary canal[3] (no prolongation of the column existing in this animal), it is without central perforation."

The other or ventral half of the centrodorsal piece was regarded by Miller as an annular or basin-shaped plate, representing the "pelvis" or basal circlet of *Pentacrinus*, though he described it as marked externally by numerous sockets for the attachment of the cirrhi, which in *Pentacrinus* are borne by the stem-segments only, and never by the basals.

Goldfuss, who in most points followed Miller's views, differed from him considerably with regard to the nature of the centrodorsal piece of *Comatula mediterranea*, which they had both studied; and his conclusions, though not absolutely correct, are much nearer the truth than those of Miller. Finding most specimens to bear three rows of

[1] *Op. cit.* p. 64. [2] *Op. cit.* pp. 129, 130.

[3] It must be remembered that the canal which occupies the centre of the Crinoidal stem was originally supposed to be a continuation of the alimentary canal, and not, as we now know it to be, of the general perivisceral cavity or cœlom.

dorsal cirrhi, he described this species as having a column of three segments, and gave a sectional figure in support of his statements [1], which shows three segments below the circlet of first radials, each bearing a row of cirrhi. It is doubtful how far this figure can be relied on as accurate, though I have occasionally met with somewhat similar appearances myself. Goldfuss, like Miller, was unacquainted with the remarkable condition of the basals in this type; and as the "pelvis" described by Miller in *Comatula* was rightly regarded by him as representing a part of the stem of *Pentacrinus*, he was led to believe in the absence of basals in *Com. mediterranea*, though he found them in the *Com. multiradiata* (*Comaster*), in which he described the rudimentary column as consisting of only a single segment. Müller was led, by his comparison of the component pieces of the calyx of *Comatula* with those of the calyx of *Pentacrinus asteria* (*Caput-medusæ*), to recognize the very close general correspondence between them; and he pointed out [2] that the presence of cirrhi at the upper end of the stem of the Pentacrinoid larva on the one hand, and on the centrodorsal plate bearing the first radials of the young *Comatula* on the other, indicate that the latter is comparable to the stem of *Pentacrinus*, which bears the cirrhi in verticils separated by longer or shorter intervals. This view of Müller's was pretty generally recognized as the true one, and it was adopted and greatly strengthened by Wyville Thomson and Dr. Carpenter, who came to precisely the same conclusions upon developmental grounds. The former defined it as representing a "coalesced series of the nodal stem-joints in the stalked Crinoids," namely, of those joints which bear whorls of cirrhi, so that "the centrodorsal plate with its dorsal cirrhi in *Antedon* is the homologue of the stem with its cirrhi in the stalked Crinoids." Ludwig [3] also, while referring to the development of the centrodorsal as the enlarged uppermost stem-segment, speaks of it as "ein zusammengedrängter, oberer Stengelabschnitt, in welchem das verkalkte Gewebe keine Sonderung in untereinandergelegene Glieder erfahren hat."

(§ 47) The first rudiment of the stem of the Pentacrinoid larva as described by Wyville Thomson [4] consists of a series of delicate calcareous rings forming a curved line, which passes backwards from beneath the centre of the lower ring of plates, the embryonic basals. Within each of these is formed a hollow sheaf of parallel calcareous rods, united together by short anastomosing lateral branches; the upper one of these, on which the lower edges of the basal plates rest, soon becomes considerably wider and thicker than the rest. "During the earlier stages of the growth of the Pentacrinoid it is simply a circular band of the ordinary calcified areolar tissue, enclosing a sheaf of the peculiar fasciculated tissue of the stem, gradually enlarging, with a central aperture continuous with the bore of the tube-like stem-joints."

This ring is subsequently developed into the permanent centrodorsal piece; but the rudiments of the first dorsal cirrhi do not appear around its lower contour until very much later. New rings are developed immediately beneath it, until there are fifteen or sixteen

[1] Petref. German. p. 202. [2] Bau des *Pentacrinus*, p. 10.

[3] "Zur Anatomie des *Rhizocrinus lofotensis*," Zeitschr. für wiss. Zool. Bd. xxix. p. 127.

[4] "On the Embryogeny of *Antedon rosaceus* (Linck) (*Comatula rosacea* of Lamarck)," Phil. Trans. 1865, pp. 536, 537.

in all, the length and diameter of which are gradually increased by the deposition of new calcareous material at their extremities and upon their outer cylindrical surface.

Dr. Carpenter[1] has shown that, at or about the period at which the suppression and metamorphosis of the embryonic oral and basal plates begins, "the production of new calcareous segments in the stem appears to cease, and a remarkable change begins to show itself in the one on which the calyx rests. Instead of increasing in length, its original annular disk augments in diameter, becoming convex on its lower surface and concave on its upper, and it extends itself over the bottom of the calyx in such a manner as to receive in its concavity the apices of the basal plates;" and that portion of its under surface which extends itself beyond the segments whereon it rests begins to be marked by small tubercles, which are the origins of the dorsal cirrhi, while it also "augments not only in absolute but in relative diameter, extending itself over the dorsal or outer surface of the basal plates, which at the time of the detachment of the body from the stem are almost entirely concealed by it. . . . . . A second whorl of cirrhi is now developed, after the same manner as the first, between the latter (with which it alternates in position) and the base of the calyx (pl. xlii. fig. 3), and a third whorl generally makes its appearance before the detachment of the Pentacrinoid, so that the young *Antedon* possesses *ten* cirrhi in different stages of advanced development, and from *one* to *five* still rudimentary."

After the detachment of the young *Antedon* from its stem a minute five-rayed perforation is visible for a short time in the somewhat depressed central portion of the inferior surface of the centrodorsal piece. It is the remains of the original "communication between the cavity of the basin-shaped plate and the central canal that is still left in the upper segments (at least) of the stem. This perforation, however, is very soon closed up by an extension of the calcareous network, so that no trace of it remains visible either internally or externally."

We have thus seen that the centrodorsal piece "first presents itself in a form which nowise differentiates it from the other joints of the cylindrical stem, but begins to take on an extraordinary increase in a peripheral direction at the time when the dorsal cirrhi first sprout forth, and thenceforward remains in closer connexion with the calyx than with the rest of the stem, from which it separates itself so soon as the dorsal cirrhi are sufficiently developed to serve for the attachment of the animal." Each of these cirrhi receives a "sarcodic thread, which proceeds from the sarcodic axis contained within the cavity of the basin, and runs along the central canal of the cirrhus to its termination."

New cirrhi gradually appear between those previously formed and the base of the calyx, and each receives a peduncle of sarcodic substance from the central axis; and "since the arrangement of the whole aggregate of such peduncles is distinctly verticillate, the want of a definite plan in the grouping of the cirrhi on the external surface of the centrodorsal plate seems attributable to their very close apposition."

During the whole period of the growth of the centrodorsal basin there is a "progressive exuviation of the first-formed cirrhi from within outwards, concurrently with the development of new ones near the margin, those cirrhi which surrounded the summit of the

[1] Phil. Trans. *loc. cit.* p. 732.

stem being first shed and their sockets filled up by new deposit, and the space thus formed being gradually widened by the progressive exuviation of the cirrhi that bound it, and the filling up of their sockets." Thus the flattened central portion of the dorsal surface of the plate by which it was originally attached to the joint of the stem next beneath it increases very much in extent, and finally comes to bear a considerable proportion to its diameter (Pl. IV. fig. 1). In *Act. polymorpha* (Pl. VI. figs. 2, 7, 14, 16, 20), as we have seen, it extends over the whole of the dorsal surface of the plate, and to a certain extent also in *Act. robusta* (Pl. V. fig. 15). In *Ant. Eschrichtii*, however, it does not reach any great extent, for most of the first-formed cirrhi do not appear to be cast off as in *Ant. rosacea* and *Ant. celtica*, or, if they are lost, their sockets are not obliterated, but they seem to be replaced by others, for I have frequently found young and rudimentary cirrhi among the larger and perfectly developed ones around the central portion of the large hemispherical "Knopf" of this species [1].

(§ 48) In most pedunculate Crinoids, in which the calyx rests upon the uppermost segment of the stem, this segment, instead of being the largest, is the smallest, being the latest formed, while the base of the calyx is formed by the thickened and expanded basals. Hence, as Dr. Carpenter remarks [2], "it seems clear that the extraordinary development of the highest segment of the stem into the centrodorsal basin, which is characteristic of the mature *Antedon*, is connected with the multiplication of the prehensile cirrhi which extend themselves from its dorsal surface."

At the base of the quinquelocular organ, and lying on the bottom of the centrodorsal basin, but enclosed, together with the five chambers, in the above-mentioned fibrillar envelope (*N*), which is probably of a nervous nature, there is, both in *Antedon* and in *Actinometra*, a succession of verticils of five triangular leaflets [3]. As already shown by Dr. Carpenter, there can be little doubt but that the lower ones of these mark the origins of the earlier cirrhal cords from the crinoidal axis. They increase in size from below upwards, and from the extremities of some of the upper leaflets there issue groups of three diverging cords that proceed to the cirrhi which are developed at a later period around the periphery of the centrodorsal piece.

Greeff [4] has found the older cirrhus-cords still in connexion with these leaflets. Apparently unaware of the original existence and subsequent removal of the cirrhi corresponding to them, he drew a distinction between the vessels which they enclose, and which end close under the dorsal surface of the plate, and the vessels enclosed in the

[1] I cannot altogether confirm Müller's statement ('Gattung *Comatula*,' p. 239 (3)) that the central apical portion of the centrodorsal in *Ant. Eschrichtii*, where it was formerly united to the stem, may be covered with cirrhi. In all the individuals of this species which I have examined (and they are many) there is always a small apical space quite free from cirrhi; it may not be wider than the diameter of a large cirrhus-socket, but it is always to be found. I imagine that by the expression "Da es Antedon-Arten giebt, bei denen auch der mittlere Theil des Centrodorsale Cirrhen trägt (*Antedon Eschrichtii* z. B.)" (Crinoideen, p. 69, note), Ludwig does not mean any thing more than that the centrodorsal is covered with cirrhi to a much greater extent than is usual in most *Comatulæ*, where there is generally a central space of considerable extent entirely free from cirrhi. Schlüter has also expressed his doubts respecting the accuracy of Müller's statement.

[2] Proceedings R. S., No. 166, 1876, p. 218.

[3] These are seen in section in Pl. VIII. figs. 3, 7.

[4] Marburg Sitzungsberichte, No. 5, 1876, p. 91.

more peripherally placed cords proceeding from the upper leaflets, which enter the later-developed cirrhi. Ludwig[1] regarded them as rudimentary structures in *Ant. rosacea*, because he found them in *Ant. Eschrichtii* to enter the more centrally placed cirrhi, which are not removed, but persist throughout life, as already mentioned. It will be evident, however, from the facts stated above, that these cirrhus-cords, which end on the dorsal surface of the plate, are not rudimentary structures, but the proximal ends of more complete cords that have undergone a retrogressive metamorphosis, which in *Ant. Eschrichtii* is not carried so far as in *Ant. rosacea*.

These facts all tend to strengthen the view first expressed by Wyville Thomson, that the centrodorsal piece represents a coalesced series of the nodal stem-joints of the stalked Crinoids. In *Ant. Eschrichtii* six or even more rows of cirrhus-sockets may be traced on the hemispherical surface of the "Knopf," each row corresponding to a node in the stem of *Pentacrinus*. Even in those *Actinometræ* in which only one row of sockets is visible externally, the composite character of the centrodorsal piece is indicated by the verticils of degenerate cirrhus-vessels at the base of the chambered organ (Pl. VIII. figs. 3, 7), and by the partially obliterated openings on the central part of the floor of the centrodorsal cavity (Pl. V. figs. 2, 7, 14; Pl. VI. figs. 3, 8, 10, 15, 17, *u*).

Sometimes, indeed, the "Knopf" may actually assume a more or less columnar form, as in the specimen of *Ant. macrocnema* mentioned in sect. 41, and in the genus *Solanocrinus*; in both of which three or four alternating rows of cirrhi are visible. In these forms we may reasonably suppose that the columnar centrodorsal was developed by the enlargement of the uppermost stem-segment on which alternating whorls of cirrhi successively appeared, just as in *Ant. celtica* (Pl. IV. figs. 1, 6, 8), *Ant. rosacea* (fig. 14), and *Act. robusta* (Pl. V. fig. 15), but not in such numbers as to obscure the alternate arrangement (p. 69).

(§ 49) Götte[2], to whom we owe a series of most beautiful observations on the development of the water-vascular system and perivisceral cavity of *Comatula*, has recently questioned the accuracy of those observations of Wyville Thomson and Dr. Carpenter, according to which the uppermost of the embryonic stem-segments developes into the centrodorsal piece, and has also attacked the view that it may possibly in some cases arise from the fusion of two or more stem-segments as represented in Goldfuss's figure.

His description of its origin is as follows:—"Die Anlagen der Centrodorsalplatte sind schmale, aber doch netzförmige Skeletstreifen, welche gleichzeitig mit den Basalia an deren unteren Rändern entstehen und die obersten, noch eng zusammengedrängten Stielgliederanlagen umgeben (fig. 13). Es ist daher später, wenn diese Stelle sich verschmächtigt, nicht immer ganz leicht, jene Anlagen der Centrodorsalplatte von den obersten Stielgliedern zu unterscheiden. Beachtet man jedoch, dass sie anfangs das 5.–8. Stielglied, und nachdem diese abwärts gerückt sind, das 9., 10., 11., 12. u. s. w. umschliessen, was Thomson überhaupt nicht erwähnt, so kann man sich der Ueberzeugung

[1] Beiträge, *loc. cit.* p. 69.

[2] "Vergleich. Entwickelungsgesch. d. *Comatula mediterranea*." Archiv, f. mikrosk. Anat. Bd. xii. 1876, p. 597.

nicht verschliessen, das die Skeletzone, aus welcher die Centrodorsalplatte hervorgeht, unabhängig von den eigentlichen Stielgliedern, mehr in Anschluss an die Basalia und wohl als rudimentäre Wiederholungen derselben sich entwickelt. Besonders lehrreich für diese Auffassung sind die gar nicht seltenen stiellosen Missbildungen der Comatula-larven welche ich beobachtet habe. An solchen finden sich in der hinteren Körperhälfte, welche ihre ursprünglichen Dimensionen behält, statt der Stielglieder grosse netzförmige Platten welche den Raum zwischen den Basalia und dem Endknopf ausfüllen (pl. xxviii. fig. 50). Vergleicht man sie mit den viel schwächeren Anlagen der Centrodorsalplatte, so spricht die Darstellung sehr an, dass sie durch die Stielbildung in ihrer Entwickelung gehemmt und im umgekehrten Falle gefördert werden."

The only normal figure given by Götte in support of his views represents a ciliated larva, very much younger than the pentacrinoid stage, and with only eight stem-segments, over parts of the four uppermost of which are traces of a calcareous network connected with the lower end of one of the embryonic basal plates. This network, which reaches a more extensive development in the malformation represented in Götte's other figure, does not appear in any one of Wyville Thomson's figures of *Comatula* larvæ, either in the free-swimming or in the pentacrinoid condition. As his observations were carried on for four years, in each of which he followed out the development of several broods of embryos, it is impossible to suppose that he can have overlooked it had it been present in the larvæ of the British variety investigated by him. It is possible that the early-formed irregular calcareous ring, "considerably wider and broader than the ordinary rings of the stem, which lies immediately beneath the basal plates, and subsequently develops into the permanent centrodorsal plate," may represent the network figured and described by Götte. But then, as the latter says, Thomson makes no mention of its extending downwards around the other stem-segments; he gives, however, a series of figures which, taken in connexion with those of the later stage given by Dr. Carpenter, demonstrate conclusively that the above-mentioned ring *does* develope into the permanent centrodorsal piece. Götte gives no figures whatever of the pentacrinoid stage. If, as I believe to be the case, the network described by him as the rudiment of the centrodorsal piece really *does* represent the primitive centrodorsal ring of Wyville Thomson, commencing, be it remembered, as a network of small curved hollow spicules, then his observations are in complete accordance with the views of Wyville Thomson and Dr. Carpenter. Götte offers no explanation of its downward extension over the remaining stem-segments as described by him in the Mediterranean variety; and nothing of the kind is described by the two above-mentioned observers as occurring in the British variety, unless, indeed, it be the deposit of calcareous material upon the outer cylindrical surface of each stem-segment by which its diameter is increased.

It is possible that this deposit might commence to be formed at an earlier period in the Mediterranean variety than in the British one; but it is difficult to understand its downward extension from the rudiment of the centrodorsal plate as described by Götte.

(§ 50) The condition of the centrodorsal piece in *Ant. rosacea* and in *Actinometra* gives us, I believe, the means of understanding a problematical Cretaceous fossil, first described by Goldfuss [1], of which neither he nor any subsequent observer has given a satisfactory explanation [2].

Glenotremites was at first placed by Goldfuss among the *Echinoidea,* and was supposed by him to have some relationship with the *Cidaridæ.* It is a somewhat hemispherical body, in the centre of the flattened upper surface of which is a large round opening, called by Goldfuss the mouth. "Um den Mund liegen fünf grösse ovale Löcher und zwischen diesen fünf flache Rinnen, die sich bis zum Rande erstrecken, wo ihre Vertiefung nicht ausläuft, sondern durch einen erhabenen Saum begränzt wird. . . . . Die Löcher gehen trichterförmig in die Tiefe; die Rinnen sind die Felder der Fühlergänge." These grooves were supposed by Goldfuss to be perforated by minute pores for the passage of tentacles.

The convex dorsal side of the body bears numerous sockets for the attachment of cirrhi; but Goldfuss compared these at first to the large tubercles of the *Cidaridæ.* At the apex are five smaller apertures; and Goldfuss suggested that these might be respiratory and the others genital, or, more probably, that both, like the cirrhus-sockets, marked the points of attachment of various kinds of spines. Subsequently, however, in his description of a second species, *G. conoideus,* he spoke of the larger apertures as ovarian openings, and recognized the resemblance between the sockets on the convex surface and the similar ones on the dorsal surface of the centrodorsal piece of *Comatula* to which the cirrhi are articulated; and he suggested that *Glenotremites* might be more nearly related to the *Comatulidæ* than to the *Echinidæ,* as he had at first thought. Agassiz [3] adopted this view, and placed *Glenotremites* among the Crinoids, and near to *Comatula.* Like Goldfuss, he regarded the central aperture as a mouth; but the five punctated grooves radiating from it, which were supposed by Goldfuss to be provided with tentacles, were regarded by Agassiz as the points of insertion of the radii. He did not attempt to explain the five large openings on the ventral surface and the five smaller apical ones. Rœmer [4], who, like all subsequent writers, accepted the view that *Glenotremites* is the centrodorsal piece of a Crinoid allied to *Comatula,* regarded the former as "trichterförmigen Arm-Anfängen oder Mund-Winkeln," but did not understand those of the dorsal surface.

D'Orbigny [5], who confused *Glenotremites* with *Comaster* and *Solanocrinus* under one name, *Comatula,* and Pictet [6], who retained it as a separate genus, did not attempt to offer any further explanation of its peculiarities, and, so far as I know, Agassiz and Rœmer's views have been generally accepted.

[1] Petref. German. i. p. 159, Taf. xlix. fig. 9, Taf. li. fig. 1, and ii. p. 186, Taf. clx. fig. 18.

[2] The following section was written early in 1877, and was in the hands of the Secretary of the Linnean Society in June of that year. The substance of a portion of it was referred to in my paper on *Pentacrinus* and *Rhizocrinus* ('Journal of Anatomy and Physiology,' Oct. 1877, p. 45). I am therefore exceedingly glad to find, from a paper published early in 1878 ("Ueber einige astylide Crinoiden," Zeitschrift der deutschen geologischen Gesellschaft, Jahrgang 1878, p. 33), that Schlüter has independently given the same explanation of *Glenotremites* as had occurred to myself. I learn from his paper that even as late as 1871 Goldfuss's original views were still held by Geinitz (Elbthalgebirge, i. 1871, p. 91).

[3] Prodrome, *loc. cit.* p. 289.

[4] Lethæa Geognostica, v. p. 177.

[5] Cours élémentaire, ii. p. 138.

[6] Traité de Paléontologie, iv. p. 290.

That *Glenotremites* is the centrodorsal piece of a *Comatula* there can, I think, be little doubt; but I see no reason to regard the central opening as a mouth, any more than in any other of the centrodorsal pieces represented in Plates IV., V., and VI. In all these cases the centrodorsal cavity, as we know from Götte's observations, is derived from the posterior part of the right peritoneal diverticulum of the larval alimentary canal, and is therefore a part of the general body-cavity or enterocœl. It is occupied by the dorsal half of the quinquelocular organ which rises through its central opening, the so-called mouth of *Glenotremites,* and is continued as the "axial prolongation" (Pl. VIII. fig. 3, *a.p*) through the central aperture of the rosette upwards into the middle of the visceral mass.

In *Ant. rosacea* this central opening is surrounded by five depressions (Pl. IV. fig. 15, *q*), which are the dorsal terminations of the five radial diverticula of the body-cavity enclosed between the radial spout-like processes of the rosette and the internal faces of the first radials. These diverticula exist both in *Antedon* and in *Actinometra* (Pl. VIII. fig. 3, *a.r.c*), but do not always reach the ventral surface of the centrodorsal piece as in *Ant. rosacea* (Pl. IV. fig. 15). If we suppose the above-mentioned depressions (*q*) placed radially around the centre of this surface to be deepened sufficiently to become openings leading into the centrodorsal cavity, they would occupy precisely the same position as the so-called genital openings[1] of *Glenotremites*; and simply effect a more open communication between the two parts of the cœlom contained in the centrodorsal piece on the one hand, and the general cavity of the calyx on the other, than when the ventral surface of the former presents only a single central opening, as in *Antedon* and *Actinometra.*

If the view advanced above be correct, it follows that the peripheral part of the areas around the "genital openings" of *Glenotremites* are the representatives of the radial

[1] These so-called "genital openings" were described by Goldfuss as "Löcher." Schlüter, however, merely speaks of them as "Gruben" (pp. 33, 42), and uses the same term for the whole cavity of the centrodorsal piece, "welche das Herz (??) oder gekammerte Organ aufnimmt," and is therefore spoken of by him as the "Herzgrube." But from his expressions, "centrale Herzgrube fünfseitig" or "zehnseitig," he obviously intends "Herzgrube" to mean nothing more than the central opening of the ventral surface of the centrodorsal, which he elsewhere calls the "Nahrungscanal" (!), although he evidently understands its real meaning.

I cannot therefore clearly make out from Schlüter's paper whether the "Radialgruben" are real perforations or mere depressions, as in *Ant. rosacea*, which, by-the-bye, is the same species as the *Antedon europæus* of Greeff, and not different from it as Schlüter seems to think. His figures (pl. i. figs. 1, 4, & 10, and pl. ii. figs. 1 & 3) appear to represent ventral openings in the centrodorsal of some fossil *Antedons*, just as described by Goldfuss in *Glenotremites*; but then he refers (p. 33) to Ludwig and Greeff (!) as describing the radial pits of *Ant. rosacea* as "sackförmige, in den Kalkscheitel eindringende *blindgeschlossene* Erweiterungen der Leibeshöhle."

His use of the word "blindgeschlossene" would seem to indicate that the "Radialgruben" of his specimens are really pits, closed below as in *Ant. rosacea*, and not actual openings; for in the latter case these extensions of the cœlom contained within the radial axial canals would have opened into the centrodorsal cavity (also a part of the cœlom), *i.e.* into that part of it which was not filled up by the chambered organ, and they could not then be accurately described as "blind." The "Radialgruben" seem, however, to have been actual perforations in *Ant. semiglobosus* (Schl. pl. i. fig. 10); for Schlüter speaks of them (p. 42) as "mit der Centralgrube verschmolzen (reichen aber tiefer hinab)," though he suggests the possibility of this being due to an accidental fracture of their central bony border. The point is one of some interest; for in no recent *Comatula* yet known are the "Radialgruben" more than simple pits, such as are generally found in *Ant. rosacea.*

areas on the ventral surface of the centrodorsal piece of *Ant. rosacea* (Pl. IV. fig. 15, *r.ar*), in each of which lies the convex dorsal surface of a single first radial.

What, then, are the five radiating punctated grooves which Agassiz and Rœmer regarded as the articular surfaces for the attachment of the five arms of *Glenotremites*? I believe them to be the representatives of the basal grooves on the ventral surface of the centrodorsal piece of *Actinometra* (Pl. V. figs. 2, 7, 14, Pl. VI. figs. 3, 8, 10, 15, 17, 21, *b.g*). They are sometimes slightly developed in *Ant. rosacea*, one lying between every two of the depressions (*q*) mentioned above (Pl. IV. fig. 15), in precisely the same manner as the grooves and " genital openings " alternate on the ventral surface of *Glenotremites*.

We thus see that the peculiarities of the ventral surface of *Glenotremites* may be readily explained by what we know of the corresponding parts in *Antedon* and *Actinometra*. The apertures in the centre of the dorsal surface admit of an equally simple explanation.

The quinquelocular organ forming the dorsal termination of the axial prolongation of the adult *Comatula* consists of five chambers, arranged around a central axis which contains numerous vessels. In *Pentacrinus* there is no centrodorsal piece, but the quinquelocular organ is contained in a cavity, the sides of which are formed by the first radials above and by the basals below. Its five chambers are not closed below, but narrow considerably, and are continued down the stem as five long vessels arranged symmetrically around a central axis. The same appears to be the case in the stem of the Pentacrinoid larva of *Comatula*; for, as already mentioned, Dr. Carpenter has described a minute five-rayed perforation occupying the central portion of the dorsal surface of the recently detached *Antedon*. I regard this perforation as homologous with the five small apertures arranged around a single central one on the dorsal surface of the centrodorsal piece of *Glenotremites*, and with the similar openings on the underside of the calyx of the other stalked Crinoids—for example, of *Cupressocrinus*. The fact that the young *Antedon rosacea* has only three rows of dorsal cirrhi when liberated from its stem, while there are four or six rows on the dorsal surface of *Glenotremites*, does not at all tell against this view. Indeed Sars[1] has shown that the pentacrinoid stage persists in *Antedon Sarsii* very much longer than in *Ant. rosacea*, and he has found specimens with nearly thirty cirrhi still in a pedunculate condition, the cirrhi being placed in such close proximity to one another that any trace of a distinct order in their arrangement was entirely obliterated. The exterior of the centrodorsal piece of *Ant. Sarsii*, therefore, immediately after its liberation from the stem, would present (its size, of course, excepted) a very similar appearance to the convex dorsal surface of *Glenotremites*, viz. a central five-rayed opening, or possibly even a single opening with five others round it, the rest of the surface being covered with sockets for the articulation of the dorsal cirrhi.

(iv.) *The Pentagonal Base of the Calyx.*

(§ 51) In all the *Actinometræ* with which I am acquainted the Pentagonal Base of the calyx formed by the close mutual adhesion of the five first radials, together with the

[1] 'Crinoïdes vivants,' p. 57.

rosette or metamorphosed basals, differs in many points from that of *Ant. rosacea* and of all the other species of *Antedon* which I have examined.

In all of these the external or distal faces of the first radials slope at a considerable angle from above and within downwards and outwards, so that a view of the upper or ventral aspect of the radial pentagon formed by their union (Pl. IV. figs. 4, 17) shows, not only their small superior or ventral faces around the central funnel-shaped space (*F*), but also the greater part of their inclined external faces (Pl. IV. figs. 6, 8, 14), viz. the fossæ (*f*) for the attachment of the muscles between the first and second radials (Pl. IV. fig. 5, *r.m*) and the smaller ones (*h*) which lodge the interarticular ligaments, the distal opening of the central canal (*c.c*), and the large transverse articular ridge (*i*), together with more or less of the large fossa (*j*) which lodges the elastic ligament. The amount of this fossa which is visible on the ventral aspect of the radial pentagon varies in different cases.

In correspondence with this inclination of the distal faces of the first radials of *Antedon* to the vertical or dorsoventral axis of the calyx, their ventral faces are much reduced and are very small in comparison with the dorsal ones.

When the ventral surface of an isolated first radial of *Ant. rosacea* is examined (Pl. IV. fig. 12 a), it is seen to be divided into a central and a peripheral portion by two curved ridges, bending towards each other along the median line, and there separated by a furrow (f_1). The central portion only is the true ventral face of the radial. It slopes inwards, so as to contribute to the formation of the central funnel-shaped space (Pl. IV. fig. 17, *F*) occupying the centre of the radial pentagon, and partially filled up by a calcareous network formed by the inosculation of processes which proceed from the internal and ventral faces of the surrounding radials (Pl. IV. fig. 12 a, *c.n*). The peripheral portion, on the other hand, slopes outwards, and is, in fact, the upper or ventral half of the inclined external face (fig. 14), namely, the large vertical lamellæ in which the muscular fossæ are excavated. The upper and inner edges of these lamellæ form the curved ridges above mentioned, each of which has two limbs, one superior (fig. 12 a, g_1), which is horizontal, or nearly so, and forms the external boundary of the ventral face, and one inferior (g_2), which descends along the median line of the inclined external face towards the great transverse articular ridge (*i*); it is separated from the corresponding inner edge of the other muscular fossa by the furrow (f_1), which may therefore be called "intermuscular."

These curved ridges thus produce great inequalities in the ventral aspect of the radial pentagon (Pl. IV. fig. 17). The walls of its central funnel present an alternation of radiating ridges and furrows, of each of which there are ten. Five of the furrows (*v.i.f*) correspond with the divisions between the component pieces, and are therefore *interradial*, while the ridges which bound them are the superior limbs (g_1) of the curved ridges above mentioned, one belonging to each of the two contiguous radials. Of the other five furrows, one passes along the middle of each of the five radials, and both the ridges which bound it belong to the same piece—being, in fact, the median or descending margins (g_2) of the large vertical lamellæ in which the muscular fossæ (*f*) are excavated. These furrows, therefore, are simply the intermuscular furrows of the distal faces (Pl. IV.

figs. 12 a, 14, f_1), and they only appear on the ventral aspect of the radial pentagon because of the inclination of these faces to the vertical axis of the calyx. They do not appear to exist in *Ant. celtica* (Pl. IV. figs. 4, 6, 8), in which the radial muscles are far larger than in *Ant. rosacea*, so that the vertical lamellæ to which they are attached attain a much greater size. These are placed at such an angle to the dorsal portions of the distal faces of the radials that they stand up nearly vertically, and form the outer wall of the central funnel-shaped space (fig. 4, *F*) which leads downwards into the cavity of the centrodorsal piece. Its pentagonal rim is formed, as in *Ant. rosacea* (fig. 17), by their superior margins, two of which, belonging to contiguous radials, bound each of the five ventral interradial furrows (*v.i.f*) which mark the angles of the pentagon. In the centre of each of the five sides of this pentagonal rim is a deep notch (fig. 6, f_2); but it does not descend on to the distal face of the corresponding radial so as to form an intermuscular furrow bounded by the median descending margins of the muscular fossæ, as in *Ant. rosacea* (figs. 14, 17, f_1); for these fossæ are so large, and extend so far towards the median line, that their inner margins unite and form a prominent vertical ridge (figs. 4, 6, g_3), which passes below into the elevated rim around the opening of the central canal (*c.c*).

(§ 52) These five notches in the sides of the pentagonal rim of the central funnel of the radial pentagon in *Ant. celtica* (Pl. IV. fig. 6, f_2) represent the points at which in *Ant. rosacea* the superior or central end of each intermuscular furrow (f_2) passes at a slight angle, due to the inclination of the distal face, into a shallow depression (figs. 12 a, 17, *v.r.f*) occupying the centre of the small ventral face of each first radial. This depression, which is much better developed in *Actinometra*, is far more distinct in some specimens of *Ant. rosacea* and *Ant. celtica* than in others, and in the dry state is barely visible. When, however, the interior of the calyx is viewed from above after the visceral mass has been removed, so as to lay open the circumvisceral cœlom, and expose the ventral aspect of the radial pentagon, the position of the ventral radial and interradial furrows is indicated by dark lines converging towards the centre (fig. 5). These are due to the fact that the parietal layer of the peritoneum which lines the interior of the calyx descends into these depressions, so that its pigment is here more thickly aggregated than on the rest of the ventral surface. A similar slight depression lined by the pigmented peritoneum exists on the median line of the ventral face of the second and third radials and of the basal brachial segments, and it lodges the dorsal portion of the cœliac canal, which, in the intervals between the segments, sends down diverticula between the muscles connecting them, so that its course is readily traceable by the greater intensity of the pigment along the median line of the segments and between the two muscles connecting every pair (fig. 5, *v.r.f*). At the base of the arms the cœliac canal becomes broken up by connective-tissue septa into a number of intercommunicating spaces, which open freely into the general cavity of the calyx or circumvisceral cœlom. The dorsal part of the canal, however, retains its primitive relation to the skeleton and muscles, and is lodged in the furrows on the ventral faces of the radials (fig. 5).

We have already seen that the inner wall of the funnel-shaped space (*F*) occupying the centre of the radial pentagon is formed by the inclined ventral faces of the five first radials (figs. 4, 12 a, 17). These are not simply plane, but are usually more or less divided up by delicate calcareous processes which extend to meet the ventral face of the rosette, and collectively form a complicated network (*c.n*), filling up the central funnel, and often partially bridging over the ventral radial furrow, so as to convert it into an incomplete canal.

At the inner margin of the ventral face this furrow turns downwards, and passes directly into a nearly vertical furrow occupying the median line of the proximal or internal face (Pl. IV. fig. 12 c, *a.r.f*), and more or less completely converted into a canal by the union of irregular processes, which extend themselves from its sides to meet the rosette. As it descends towards the dorsal face and passes between the inner raised edges of the two apertures (*x'*, *y*) of the central canal, this axial radial furrow becomes a complete canal, for its edges are closely applied to the inflected margins of one of the five radial spout-like processes of the rosette (Pl. IV. figs. 13, 16, *p*).

The five canals thus formed may hence be regarded as enclosing cavities directly continuous with the cœliac canals of the arms, in the direction of which they lie; and they thus enclose portions of the body-cavity, which I will call the radial cœlom[1].

They open on the dorsal surface of the radial pentagon by five large openings (Pl. IV. fig. 16, *Q*), that correspond with five more or less distinctly marked circular depressions, which are placed radially on the ventral surface of the centrodorsal piece around the margins of its central cavity (fig. 15, *q*), and the canals end blindly in these depressions. Where these canals are enclosed by the spout-like processes of the rosette, they are completely shut off both from one another and from the dorsal extension of the cœlom which occupies the central funnel-shaped space within the radial pentagon (figs. 4, 17, *F*), and passes down into the cavity of the centrodorsal piece through the central opening of the rosette (fig. 16, *r.o*). On the ventral side of the rosette, however, these radial axial canals are only partially complete, and are in free communication with the numerous plexiform spaces into which the funnel-shaped space is broken up by the above-mentioned calcareous network. The central portion of this system is very irregular; but peripherally the plexus becomes more regular, and five axial interradial canals are traceable between the five radial ones, with which, as with the centre of the plexus, they are in free communication.

These interradial canals are continuous with the interradial furrows which are visible on the ventral aspect of the radial pentagon (Pl. IV. figs. 4, 17, *r.i.f*), and they enclose diverticula of the circumvisceral cœlom to which the name interradial cœlom may be given. They do not descend so far towards the dorsal surface as the axial radial canals, and are not, like the latter, enclosed (normally, at any rate) by spout-like processes of the rosette; for their course towards the dorsal surface is terminated by the five short triangular processes of the rosette (figs. 3, 7, 13, 16, *o'*), which are directed towards the sutures between the five radials.

(§ 53) This is well seen in Ludwig's schematic vertical section through the body of *Ant. rosacea*[2], in which the radial cœlom (*Lr*) is rightly represented as both longer and

[1] The general relation of these axial radial canals is precisely the same in *Actinometra* as in *Antedon*. See Pl. VIII. figs. 3, 6, *a.r.c.*

[2] Beiträge &c. Taf. xix. fig. 74.

larger than the interradial cœlom (*Li*). It is also seen in Taf. xv. figs. 25, 26, on a larger scale; and in Taf. xiv. figs. 20–24 both the radial and the interradial diverticula of the body-cavity are seen in transverse section, separate from one another towards the dorsal side, but communicating freely nearer the ventral surface, both with one another and with the centre of the plexus. In figs. 20–24, Ludwig has accidentally lettered them *L′* and *L″* respectively. This is unfortunate, as these letters are employed by him in his other figures to designate the circumvisceral and axial body-cavity; while in fig. 26 he uses the same letter L to designate the system of plexiform spaces occupying the central funnel of the pentagonal base, as he employs in his other figures for the intervisceral division of the body-cavity.

This hardly agrees with his text; for on p. 43 he says:—"Ueber den ersten Radialien löst sich die axiale Leibeshöhle in eine Summe von mit einander allseitig communicirenden Maschen räumen auf, welche zwischen die ersten Radialien eindringen, hier das dorsale Organ [*i. e.* axial prolongation] umgeben und endlich mit zehn blindgeschlossenen Fortsetzungen endigen, von denen fünf radiär gerichtet sind (*Lr*), fünf interradiär (*Li*). Der Dorsalcanal [=cœliac canal] des Armes giebt seine Lage dicht über den Kalkgliedern und zwischen und über deren Muskelpaaren nicht auf bis er über dem ersten Radiale angekommen ist, wo er sich gleichfalls in die schon erwähnten Maschenräume auflöst. Letztere stehen also in Verbindung mit der axialen Leibeshöhle und mit den Dorsalcanälen der Arme, aber sie dehnen sich auch ferner nach oben und seitlich aus, und erfüllen hier den Raum der rings um die axiale Leibeshöhle zwischen dem Ventralcanal und dem Dorsalcanal in der radiären Hälfte, zwischen Ventralperistom und Dorsalperistom in der interradiären Hälfte der Scheibe übrig bleibt." This space, the general perivisceral cavity, falls naturally, as Ludwig has pointed out, into two divisions—one external or circumvisceral, between the visceral mass and the body-wall, and corresponding to the "cœlom" of Dr. Carpenter; and one internal or intervisceral, surrounding the axial body-cavity (or axial canal of Dr. Carpenter), and occupying the spaces between the various coils of the alimentary canal within the visceral mass. This last corresponds to the intramural spaces and mesenteric sinuses of Dr. Carpenter [1], and not to the former only, as Ludwig appears to think (p. 55).

Of all the divisions of the body-cavity this intervisceral cœlom is the one which is least directly connected with the plexiform network between the first radials (Ludwig, figs. 26, 74, *L*) and with the cœliac canals of the arms; for it is completely separated from the latter by the visceral layer of the peritoneum, except at the minute aperture in the under surface of the visceral mass, where the axial prolongation, coming up from the quinquelocular organ through the central vacuity of the pentagonal base, enters the intervisceral cœlom contained within the visceral mass. When the latter is turned out of the calyx the intervisceral cœlom contained within it is, of course, removed at the same time, while the plexiform system of spaces between the first radials, and the continuations of the cœliac canals of the arms which terminate in it, are laid open; both of these, therefore, are manifestly portions of the general *circum*visceral cavity surrounding the visceral mass. Ludwig, however, makes the following statement (p. 90):—"Die Hauptab-

[1] Proc. R. S. no. 166, 1876, pp. 216, 217, 225.

schnitte der Leibeshöhle in Scheibe und Armen stehen miteinander paarweise in engerer Beziehung, indem sich die axiale Leibeshöle fortsetzt in die Ventralcanäle [subtentacular] der Arme und Pinnulæ, die intervisccrale in die Dorsalcanäle [cœliac] und die circumviscerale in die Genitalcanäle."

I cannot corroborate this statement except with regard to the axial body-cavity, the connexion of which with the subtentacular canals of the arms was first shown by Dr. Carpenter.

The ventral portion of the circumvisceral body-cavity, viz. the limited and much divided space between the parietal and visceral layers of the ventral peritoneum, certainly does stand in direct connexion with the genital canals of the arms; but its dorsal portion, viz. the space between the visceral mass and the skeleton of the calyx, is, as already mentioned, far more directly a continuation of the cœliac than of the genital canals. The former gradually increase in size as they approach the disk, becoming very large in the second and first arm-segments, and traversed by numerous connective-tissue bands, which are directly continuous with those of the circumvisceral space; while the genital canal remains relatively small, and is nothing more than a space in the horizontal septum separating the subtentacular and cœliac canals.

The beautiful investigations of Götte[1] have shown that the primitive cœlom of the pentacrinoid larva of *Antedon* consists of two parts: (1) an oral or ventral one, developed from the left peritoneal diverticulum of the primitive alimentary canal; and (2) a dorsal one, which sends a prolongation backwards into the stem, and is developed from the corresponding right peritoneal diverticulum. These divisions of the primitive cœlom had been previously described by Dr. Carpenter[2], Metschnikoff[3], and Greeff[4], to all of whom, however, their origin was unknown. The last observer regarded the ventral division as "den vom Wassergefässsystem und der hinteren Leibeshöhle geschiedenen ursprünglichen Blutsinus;" for he supposed it to be continuous with the cavity of the axial prolongation, which he called the "dorsoventral Gefässstrang." Dr. Carpenter has found, however, that this structure breaks up into five branches, one of which goes to each of the primitive rays, and developes into the so-called "genital rachis" of the arms, while the oral cœlom of the pentacrinoid larva (the "Bloodsinus" of Greeff), sends off an extension into each of the arms as its subtentacular canal. In the direction of the radii it forms, of course, the subtentacular canals of the disk; but elsewhere, or interradially, it becomes gradually limited by the enlargement of the visceral mass, and by the formation of adhesions between its upper surface (visceral layer of the peritoneum) and the parietal layer lining the under surface of the ventral perisome; so that the ventral portion of the circumvisceral cœlom enclosed between these layers, to which the primitive oral cœlom gives rise, becomes very much reduced in extent. We do not yet know the precise origin of the genital canals of the arms; but it seems most probable that, like the ventral portion of the circumvisceral cœlom with which they are connected in the disk, they are developed out of the lower or dorsal half of the extension into the

[1] *Op. cit.* p. 591, Taf. xxvi. fig. 19.

[2] Phil. Trans. *loc. cit.* p. 728; Proc. R. S. no. 166, p. 228.

[3] "Beitr. z. Entwickelungsgesch. einiger niederen Thiere," Bull. de l'Acad. Imp. des Sciences de St. Pétersb. tom. xv. 1871, pp. 502–509.

[4] Marburg Sitzungsberichte, 1876, No. 5, p. 89.

arms of the primitive oral cœlom—the upper or ventral portion of which gives rise to the subtentacular canals of both arms and disk.

The dorsal or aboral cœlom of the pentacrinoid larva lies beneath the annular mesentery, and forms the dorsal half of the primitive circumvisceral cœlom, long before the alimentary canal is sufficiently convoluted to give rise to a distinct intervisceral cœlom. Like the oral cœlom it sends off radial extensions into the developing arms, but *beneath* the horizontal partition extended from the mesenteric bands, and these become the cœliac canals. Its dorsal prolongation gives rise to the cavity of the centrodorsal piece, and ultimately to the central canals of the calcareous segments. Both of these, together with the plexiform space between the first radials and the cœliac canals converging to it, are therefore, like the greater part of the circumvisceral cœlom, derived from the right peritoneal diverticulum of the primitive digestive cavity; while the left one gives rise to the subtentacular canals of the disk and arms, and to the ventral portion of the circumvisceral cœlom. The primitive distinction between the oral and the aboral cœlom of the larva, indicated by the mesenteric fold, becomes, however, gradually obliterated by the development of numerous similar septa of connective tissue, and by the growth of the alimentary canal and its consequent winding.

The axial canal, continuous above with the oral, and below with the aboral cœlom, is produced by the limitation of the central space left by the coiling of the intestine around the stomach; while the remainder of the spaces between the coils become the intervisceral cœlom, which is therefore not developed to any extent until after the cœliac canals of the rays have been extended from the primitive aboral cœlom.

(§ 54) All the species of *Antedon* do not agree with *Ant. rosacea* and *Ant. celtica* in the great inclination of the distal faces of the first radials to the vertical axis of the calyx, so that these faces enter into the composition of the ventral aspect of the radial pentagon. In a new and undescribed *Antedon* from the Philippines this inclination is very slight; and in a view of the pentagonal base from above but little more is seen than the proper ventral faces of the component radials. In this respect, therefore, forms such as these present an approximation to *Actinometra* (Pl. V. fig. 4, Pl. VI. figs. 5, 12, 23), in which the distal faces of the first radials are nearly or quite vertical, and do not at all enter into the composition of the ventral aspect of the pentagonal base, which consists simply and entirely of the five adjacent ventral faces of the component radials.

In *Ant. rosacea* (Pl. IV. fig. 17) these form a five-pointed star, the central surface of which slopes rapidly downwards and inwards as the inner wall of the central funnel (*F*); while its five rays correspond with the divisions between the component radials, and are bounded by the large ridges which form the upper and outer margins of the two adjacent muscular fossæ (*f*) of every pair of contiguous radials (Pl. IV. fig. 12 a, g_1). The sutures between the radials are marked by slight depressions of their ventral surfaces, and these are completed by the ridges at their sides into the ventral interradial furrows already described (Pl. IV. figs. 4, 17, *v.i.f*); they occupy the five rays of the star, and alternate with the five shallow depressions (*v.r.f*) lying in the centre of the ventral faces of the first radials. In *Actinometra*, as will be seen further on, these depressions become very marked; but in *Ant. rosacea* they are hardly deep enough to be called furrows, and are generally more or less concealed by the calcareous network occupying the opening of the central funnel. They are the ventral continuations of the five canals enclosed by the radial spout-like processes of the rosette, and they pass downwards and outwards in the reentering angles of the star into the intermuscular furrows on the distal faces of the component radials (Pl. IV. figs. 12 a, 14, 17, f_1). These reentering angles, which are bounded by the superior margins of the two muscular fossæ of each radial, are more open in *Ant. celtica* (fig. 4) than in *Ant rosacea* (fig. 17), so that the rim of the central funnel becomes more nearly pentagonal, having somewhat the shape of a *Goniaster*. This is still more marked in *Ant. Eschrichtii*, while in *Actinometra* it becomes a regular pentagon (Pl. V. fig. 4, Pl. VI. figs. 5, 12, 23).

In correspondence with the nearly vertical position of the distal faces of the radials in *Actinometra*, their ventral faces, which in *Ant. rosacea* and *Ant. celtica* have a very steep inward slope, occupy a nearly horizontal position, sloping but very gently inwards towards the central space, so that the opening of the funnel becomes widely expanded. Its inner walls, formed by the adjacent ventral faces of the contiguous radials, which are relatively much larger than in *Antedon*, are generally more or less sculptured out into a series of radiating ridges and furrows, the number and distribution of which vary in different species.

(§ 55) In *Act. pectinata* the ventral surface of each first radial (Pl. V. fig. 9 a) is nearly as even and regular as that of *Ant. celtica* (Pl. IV. fig. 4) or *Ant. rosacea* (Pl. IV. figs. 12 a, 17), and in some cases it may be even more so. It is, however, both absolutely and relatively larger, as it is not encroached upon by the distal face, which stands nearly at right angles to it, and the furrow (*v.r.f*) occuping its median line is far more distinct than in either of the two species of *Antedon*. These points are clearly seen in a comparison of figs. 5 on Plates IV. and V., which represent the ventral aspect of the calyx, as seen after removal of the visceral mass, in *Ant. celtica* and *Act. pectinata* respectively. In the former (Pl. IV. fig. 5) the second and third radials and the bases of the arms are at a higher level than the pentagon of the first radials, owing to the inclination of the distal articular faces of the latter; but in *Actinometra* (Pl. V. fig. 5) the whole ventral surface of the calyx is in one horizontal plane, as the opposed articular faces of the first and second radials are parallel to the vertical axis of the calyx, and not more or less inclined to it, as in *Antedon*.

We have seen that in *Ant. rosacea* the lateral margins of the ventral faces of the first radials (Pl. IV. figs. 12 a, 17) are somewhat depressed, so that when two pieces are in contact a shallow interradial groove marks their line of union on the ventral side. It is deepened into a furrow (*v.i.f*) by the elevation at its sides of the ridges forming the superior margins of the muscular fossæ of the inclined distal face. This interradial depression also occurs in *Act. pectinata* (Pl. V. figs. 5, 9 a &c.); but as the vertical lamellæ (fig. 9 c, *g*) in which the muscular fossæ are excavated are very small, and do not extend inwards so as to encroach upon the ventral face, there are no ridges at the sides of this interradial depression (fig. 5, *v.i.f*) converting it into a deep furrow as in *Ant. rosacea* (Pl. IV. fig. 17), so that it is far less conspicuous than the corresponding radial furrow (Pl. V. figs. 5, 9 a, *v.r.f*).

The ventral aspect of the radial pentagon of *Act. solaris* (Pl. V. fig. 4) consists almost entirely of the conjoint ventral faces of its component pieces; the distal faces are very slightly inclined to the vertical axis of the calyx, so that portions of the fossæ lodging the radial muscles and the interarticular ligaments become visible (Pl. V. fig. 4, *f*, *h*). The ridges (g_1) which bound the muscular fossæ superiorly form by their apposition the outer margin of the ventral surface of the pentagonal base, which is interrupted at ten points, five being radial and five interradial. The former, which lie between the two muscular lamellæ of each radial, indicate the union of the intermuscular furrows of the distal face with the ventral radial furrow occupying the median line of the superior face (Pl. V. fig. 4, *v.r.f*); while the latter, which are at the angles of the pentagon, are the outer ends of the ventral interradial furrows (*v.i.f*) corresponding with the sutures between every two contiguous radials, the superolateral edges of which are slightly cut away, so that by the apposition of every two pieces an interradial furrow is formed.

These interradial furrows, like the radial ones, slope gently inwards towards the centre. The two sets, as soon as they pass into the axial furrows on the internal faces, become respectively converted into five radial and five interradial axial canals by the union with one another in successive pairs of small processes extending from the intervals between them towards the central calcareous network (Pl. V. fig. 4, *c.n*). These processes are the central ends of ridges which are developed on the two halves of the ventral surface of each first radial, between its median furrow (*v.r.f*) and its lateral margins. The small and irregular furrows between them usually converge towards the radial or interradial furrows, where they begin to descend into the corresponding axial canals; but in two cases (Pl. V. fig. 4, ×) they are also converted into canals by the small bridge-like processes above mentioned. These intermediate canals, like the normal radial and interradial ones, are in free communication with the rest of the spaces in the calcareous network, just as in *Ant. rosacea*; but the radial ones do not extend so far towards the dorsal surface of the pentagonal base as in this species, as will be seen when we come to study its dorsal aspect (Pl. V. fig. 3).

(§ 56) In *Act. robusta* (Pl. V. fig. 11) this sculpturing or development of ridges and furrows on the ventral faces of the first radials is carried much further than in *Act. solaris*. The muscular fossæ (*f*) are also somewhat deeper, and the median radial furrows which proceed inwards from the intervals between their superior margins (g_1) along the ventral faces of the radials are broken up very soon into a number of small irregular furrows; all converge, however, towards the centre, by the development of numerous ridges of a similar nature to those rising from the lateral halves of the ventral faces in *Act. solaris*.

These ridges completely obliterate all traces of any regularity in the passage of the radial furrows into the central calcareous network (*c.n*), as was so marked in *Act. solaris* (fig. 4). The interradial furrows, too, are not particularly distinct, as the ventral surfaces of the radials fall away but little towards their lateral margins. Towards the centre, however, they become more distinct, and are bridged over by processes extended from the above-mentioned ridges, so that they pass downwards as canals into the system of plexiform spaces occupying the central funnel of the pentagonal base. The position of one of these axial interradial canals is indicated, in Pl. V. fig. 11, by a brown bristle (II) which has been passed along it.

In the type of *Act. polymorpha* the distal faces of the radial pentagon are placed somewhat more vertically than in *Act. solaris*, so that scarcely any trace of the muscular fossæ is to be seen on its ventral aspect (Pl. VI. fig. 5). This is still more the case in var. 4 (fig. 23), in which the ventral aspect of the radial pentagon exhibits nothing but the extremely sculptured and inclined ventral faces of its component pieces; it is divided into a very large number of ridges and furrows, nearly every one of the latter having a canalicular opening into the central network (*c.n*). The radial furrows are thus entirely obliterated; and as there is no corresponding intermuscular furrow on the distal face (as in *Ant. celtica*, Pl. IV. figs. 4, 6), there is nothing to indicate their position on the outer margin of the radial pentagon. But the interradial furrows (Pl. VI. fig. 12, *v.i.f*) are readily distinguishable by their being somewhat deeper and straighter than the secondary radial furrows. This is also the case, but to a less extent, in the type (fig. 5) and in varieties 2 and 3; but var. 1 is somewhat different, and in this respect approaches *Antedon rosacea* more than any other *Actinometra* with which I am acquainted. The distal faces of the radial pentagon (Pl. VI. fig. 12) are perceptibly inclined to the vertical axis of the calyx, so that even the opening of the central canal (*c.c*) appears on its ventral aspect. The muscular fossæ (*f*) are deep, so that their superior margins project inwards and encroach somewhat on the ventral faces; and the median furrows of the latter are tolerably deep, their outer extremities passing over into the intermuscular furrows (f_1) of the distal faces. The interradial furrows between the elevated lateral halves of the ventral faces (Pl. VI. fig. 12, *v.i.f*) are also deep, but the ventral faces are plain and scarcely at all sculptured, so that both radial and interradial furrows pass down with tolerable regularity into the peripheral axial canals of the central calcareous network (*c.n*).

(§ 57) In *Antedon rosacea*, as we have already seen, the five radial diverticula of the cœlom terminate blindly on the ventral surface of the centrodorsal piece in five depressions (Pl. IV. fig. 15, *q*), which are disposed around the opening of its central cavity (*cd.c*). In correspondence with these depressions the dorsal surface of the pentagonal base presents five large openings (Pl. IV. fig. 16, *Q*), disposed in like manner around the margins of its central space. These openings are the dorsal terminations of the five radial axial canals, and are formed by the application of the five radial spout-like processes of the rosette (figs. 13, 16, *p*) to the inflected margins of the two openings (x', y) on the internal face of each first radial (fig. 12 c), through which the secondary basal cords (X_2, Y_1) pass on their course from the fibrous mass enveloping the quinquelocular organ to the circular commissure contained within the radial pentagon (compare Pl. VIII. fig. 2).

The existence of these five large openings (Pl. IV. fig. 16, *Q*) is due to the fact that the dorsal face of each first radial presents a deep notch in the centre of its inner margin (fig. 12 b, *Q'*); this notch indicates the continuation towards the dorsal surface of the radial axial furrow on the internal face (fig. 12 c, *a.r.f*); and when this furrow becomes converted into a canal by the application to its inflected edges of one of the spout-like processes of the rosette, the notch on the dorsal face also becomes converted into a circular opening. So far as I know, these openings are tolerably constant on the dorsal surface of the radial pentagon of *Ant. rosacea*; but the five depressions corresponding to them on the ventral surface of the centrodorsal piece are very variable in the distinctness of their development; and Dr. Carpenter has found that in some cases they may be absent altogether [1].

This last condition, in which there are no radial depressions (*q*) on the ventral surface of the centrodorsal piece, appears to be the normal one in *Ant. celtica*, in which I have rarely found any traces of such depressions (Pl. IV. fig. 2). The margin of the central opening is usually almost circular, though sometimes bluntly stellate as in *Ant. rosacea* (fig. 15); at the same time, the five openings (*Q*) upon the dorsal surface of the radial pentagon are but little developed or even entirely absent. In Pl. IV. figs. 3, 7, they are represented as present in the small variety and absent in the large one; but I have sometimes found exactly the reverse to be the case.

We shall find the same variability in the presence or absence of these openings in *Actinometra*, not only in different individuals of the same species, but in the same individual. This fact shows that too much reliance must not be placed on the presence, absence, or difference in size of similar openings in the calyx of the fossil Crinoids (the interradial "Lücken" in *Cupressocrinus*, for example) as characters of any systematic value. The absence or slight development of these openings in *Ant. celtica* is principally due to the fact that the inner margin of the dorsal surface of the first radials is not notched but straight, the radial axial furrow not being continued so far towards the dorsal surface as in *Ant. rosacea*; and also that processes grow inwards from the two sides of the dorsal end of each of the five spout-like rays of the rosette, so that the lumen of the canal it encloses becomes much diminished; while in some cases similar processes are put forward from the margin of the first radial, which unite with the others so completely as entirely to obliterate the lumen of the radial axial canal, and thus form its dorsal boundary.

(§ 58) The dorsal aspect of the pentagonal base of the calyx of *Actinometra* is by no

[1] Schlüter (*op. cit.* p. 37) has proposed a division of the (fossil) *Comatulæ* into two groups, characterized as follows:—(1) Centrodorsal with no radial pits and a round "Nahrungscanal" (central opening); and (2) Centrodorsal with radial pits and a quinquepartite opening.

These characters, however, are far too uncertain to be of any systematic value. For example, Schlüter himself notes the absence of the "Radialgruben" in his own specimen of *Solanocrinus scrobiculatus*, while they were present in one examined by Quenstedt (Echinodermen, p. 179). I have some specimens of *Ant. celtica* answering to the first, and others to the second of the above definitions; and although most specimens of *Ant. rosacea* would be classed in group (2), yet individuals with a pentagonal or even quinquepartite opening, *but no radial pits*, are not uncommon. This last condition is very common among the 'Challenger' *Antedons*. In fact, the radial pits of *Ant. rosacea* and *Ant. celtica* are peculiar to these species, and not always present even in them. In no other recent *Comatula* have I found any thing exactly like them. They are not parts of the generally concave surface of each radial area, but have distinct peripheral borders marking them off from these surfaces, and corresponding to the openings of the radial axial canals enclosed within the spout-like processes of the rosette. In *Act. pectinata*, *Act. polymorpha*, var. 2, and in a new 'Challenger' *Antedon* there is a distinct pit at the central end of each radial area, which is merely the deepened termination of a depression occupying its median line. Its nature (sects. 45 & 61) is essentially the same as that of the radial pits of *Ant. rosacea*, but its appearance is very different. Hence I cannot corroborate Schlüter's statement that "Manche Arten" possess "Radialgruben." He only describes them in 5 out of his 11 fossil species, besides the *Solanocrinus scrobiculatus* examined by Quenstedt.

means of such a simple nature as it is in *Ant. celtica* (Pl. IV. figs. 3, 7), where it consists solely of the five adjacent dorsal surfaces of the component radials. These are somewhat elevated in the centre but fall away towards the sides, where they are separated from one another by slight furrows, corresponding in position with the five interradial ridges on the ventral surface of the subjacent centrodorsal piece (Pl. IV. fig. 2, *i.e*). In *Actinometra*, however, these dorsal interradial furrows are very marked; but they are not usually visible on the dorsal aspect of the radial pentagon, as they are occupied by five long processes which radiate outwards from the angles of the central vacuity in which the rosette lies (Pl. V. fig. 3; Pl. VI. figs. 4, 9, 13, 24, *S*).

The presence of these rays of the basal star introduces an element of considerable complexity into the dorsal aspect of the pentagonal base of *Actinometra*; and its nature will be best understood if we commence with the study of its component pieces in the large *Act. robusta*. The dorsal face of each first radial of this species (Pl. V. fig. 12) is slightly convex, so as to fit into the somewhat depressed radial area corresponding to it on the ventral surface of the centrodorsal piece (Pl. V. fig. 14, *r.ar*). The centre of its inner margin is, as in *Ant. rosacea*, marked by a deep notch, which indicates the position of the axial radial furrow occupying the median line of the internal face (fig. 10, *a.r.f.*). The latter is converted into a canal by the union of its inflected edges with those of one of the radial spout-like processes of the rosette (figs. 12, 13, *p*), in the manner already described by Dr. Carpenter for *Ant. rosacea*.

The central notch on the inner margin of the dorsal face thus becomes a round opening (fig. 12, *Q*), similar to that seen in *Ant. rosacea* (Pl. IV. fig. 16, *Q*). A bristle passed through this opening towards the ventral side, therefore, will follow the course of one of the axial radial canals, in which its lower end is concealed by the spout-like radial process of the rosette (Pl. V. figs. 12, 13, I). On the ventral side of the rosette the radial axial canal is incomplete, as the furrow on the internal face is only partially bridged over by the calcareous processes which extend themselves from its sides to meet the rosette; the bristle which lies in the furrow is therefore visible here and there through the openings in the network (*c.n*) formed by the inosculation of these processes (figs. 10, 13, I). This is best seen in fig. 13, which is a view of two radials from within, together with that portion of the rosette which corresponds to and is united with them; and also in fig. 10, which represents the internal face of a single radial, from which the portions of the rosette that are normally united with it have been removed, so that the whole of the internal face is exposed. The bristle I is seen to lie in the deep furrow between the two raised edges of the apertures (x', y) of the central canal, and to pass upwards under the network extending from the ventral half of the internal face, where it follows the course of the axial radial furrow and emerges on the ventral aspect of the radial. The furrow in which it lies is here continued into the numerous irregular furrows of the ventral face which converge towards the centre of its inner margin (Pl. V. fig. 11).

Just above the dorsal surface of the radial, the axial furrow occupying the median line of its internal face gives off a large horizontal diverticulum into the substance of its calcareous tissue, which extends outwards for some distance between the central canal and the dorsal surface of the radial (fig. 10, *r.c'*); and, like the axial furrow or canal as it is in the natural condition when the rosette is *in situ*, encloses a dorsal extension of the body-cavity or cœlom. I have seen no trace of these diverticula in any other species of *Comatula* that I have yet examined; but they are very large and well marked in each of the five first radials in *Act. robusta*.

(§ 59) The furrows which occupy the median line of the ventral and internal faces of the first radials thus terminate in *Act. robusta* (Pl. V. fig. 12) precisely as in *Ant. rosacea* (Pl. IV. fig. 16), by five large openings (Q) on the dorsal aspect of the radial pentagon, which are closed in the natural condition by the ventral surface of the centrodorsal plate on which the radial pentagon rests.

In *Ant. rosacea* the course of the slightly marked interradial furrows which pass down from the ventral aspect of the radial pentagon into the peripheral portion of the central calcareous network is terminated inferiorly by the five triangular interradial processes of the rosette; for the apices of these processes unite with the two members of every pair of contiguous radials, just between the two adjacent apertures of their central canals (Pl. IV. figs. 3, 7, 16, o').

In *Actinometra*, however, the interradial furrows both are more marked on the ventral surface of the radial pentagon, and, like the radial ones, become converted into canals, terminating by five openings upon its dorsal aspect.

In *Ant. rosacea* the edge which separates the lateral and dorsal faces of each first radial is tolerably sharp and straight (Pl. IV. fig. 12 b, c); but in *Act. robusta* it is somewhat truncated (Pl. V. figs. 10, 12, 13), so that when the lateral faces of two radials are in apposition a deep interradial furrow appears along the line of union of their dorsal surfaces (fig. 12, *a.i.f*). In the middle of the inner margin of the floor of this furrow is a notch similar to that marking the centre of the inner margin of the dorsal face of each single radial, both in this species and in *Ant. rosacea* (Pl. IV. fig. 12 b, Q'), except that two radials take part in its formation instead of only one. This notch marks the continuation towards the dorsal surface of an interradial furrow from the ventral aspect of the pentagonal base.

The edges between the internal and lateral faces of each first radial are truncated in the same way as those between the dorsal and lateral faces (Pl. V. figs. 10, 13). In the natural condition, therefore, when the lateral faces of all the radials are in apposition with one another in pairs, there are five axial interradial furrows alternating with the radial ones, which occupy the median lines of the internal faces. The ventral portions of these, as of the axial radial furrows, are partially bridged over by the inosculating calcareous processes which extend themselves towards the ventral aspect of the rosette from the internal faces of the five first radials, so that a bristle passed along their course is only partially visible (Pl. V. fig. 13, II).

These superior portions of the axial interradial furrows are in free communication, both laterally, with the radial furrows occupying the intervals between them, and centrally with the remaining spaces of the calcareous network, of which system these two sets of furrows form the peripheral part. Inferiorly, *i. e.* towards the dorsal surface, each of these axial interradial furrows passes between the two outer lips of the adjacent apertures (x, x') of the central canals of two contiguous radials along the line of union of which the interradial furrow is situated. The outer lips of these apertures, like the inner ones (Pl. V. fig. 10), are raised and applied to the similarly inflected edges of the five spout-like *interradial* processes of the rosette, so that the furrow lying between the apertures becomes converted into a complete canal. A bristle, therefore, which lies in the course of this furrow (Pl. V. figs. 12, 13, II) is concealed by the interradial process (*o*) of the rosette. The dorsal end of the latter unites with the margins of the notch described above at the central end of the dorsal interradial furrow, so as to produce a roundish interradial opening on the dorsal aspect of the pentagonal base, through which the bristle passed along the axial interradial furrow emerges from its concealment beneath the interradial process of the rosette (figs. 12, 13, II). The manner in which these openings are closed in the natural condition by the central ends of the rays of the basal star will be best described further on.

(§ 60) In the condition and relative inclination of their dorsal and internal faces, the first radials of *Act. robusta* are more like those of *Ant. rosacea* than those of any other of the various *Actinometræ* which I have examined. In *Ant. rosacea* the ventral surface of the centrodorsal piece (Pl. IV. fig. 15) is almost flat, as the five radial areas into which it is divided lie nearly in a horizontal plane; and the corresponding dorsal surfaces of the five first radials are likewise horizontal, and form an angle of but little more than 90° with the internal faces (Pl. IV. fig. 12 b, c). In *Act. robusta* this angle becomes more obtuse, so that the dorsal surfaces of the radials are somewhat inclined to the horizontal plane (Pl. V. figs. 10, 13); and, in correspondence with this, the radial areas on the ventral surface of the centrodorsal (fig. 14, *r.ar.*) have a slight downward and outward slope between their central and peripheral margins, so that the whole surface rises very gradually from the circumference towards the centre.

This is also the case in *Act. solaris*, in which the dorsal surface of the radial pentagon slopes slightly downwards from its margin towards the opening of the central vacuity in which the rosette is situated (Pl. V. fig. 3), so as to correspond with the gradual elevation between the circumference and centre of the ventral surface of the centrodorsal on which it rests (fig. 2).

Act. solaris also agrees with *Act. robusta* in the fact that the sides of the dorsal interradial furrow (fig. 3, *a.i.f*) which is produced by the truncation of the adjacent superolateral edges of two contiguous radials are simple and straight, and not raised into leaf-like folds, as in *Act. pectinata* (fig. 9 b) and *Act. polymorpha* (Pl. VI. figs. 9, 13, 24; Pl. VII. figs. 1 d, 4 d, *b.g*).

In *Act. solaris* there are none of the apertures which occur in *Ant. rosacea* and *Act. robusta*, by which the axial radial canals open upon the dorsal surface of the radial pentagon (Pl. IV. fig. 16, and Pl. V. fig. 12, *Q*). We have already seen (sect. 57) that they may be absent in *Ant. celtica* (Pl. IV. fig. 3); and their absence in *Act. solaris* is due to the same cause as in this case, viz. to the want of a central notch on the inner margin of the dorsal face of each first radial, and to the obliteration of the lumen of each canal by the ingrowth of calcareous tissue from its sides.

In the closely allied *Act. pectinata*, however, these openings may be present (and not improbably also in other specimens of *Act. solaris* than the one which I have examined);

for the inner margin of the dorsal face of each first radial exhibits a slight median notch (Pl. V. fig. 9 b, Q'), though it is by no means so distinct as in *Ant. rosacea* (Pl. IV. figs. 12 b, 16) and *Act. robusta* (Pl. V. fig. 12).

In this species too the ventral surface of the centrodorsal plate (Pl. V. fig. 7) rises very perceptibly from its circumference towards its centre; and the dorsal face of each first radial is very considerably inclined to the vertical internal face, the angle between the two almost reaching 135° (Pl. V. fig. 9 b, c). Consequently, when the radial is viewed from its dorsal side, the large projecting lips of the two apertures of its central canal are seen below the central or inner edge of the inclined dorsal face (fig. 9 b, x', y). These are not seen in a similar view of a first radial of *Ant. rosacea*, in which the inclination of the dorsal to the internal face is very little over 90° (Pl. IV. fig. 12 b, c).

(§ 61) In *Ant. rosacea* and *Act. robusta* the slight convexities of the dorsal surfaces of the first radials fit into the correspondingly slight concavities in the centre of the radial areas on the ventral surface of the centrodorsal piece (Pl. IV. figs. 2, 3, 15, 16; Pl. V. figs. 12, 14). In *Act. pectinata*, however, these areas are occupied by median depressions, increasing somewhat in depth from their peripheral to their central ends (Pl. V. fig. 7, *r.ar*); but the dorsal faces of the first radials do not exhibit corresponding ridges, for they have similar median depressions, which are also deepest at their central ends (Pl. V. fig. 9 b, c, *d.r.f*).

When, therefore, the dorsal surface of the radial pentagon and the ventral surface of the centrodorsal piece are in their normal state of apposition, they are separated from one another along the median lines of the five radials by five cavities or radial spaces; these are largest at their central ends, and extend in a peripheral direction to open externally by five small openings situated on the margin of the small centrodorsal piece, beneath the radial pentagon which rests upon and extends considerably beyond it.

These "radial spaces" are seen in section in Pl. VIII. figs. 5–8, which represent parts of four sections selected out of a series that was cut through a decalcified calyx of *Act. pectinata*.

The section represented in fig. 5 was cut across the angle of two radials (A, B) near the edge of the centrodorsal piece, and the open outer ends of the radial spaces are cut somewhat obliquely (*r.s*). Fig. 6 represents a section much nearer the centre, and the closed inner ends of the radial spaces are seen just beneath the lower ends of the axial radial canals (*a.r.c*), but not communicating with them. In fig. 7 two other spaces are seen, cut almost longitudinally, as the section is one from the other side of the centre, through the radii, C & E, almost in the direction of their axial nervous cords (n), beneath which are the radial spaces (*r.s*) between the dorsal surfaces of the first radials and the ventral surface of the centrodorsal piece. Lastly, in fig. 8, which represents a section still further from the centre, and cut transversely to the direction of radius D, the closed central end of the corresponding radial space is seen, as in fig. 7, on the dorsal side of the axial nervous cord (n); at either side of it (s) is the expanded lower end of one of the axial interradial canals seen in fig. 7 (*a.i.c*).

The external medium which occupies these radial spaces between the radial pentagon and the centrodorsal piece is only shut off from the dorsal portion of the cœlom enclosed within the radial pentagon, and from the centrodorsal cœlom, by the small bony bars at their expanded central ends, which form the thickened inner or central edges of the dorsal faces of the first radials (Pl. V. fig. 9 b, c.) They are slightly developed in one of the varieties of *Act. polymorpha*, in which the radial areas of the small centrodorsal piece (Pl. VI. fig. 17, *r.ar*) and the corresponding dorsal faces of the first radials (Pl. VII. fig. 4 a, d) both exhibit median depressions, which gradually increase in depth from their peripheral to their central ends. In both these cases the centrodorsal piece is relatively very small and by no means conceals the first radials, while its ventral surface rises very considerably from the circumference towards the centre (Pl. V. fig. 7, and Pl. VI. fig. 17). The meaning of these radial spaces is to me quite obscure. In no other *Comatula* have I found any thing at all comparable to them except in *Act. robusta*, where the axial radial canals give off horizontal diverticula (Pl. V. fig. 10, *r.c'*), which extend outwards in a peripheral direction in the substance of each first radial just beneath its dorsal surface. These, enclosing diverticula of the dorsal portion of the cœlom, are, of course, in indirect communication with the external medium, while the radial spaces in *Act. pectinata* are altogether outside the substance of the first radials, communicate directly with the exterior, and are completely shut off from the dorsal cœlom. There is, therefore, scarcely any resemblance between the two sets of cavities, although they occupy very nearly similar positions, *i. e.* between the centrodorsal piece and the whole or the greater part of the mass of the first radials.

In some species of the fossil *Apiocrinus*, however, cavities similar to the radial spaces in *Act. pectinata* appear to exist between every pair of contiguous basals and the first radial, which rests upon them and alternates with them in position. As the basal circlet is generally regarded as comparable to a stem-segment, it is evident that the positions of these cavities in *Act. pectinata* and in *Apiocrinus* respectively are homologous with one another. In *Apiocrinus rotundus* five lateral openings were discovered by Miller[1] on the circumference of the body, "in or between the lateral surfaces of the joints of the pelvis (basals) and the insertion of the first costal (radial) joints," which in one case he thought he was able to trace as a canal or perforation "passing through the joint of the pelvis into the space between it and the costal joints, extending perhaps thence into the perivisceral cavity" (*i. e.* into the dorsal division of the body-cavity).

Miller supposed these to be the openings of oviducts leading to an ovary situated in this dorsal cœlom, just in the same manner as the five openings on the ventral surface of the centrodorsal piece of *Glenotremites* were (till lately) regarded as genital openings, although the genital glands of all the recent Crinoids with which we are acquainted are situated in the arms and pinnules.

Similar openings to those seen by Miller in *Ap. rotundus* have been described in *Ap. obconicus* by Goldfuss[2], who also supposed them to lead into the body-cavity. This is, however, certainly not the case with the homologous openings in *Act. pectinata*.

The interarticular pores in the upper part of the stem of *Pentacrinus* are also homologous with the external openings of the radial spaces in *Act. pectinata*. They are the

[1] *Op. cit.* p. 31. [2] Petref. German. p. 187, Taf. vii. fig. 5, *a*, *b*, *c*.

openings of spaces between the successive segments, which are similarly situated, with regard to the radial symmetry of the animal, to the radial spaces in *Act. pectinata*, viz., in the direction of the radii; and they are produced in the same way, by the apposition of two grooves radiating outwards from the centre of each stem-segment, which are largest at their central ends and shallowest towards the periphery.

(§ 62) In *Ant. rosacea* and *celtica* (Pl. IV. figs. 3, 7, 16), and in *Act. robusta* and *solaris* (Pl. V. figs. 3, 10, 12, 13), the sides of the interradial furrows (*d.i.f*) on the dorsal surface of the radial pentagon are simple and straight; but in *Act. pectinata* that portion of the dorsal surface of each first radial which is next to its truncated lateral edge is raised into a sort of curved ridge or fold (Pl. V. fig. 12 b, *b.f*), so that in the natural condition of mutual apposition of the five first radials the dorsal interradial furrows become somewhat lancet-shaped. They correspond in position with the basal grooves on the ventral surface of the subjacent centrodorsal piece (Pl. V. fig. 7, *b.g*), and in the cavity formed by the apposition of the edges of these two grooves lie, as will be subsequently seen, the five rays of the basal star.

The first radials of *Act. polymorpha* are very similar to those of *Act. pectinata.* Those of variety 1 (Pl. VI. fig. 12) are like those of the type (Pl. VII. fig. 1), except in the simpler condition of their ventral surface, which is far less marked by secondary ridges and furrows than is the case in the type (Pl. VI. fig. 5). In the other three varieties, the first radials of which resemble one another very closely, this sculpturing of the ventral surface is even more marked than in the type (Pl. VI. fig. 23; Pl. VII. fig. 4 c). The angle between the dorsal and internal faces is considerably less in the type (Pl. VII. fig. 1 a,d) and in var. 1 than in varieties 2, 3, and 4, the first of which resembles *Act. pectinata* in the presence of a median depression of the dorsal face (Pl. VII. fig. 4 a,d, *d.r.f*), which corresponds with a similar depression along the median line of the radial areas of the small centrodorsal piece (Pl. VI. fig. 17, *r.ar*). This dorsal interradial furrow does not exist in varieties 3 and 4, nor in var. 1 (fig. 13), while there is a trace of it in some specimens of the type, but not in others (figs. 4, 9). In like manner the development of the openings of the radial axial canals on the dorsal surface of the pentagonal base, which are so large in *Ant. rosacea* and in *Act. robusta* (Pl. IV. fig. 16; Pl. V. fig. 12, *Q*), is in *Act. polymorpha* extremely variable. In two specimens of the type (Pl. VI. figs. 4, 11) they are entirely absent, as in *Act. solaris* (Pl. V. fig. 3); in another the inner margin of the dorsal face of each first radial exhibits a slight median notch (Pl. VI. fig. 9; Pl. VII. fig. 1 a, *Q′*), which would be completed into an opening by the apposition to it of the end of one of the radial spout-like processes of the rosette.

In variety 1 this notch is fairly marked, and five small openings are consequently visible around the central vacuity, on the dorsal surface of the pentagonal base (Pl. VI. fig. 10, *Q*). In varieties 2 (Pl. VII. fig. 4 a) and 3 it is somewhat more distinct; and in var. 4 it exists in three of the first radials, but not in the other two, so that there are only three openings on the dorsal surface of the pentagonal base (Pl. VI. fig. 24, *Q*).

The extent to which the basal folds are developed at the sides of the dorsal interradial furrows is also very variable in *Act. polymorpha.* We have seen that, although absent in *Act. solaris* (Pl. V. fig. 3), they are well marked in the closely allied *Act. pectinata* (Pl. V. fig. 9 b, *b.f*). In two specimens of the type of *Act. polymorpha* (Pl. VI. figs. 4, 11) they are absent altogether, while in a third they are very well marked (fig. 9, *b.f*), as also in each of the varieties, three of which are represented in Pl. VI. figs. 13, 24, and Pl. VII. fig. 4 a. In all these cases the borders of the interradial furrows on the dorsal surface of the pentagonal base, which are produced by the apposition of the truncated superolateral edges of every pair of contiguous radials, assume a leaf-like appearance, owing to the presence of the folds at their sides. The precise shape of these leaves, which is different in the type and in all the four varieties, corresponds very closely with the shape of the basal grooves on the ventral surface of the centrodorsal piece, with which they also correspond in position. They further resemble them in the fact that they are entirely devoid of the pigment which is so abundant on the other parts of the surfaces of the radial pentagon and centrodorsal piece; so that when these last are separated from one another, the dorsal interradial furrows on the pentagonal base, like the basal furrows on the centrodorsal piece, stand out sharp and distinct as five white leaflets on a dark-brown background. They are best marked in var. 4 (Pl. VI. fig. 24, *b.f*), in which the basal folds of every pair of contiguous radials are rather widely separated from each other about the middle of their length. This is also the case, though to a less extent, in var. 1 (fig. 13), where, as in var. 4, the dorsal interradial furrows correspond very closely in shape with the basal grooves on the centrodorsal piece (fig. 15).

This is particularly distinct in the specimen of the type represented in Pl. VI. figs. 8, 9, in which one of the basal grooves is much shorter than the rest, and does not reach the margin of the centrodorsal piece. The basal folds at the sides of the dorsal interradial furrow corresponding to this aborted groove are also imperfectly developed, so that the borders of its outer end are simple and straight; as they are throughout the whole course of the furrows in *Act. solaris* (Pl. V. fig. 3) and *Act. robusta* (Pl. V. fig. 12).

This last condition may also occur in the type of *Act. polymorpha* (Pl. VI. figs. 4, 11); and in correspondence with it the basal grooves on the centrodorsal piece are simple and almost parallel-sided (Pl. VI. figs. 3, 10, *b.g*), just as in *Act. solaris* and *Act. robusta* (Pl. V. figs. 2, 14).

This correspondence in the appearance of the dorsal interradial furrows and basal grooves which is also seen in *Act. polymorpha*, var. 2 (Pl. VI. fig. 17; Pl. VII. fig. 4 a), is not, however, an invariable one; for in *Act. pectinata* the basal folds are very well marked (Pl. V. fig. 9 b, *b.f*), and the dorsal interradial furrows, therefore, leaf-like in appearance, as in most specimens of *Act. polymorpha* (Pl. VI. figs. 9, 13, 24). The basal grooves, however, on the ventral surface of the centrodorsal piece are narrow and parallel-sided (Pl. V. fig. 7, *b.g*), just as in the allied species *Act. solaris* and *Act. robusta* (Pl. V. figs. 2, 14).

The external or distal faces of the first radials of *Act. polymorpha* differ not a little from the corresponding faces in *Ant. rosacea* and *Ant. celtica* (Pl. IV. figs. 4, 6, 8, 12 a, 14, 17); in which, especially in the latter, the fossæ (*f*) for the attachment of the muscles are very large, and considerably more extensive than those which lodge the interarticular ligaments (*h*).

In *Act. polymorpha* (Pl. VI. fig. 1; Pl. VII. figs. 1 b, 4 b), however, the muscular fossæ are very small, being best developed in var. 1 (Pl. VI. fig. 12, *f*); while the fossæ (*h*) lodging the interarticular ligaments are very extensive, and separated by the downward continuation of the intermuscular furrow (f_1), which reaches the dorsal margin of the opening of the central canal (*c.c*). The external faces of the first radials of varieties 2 (Pl. VII. fig. 4 b), 3, and 4 resemble one another, but differ from the corresponding faces in the type (Pl. VII. fig. 1 b) in being somewhat higher in proportion to their width, and in the fact that the fossæ (*j*) lodging the elastic ligaments are relatively smaller, not extending so far into the lower or dorsal angles of the face as is the case in the type.

(v.) *The Basals.*

(§ 63) We have already seen that all the older observers regarded *Comatula* as devoid of those five pieces resting upon the top segment of the stem to which, in the other Crinoids, Müller gave the name of "basals;" and it was not until Dr. Carpenter[1] discovered the extraordinary metamorphosis undergone by the embryonic basals of *Comatula (Antedon) rosacea* and their transformation into the "rosette," that the existence of basals, although internal and concealed in the adult animal, was recognized.

The rosette of *Ant. rosacea* and *Ant. celtica* (Pl. IV. figs. 3, 7, 16, *R*) is a peculiarly shaped circular plate, occupying the dorsal half of the central cavity in the pentagonal base of the calyx, which lies much nearer to the dorsal surface of the pentagonal base in the latter species than in the former.

A normal rosette consists of a disk perforated in the centre with ten rays proceeding from it. Five of these rays (Pl. IV. fig. 13, *o'*) are short, triangular in form, and nearly flat, and their position is interradial, as they are directed to the sutures between the five radials, their apices joining the contiguous pairs of these just between the two adjacent apertures (*x*, *x'*) of their central canals.

Alternating with these five interradial processes of the rosette are five radial ones (fig. 13, *p*), each of which has parallel margins inflected on its ventral aspect in such a manner as to form a groove; while the process itself is so curved towards its dorsal aspect that this groove reaches the periphery of the rosette, and then terminates abruptly as if truncated.

The inflected margins of each of these five radial or, as Dr. Carpenter has called them, "spout-like" processes of the rosette are applied to the similarly inflected margins of the dorsal half of the axial radial furrow, lying between the two apertures of the central canal on the internal face of each first radial (fig. 12 c, *x'*, *y*). In this manner a complete radial axial canal is formed, which, as we have already seen, terminates on the dorsal surface of the radial pentagon by the opening *Q* (fig. 16), or becomes closed before it reaches the dorsal surface by the union of ingrowths developed from its walls.

Besides this very intimate union between the peripheral portion of the rosette and the

[1] Phil. Trans. 1865, pp. 744, 745.

internal faces of the first radials, its central portion is also frequently connected with the radial pentagon by delicate processes, which sometimes sprout forth irregularly from the inner margins of the component pieces of the latter; but sometimes form a more regular ingrowth, which considerably contracts the central space on the ventral aspect of the disk, and becomes continuous with an annular projection from the ventral face of the rosette.

(§ 64) Before attempting to understand the complicated condition of the basals in *Actinometra*, it will be well to study the mode in which the embryonic basals of *Ant. rosacea* become metamorphosed into the rosette, as described by Dr. Carpenter, from whose memoir the following account is principally taken.

In the young animal each basal is a flattened irregularly pentagonal plate, the apex of which lies between a pair of radials that partially rest upon it. On the ventral surfaces of the basal plates lie the five primary basal cords V, W, X, Y, Z, proceeding from the angles of the quinquelocular organ. Each of these divides into two branches, V_1, V_2, ... Z_1, Z_2, the secondary basal cords, which pass on to the ventral faces of each pair of contiguous radial plates, *e. g.* X_2 and Y_1 to one radial, Y_2 and X_1 to the next, and so on.

Both basals and radials gradually become much thickened by an endogenous extension of the calcareous network, which takes place in such a manner that the basal cords come to lie in furrows channelled out on the ventral surfaces of the plates. By a further endogenous growth of the radial plates these furrows are converted into canals (the "central canals" of Johannes Müller), which at first lie close under the ventral surfaces of the plates, but come gradually, by a continuation of the same process, to lie in their central axis.

In the basals, however, this process of endogenous growth is followed by one of absorption; for the cribriform film of which each basal is originally composed, and which still forms its external layer, now undergoes absorption, especially in its central portion, where it covers in the dorsal side of the primary basal cord; so that the central space left by the incomplete union of the proximal ends of the five embryonic basal plates is extended on its dorsal aspect into five broad rays, though on its ventral aspect, where it is bounded by the last-formed portion of the endogenous reticulation, it shows no corresponding increase. It is this last-formed ventral portion which persists in the adult as the five triangular interradial processes of the rosette (Pl. IV. figs. 3, 7, 13, 16, o').

The formation of the five radial or spout-like processes is somewhat more complicated. The removal of the external layer in the centre of the dorsal aspect is carried so far as to leave nothing but a kind of thickened margin along those sides of the plate which are received between the first radials; and by an extension of the same process along the median dorsal line of each plate as far as its salient angle, so as completely to remove the terminal portion of its inferior or dorsal layer, its two lateral portions become separated from each other at their distal ends, and remain as small curved processes extending outwards. Those of every two contiguous basals now unite to form a sort of ray curving towards the dorsal aspect; and this is the rudiment of one of the five radial or spout-like processes of the rosette, the shape of which becomes much more strongly pronounced with the subsequent increase of its size (Pl. IV. fig. 13, *p*). The rosette is thus essentially formed at the expense of the secondary or ventral layer of the original basals, the ends of the curved spout-like processes being the sole residue of their primary or dorsal layer; and since, by the removal of the median portion of that layer in each plate, the primary basal cords are left bare upon their dorsal aspect, they now pass from the angles of the quinquelocular organ into the central canals of the first radials, on the inferior or dorsal side of the calcareous skeleton which occupies the base of the calyx; instead of reaching them by passing, as they did in the first instance, along its superior or ventral face or, as at a later period, through the middle of its substance.

Each of these primary basal cords, X, Y, &c., which are thus interradial in position, divides into two branches, X_1, X_2, Y_1, Y_2, &c., towards the periphery of the rosette, on the dorsal surface of which it rests. These branches lie in the shallow channels which mark the union of the base of each interradial triangular process (fig. 13 b, o') with the two curved lateral processes above mentioned, each of which unites with a corresponding process from the adjacent basal to form one of the five spout-like rays (*p*) of the rosette. The apex or peripheral end of each triangular process is directed to the suture between two contiguous radials (figs. 3, 7, 16, o'), to which it is attached just between the two adjacent apertures (x, x') of their central canals. Into these canals pass the secondary basal cords X_1, X_2, one into each of the two contiguous radials, so that one lies on each side of the interradial process of the rosette.

(§ 65) As a general rule, this process, both in *Ant. rosacea* and in *Ant. celtica*, is short, triangular, and slightly curved towards the ventral side. It is not always so, however, for I have frequently met with specimens of *Ant. rosacea* in which one or more of the interradial processes of the rosette, after bending for a short distance towards the ventral side, turns suddenly downwards, and extends towards the dorsal surface of the radial pentagon. At the same time the parallel margins of each of these abnormally developed processes are so inflected towards the dorsal surface as to form a narrow *interradial* spout-like process. This is so applied to the projecting and similarly inflected outer edges of the adjacent openings of the central canals (x, x') in two contiguous radials as to convert the interradial furrow lying between them into a complete axial interradial canal, precisely similar in character to the radial axial canals already described (§§ 52, 57).

In one case which I have met with, four out of the five interradial processes of the rosette were of this character. In the rosette represented in Pl. IV. fig. 13, only two of the interradial processes (*o*) are long and spout-like, the other three (o') are short and triangular, like those of a normal rosette.

This abnormal condition of the interradial process of the rosette of *Ant. rosacea* is of considerable interest, as it is the normal one in *Actinometra* and in many species of *Antedon*.

Not only the interradial, but also the radial processes of the rosette of *Ant. rosacea* may exhibit departures from their usual shape; for the removal of the primary or dorsal layer at the salient angle of one or more of the five embryonic basals may be incomplete, so that the ends of the curved rays of the rosette exhibit lateral processes, which are the remains of the upper margins of the primitive basal plates on which the first radials rested. Occasionally the apex of the original basal is left unabsorbed, so that the two lateral curved processes which remain after the removal of the primary external layer along the median line of each plate remain in connexion with one another; as is seen in the bottom part of the rosette represented in Pl. IV. fig. 13. The triangular interradial process (o'), which is developed from a secondary calcareous deposit on the ventral side of the original basal, has here become more or less completely united with these primary bars connecting the two lateral portions of the basal. The latter retain their primitive relation to the first radials, for they remain united with them along the inner margins of their dorsal faces (fig. 16, *b.b*); and as they partially cover in the secondary basal cords, X_1, X_2, &c., on their dorsal aspect before they enter the central canals of the first radials, I will call them the "basal bridge" (Pl. IV. fig. 13, *b.b*).

This basal bridge is well seen *in situ* in the specimen of *Ant. rosacea* represented in Pl. IV. fig. 16. It is remarkably well developed, being nearly as distinct as in *Actinometra* (Pl. V. figs. 3, 12, and Pl. VI. figs. 4, 13, 24, *b.b*), in which its presence is normal, and not abnormal, as in *Ant. rosacea.* It is also slightly developed in the specimen of *Ant. celtica* represented in Pl. IV. fig. 3; but in fig. 7 no trace of it is visible.

(§ 66) This tendency to an incomplete metamorphosis of the embryonic basals of *Ant. rosacea*, and consequently to the abnormal persistence of a more embryonic condition than usual, is of considerable interest, because in *Actinometra* and in many *Antedons* a basal bridge, representing the apex and unabsorbed margins of the embryonic basal plates, is normally present (Pl. V. figs. 3, 8, 12, and Pl. VI. figs. 4, 6, 13, 18, 19, 22, 24, *b.b*). While at the same time, as already mentioned, the interradial processes of the rosette (o), which are developed from a secondary or ventral layer, are large and spout-like, as is abnormally the case in *Ant. rosacea*, and acquire a connexion with the remains of the primary or dorsal layer which forms the basal bridge. The complicated rosette thus constituted also becomes united with the large, more or less spindle-shaped, rays of the basal star (S), the origin of which, as will be subsequently seen, is totally different from that of the rosette.

A single "compound basal," as it may be called, of *Actinometra*, thus consists of two distinct elements—(i) the incompletely metamorphosed embryonic basal, and (ii) a single ray of the basal star. Its position is interradial, as it occupies the space enclosed between the apposed edges of the basal furrows on the ventral surface of the centrodorsal piece, and of the interradial furrows on the corresponding dorsal surface of the radial pentagon (Pl. VI. figs. 4, 13, 24, S).

An isolated compound basal which is thus constituted, when seen from its dorsal side (Pl. V. fig. 8 b, Pl. VI. fig. 22 b), shows :—(i) more or less of the calcareous network (*c.n*) which unites the ventral surface of the rosette to the internal faces of the first radials; (ii) a large interradial spout-shaped process (o); (iii) two small, radial, curved processes (p'), extending outwards from the base of the interradial process, and representing the unabsorbed lateral portions of the primary layer forming the embryonic basal plate.

(iv) The basal bridge (*b.b*), consisting of two calcareous bars, that represent the unabsorbed peripheral margins of the embryonic basal on which two first radials rested. They extend towards one another from the outer ends of the small radial processes, until they meet at a point that represents the apex of the embryonic basal, and is situated on the dorsal side of the peripheral end of the interradial process (*o*), developed from the secondary or ventral layer, which becomes united with the basal bridge.

(v) The ray (*S*) of the basal star, which is joined to the interradial process and to the basal bridge, along the line of union of the two primary bars constituting the latter with one another and with the secondary interradial process, *i. e.* at the apex of the embryonic basal. The development of this ray is quite different from that of either the primary or the secondary portions of the compound basal. It is really a tertiary structure, being nothing more than a deposition of calcareous material in the substance of the connective tissue of the synostosis between the centrodorsal piece and the radial pentagon.

(vi) At the sides of the interradial process (*o*), bounded laterally by the radial processes (p'), and externally by the bars of the basal bridge (*b.b*), are two large apertures, x_1, x_2, y_1, y_2, &c., in each compound basal. Through these apertures pass the secondary basal cords, X_1, X_2, Y_1, Y_2, &c. (Pl. VIII. fig. 3), which result from the bifurcation of the primary cords, *X*, *Y*, *Z*, proceeding from the angles of the quinquelocular organ. The two secondary cords lie in the depressions on the dorsal surface of the compound basal, between the central ends of its radial and interradial processes. They then pass outwards through the apertures (x_1, x_2, &c.) beneath the bars of the basal bridge, and enter the adjacent openings (x, x', &c.) on the internal faces of the two contiguous first radials[1], which contribute to form the dorsal interradial furrow occupied by the single fusiform ray (*S*) of the corresponding basal.

The ventral surface of each of these rays of a compound basal (Pl. V. fig. 8 a; Pl. VI. figs. 6, 18, 22 a) is not flat, like the dorsal surface, but occupied by a prominent median ridge, so that the ray is triangular in section. This ridge does not extend quite to the central end of the ray, which is occupied by a considerable depression (*s*), forming the peripheral end of the groove contained in the spout-like interradial process (*o*). In the natural condition, when the basals are *in situ* and in connexion with the radial pentagon, the inflected edges of this process unite with those of the axial interradial furrow to form an axial interradial canal. This terminates on the dorsal surface of the radial pentagon by a small opening situated at the central end of the dorsal interradial furrow (Pl. V. fig. 12, II), in which furrow the tertiary element (*S*) of the corresponding compound basal is received. The depression (*s*) at the central end of the ray (Pl. V. fig. 8 a; Pl. VI. figs. 6, 18, 22 a) lies over this opening, and thus forms a blind end to the axial interradial canal (Pl. VIII. figs. 3, 5, 7, *a.i.c*; fig. 8, *s*)—precisely in the same manner as the depressions (*q*) on the ventral surface of the centrodorsal piece of *Ant. rosacea* (Pl. IV. fig. 15) receive the blind ends of the axial radial canals which open on the dorsal surface of the radial pentagon by the five large openings, *Q* (Pl. IV. fig. 16).

A view of a single compound basal does not, of course, show one of the large and

[1] In Pl. V. fig. 13, four of these openings are seen on the internal faces of the two contiguous first radials, viz. x', y, y', z.

spout-like radial processes of the rosette; for each of these is a composite structure, formed by the apposition of two of the small curved lateral processes of contiguous basals (Pl. VI. fig. 22, p'). This is seen in Pl. VI. figs. 6, 18, 19, particularly in the last two; for the union of the adjacent lateral processes (p') of the two contiguous basals which are there represented, is seen to be incomplete, so that a slight fissure is visible along the median line of the dorsal surface of the composite radial process (fig. 19, p). The peripheral end of this radial process is united to those of the interradial processes (o) at its sides by the bars of the basal bridge ($b.b$). Their central ends are also united around the opening of the rosette (Pl. VI. figs. 4, 19, 24, R); but their median portions are separated by the two apertures (x_2, y_1) by which the two adjacent secondary basal cords (X_2, Y_1) pass out under the bars of the basal bridge, to enter the two openings of the central canal on either side of the axial radial furrow on the internal face of the first radial (Pl. V. figs. 9 c, 10; Pl. VII. figs. 1 a, 4 a, x', y), with the inflected inner edges of which the radial spout-like process (p) unites.

The openings (x_1, y_2) by which the other branches (X_1, Y_2) of the two primary basal cords pass outwards to reach the central canals of the other two radials corresponding to these two basals are best seen in a dorsal view as shown in Pl. VI. fig. 19. This also shows the two outer lateral processes (p') of these united basals, which would naturally unite with those of the two next contiguous basals, one on each side, to form two more radial spout-like processes.

(§ 67) The tertiary elements which form the rays of the basal star vary very considerably in their shape and in the completeness with which they are developed, just as do the interradial furrows on the dorsal surface of the radial pentagon in which they lie. In *Act. solaris* (Pl. V. fig. 3, *d.i.f*) these have no curved folds at their sides, and the rays of the basal star (S) are only imperfectly calcified rods, long and narrow, like the basal grooves on the ventral surface of the centrodorsal piece into which they are received (Pl. V. fig. 2, *b.g*). In *Act. pectinata*, however, although the basal grooves are long and narrow as in *Act. solaris* (Pl. V. fig. 7), yet the dorsal interradial furrows are widened by the presence of large curved basal folds at their sides (fig. 9 b, *b.f*); and in correspondence with these the tertiary basal elements (fig. 8, S) are much wider, and also far more perfectly calcified (being solid throughout), than is the case in *Act. solaris*.

In *Act. robusta* the central ends of these basal rays are wide and stout, and completely calcified as in *Act. pectinata*; but their peripheral ends are much thinner, and consist of a simple curved plate, which forms a sort of bridge over the dorsal interradial furrow (Pl. V. fig. 12, S), the borders of which are straight, as in *Act. solaris* (fig. 3, *d.i.f*), and not marked by any lateral folds. The basal grooves on the ventral surface of the centrodorsal piece are also simple and nearly parallel-sided (fig. 14, *b.g*).

In *Act. polymorpha* and its varieties the condition of the basal star varies extremely, like that of the basal folds and basal grooves, the development and shape of which exhibit a very close correspondence with the appearance of the rays of the basal star.

Thus, in that specimen of the type of *Act. polymorpha* in which the basal grooves are narrow and parallel-sided, and all terminate well within the margin of the centrodorsal piece (Pl. VI. fig. 3, *b.g*), while no basal folds are present at the sides of the dorsal interradial furrows (fig. 4, *d.i.f*), the rays of the basal star are short and flattened, and do not by any means reach the angles of the radial pentagon (fig. 4, *S*). Their dorsal surface is somewhat depressed along the median line, while the depression (fig. 6, *s*) at the central end of the ventral surface which receives the blind end of the axial interradial canal is continued outwards in a peripheral direction somewhat further than in *Act. pectinata* (Pl. V. fig. 8 a, *s*); and the median ridge which runs from its end to the apex of the ray is less marked than in this species.

In another specimen of the type, however, in which both basal grooves (Pl. VI. fig. 8, *b.g*) and basal folds (fig. 9, *b.f*) are wide and well marked, the basal rays are stout and thick, with a fairly distinct median ridge on their ventral surface. In fig. 8, three of them are seen occupying their normal position in the basal furrows on the ventral surface of the centrodorsal piece, with which they are closely connected, while the other two rays have remained in connexion with the rosette and radial pentagon.

In a third specimen of the type the rays of the basal star are very imperfectly developed; two only extend for any distance towards the angles of the radial pentagon (Pl. VI. fig. 11, *S*), while of the other three little or nothing is to be seen. In this specimen, as in the one first described, there are no basal folds, and the basal grooves are parallel-sided and only imperfectly developed (fig. 10, *b.g*). It is also remarkable for the fact that the absorption of the apex and outer margins of each embryonic basal plate seems to have been very incomplete; for the bars of the basal bridge are so wide, and extend so far towards the centre from the inner margins of the dorsal surfaces of the first radials, with which they are closely united, that they entirely conceal the apertures in the compound basals (Pl. V. figs. 3, 8; Pl. VI. figs. 4, 6, 13, 18, 19, 22, 24, x_1, x_2, y_1, y_2, &c.) through which the secondary basal cords pass in order to reach the central canals of the first radials. Consequently nothing is seen of the rosette in a dorsal view of the pentagonal base but its central opening surrounded by a raised rim (Pl. VI. fig. 11, *r.o*). In all the other figures, however (Pl. V. fig. 3; Pl. VI. figs. 4, 13, 24), these apertures are large and distinct, every one being situated between a radial (*p*) and an interradial process (*o*) of the rosette.

In *Act. polymorpha*, var. 1, both basal grooves (Pl. VI. fig. 15, *b.g*) and basal folds (fig. 13, *b.f*) are well marked and somewhat lancet-shaped in form; the rays of the basal star which occupy the former are much flattened dorsally (fig. 22 b, *S*), as in one of the specimens of the type (fig. 4, *S*). They are not, however, so short as in this case, but, like the basal folds at their sides, reach the outer angles of the radial pentagon.

This is also the case in the other three varieties. In var. 4 the basal folds diverge considerably at about the middle of their course (fig. 24, *b.f*), so that the dorsal interradial furrow is here very wide, and then rapidly narrows towards its peripheral end. In correspondence with this, the basal rays also widen somewhat from their narrow central ends, and then begin to decrease in width as they approach the angles of the radial pentagon (fig. 24, *S*); they are also marked by a slight median furrow along their dorsal surface, as is the case in one specimen of the type (fig. 4, *S*). In varieties 2 and 3, as in the type, and in var. 1, the basal rays are widest at their central ends (figs. 18, 19, 22, *S*). In both cases the basal grooves (figs. 17, 21, *b.g*) and basal folds (Pl. VII.

fig. 4 d, *b.f*) are well developed and somewhat lancet-shaped in form, as in var. 1 (Pl. VI. fig. 13, *b.f*, fig. 15, *b.g*).

In var. 2, and still more in var. 3, the mode of union of the bars of the basal bridge (figs. 19, 22 b, *b.b*) with one another and with the basal rays (*S*), is seen very distinctly at the central end of the latter; much more so than in *Act. pectinata* (Pl. V. fig. 8 b), in which, as in the other specimens figured (Pl. V. fig. 3; Pl. VI. figs. 4, 11, 13), the various elements of each compound basal are so completely united, that the lines of unction between them become almost indistinguishable.

(§ 68) The complicated condition of the basals described above in *Actinometra* is not altogether peculiar to this genus, as I was first inclined to believe; for in *Ant. Eschrichtii* a basal star may be developed to a greater or less extent. In his paper on *Phanogenia* Lovén gives a diagram[1] of the dorsal aspect of the pentagonal base of the calyx of this species for comparison with that of *Phanogenia.* It shows five large rays extending from the periphery of the rosette to the outer angles of the radial pentagon, with the constituent elements of which they alternate in position; and in the text he speaks of them as belonging to the rosette. Unfortunately, his paper is written in Swedish, so that I have been unable to ascertain precisely what his views were with respect to the homologies of these rays.

His figure also shows five radial openings on the dorsal surface of the pentagonal base, which correspond with the dorsal openings of the radial axial canals in *Ant. rosacea* (Pl. IV. fig. 16, *Q*).

In neither of the two specimens of *Ant. Eschrichtii* which I have been able to examine do these openings exist, so that they are probably somewhat uncertain in their occurrence, as in *Ant. celtica* (Pl. IV. figs. 3, 7); and in neither of these specimens is the basal star developed to any thing like the extent that it is in the specimen figured by Lovén. In one (Pl. IV. fig. 10, *S*) the rays are excessively small and inconspicuous, only extending for a very short distance along the dorsal interradial furrows (*d.i.f*), while the corresponding basal grooves on the interradial elevations of the centrodorsal piece are also very slightly developed (fig. 11, *b.g*). The basal bridge also, connecting two successive rays of the basal star, is barely traceable around the inner margin of the radial pentagon (fig. 10, *b.b*).

In the other specimen which I examined the basal rays were somewhat better developed, occupying a larger portion of the dorsal interradial furrows, and extending further outwards towards the margin of the radial pentagon; although still remarkably slender and delicate, somewhat as in *Act. solaris* (Pl. V. fig. 3, *S*), and by no means so large as in the specimen figured by Lovén[2].

The interior of the calyx of *Ant. Eschrichtii* is much simpler than that of *Actinometra*,

[1] *Loc. cit.* p. 230, m.

[2] Since the above lines were written, I have examined several other specimens of *Ant. Eschrichtii.* None of them have the radial openings above mentioned, nor are the rays of the basal star so large as in the specimen figured by Lovén; but they are always present, though less regularly developed than in *Actinometra.* Further, my work on the 'Challenger' *Comatulæ* has brought out the fact that a basal star is nearly always present in *Antedon* as well as in *Actinometra*, so that the British species (*Ant. rosacea, Ant. celtica*) are remarkable for its absence, rather then *Ant. Eschrichtii* for its presence.

as will be seen by comparing Pl. IV. fig. 9 with Pl. V. fig. 13, both of which represent the internal aspect of two united first radials. In *Actinometra* (Pl. V. fig. 13) there is an abundant calcareous network (*c.n*) in connexion with the internal faces of the radials, which are marked by well-developed radial and interradial furrows. In *Ant. Eschrichtii*, however (Pl. IV. fig. 9), the processes forming this network are but little developed; there is no axial interradial furrow, and even the radial one is indistinct, except near the dorsal surface, where it passes between the raised edges of the two apertures (x', y, y', z) of the central canal which unite with the inflected edges of a radial spout-like process (p) of the rosette.

The interradial process of the rosette (o') is short and broad, but without the spout-like character which it has in *Actinometra*—being simply directed, as in the normal condition of *Ant. rosacea* (Pl. IV. figs. 3, 7, 16), to the line of suture between the two contiguous radials, to which it is attached between the two adjacent apertures (fig. 9, y, y') of their central canals.

(§ 69) The remarkable variation in the extent to which the rays of the basal star may be developed, as described above in *Actinometra* and in *Antedon Eschrichtii*, is due to the fact that they are not calcifications in a nucleated protoplasmic network like the ordinary elements of the skeleton. They are the result of a calcareous deposition, of a more or less regular character, around the connective-tissue fibres which effect the synostosis with the centrodorsal piece of every pair of contiguous radials along the line of contact of the latter; so that their position is, as we have already seen, interradial.

In Pl. III. fig. 5 is seen the lower end of a vertical section cut transversely to the plane of synostosis of two decalcified first radials (r_1) of *Act. polymorpha*, close to their peripheral margin where they are not concealed by the centrodorsal piece, so that the fibres of the elastic ligaments connecting them with the second radials are cut somewhat obliquely (l_1).

The threads of the protoplasmic network of which the organic basis of the radials is composed pass somewhat rapidly at their surfaces into the connective-tissue fibrils (L) which run horizontally between them and effect the synostosis. These fibrils being very closely set, the superficial portions of the calcareous reticulation forming the skeleton of the radials, which are ossified around their ends, are very much more dense than the central portion produced by calcification of the protoplasmic network.

Pl. VIII. fig. 4 represents a section, from the same series as the previous one, across the line of union of the same two radials (A, B), rather nearer to the centre of the calyx, so that their dorsal surface appears no longer free, but partially covered by the centrodorsal piece (*cd*). The lower portion of this section, more highly magnified, is seen in Pl. III. fig. 6. The synostosis of the radial areas of the centrodorsal piece with the dorsal surfaces of the first radials is effected by simple and not specially numerous connective-tissue fibres (l); these pass directly from the protoplasmic basis of the one piece into that of the other, in a direction vertical to the plane of the opposed surfaces, just as in an ordinary synostosis. But in the direction of the interradii the course of the fibres is different, and they have a deeper origin in the substance of the centrodorsal piece than those which occupy the radial areas (Pl. III. fig. 6).

There are three principal masses of these longer interradially placed fibres:—two smaller ateral ones (S_3), in which the fibres have the same direction as those occupying the radial areas; and a large median mass, in which the fibres ascend vertically for some distance (S_2) and then diverge to the two sides (S_1), where they pass into the protoplasmic basis of the radials; and the horizontal fibres (L) which pass between the radials fill up the open angle caused by the divergence of the ascending fibres. There is thus a much greater development of connective-tissue fibres, effecting the synostosis of the centrodorsal piece with the radial pentagon, in the interradial than in the radial planes. This is well seen in Pl. VIII. fig. 3, which represents a longitudinal section through the calyx of *Act. polymorpha*. On the right side it is interradial, passing through the synostosis of the first and second radials of the two radii, *A*, *B*; and the connective-tissue fibres (S_2) connecting the centrodorsal piece with the edges of these two radii are longer and more abundant than those on the left side (l), passing between the centrodorsal piece and the first radial of radius *D*, which is cut longitudinally.

This is also seen in Pl. VIII. figs. 5–8, which represent portions of four out of a series of sections through a decalcified calyx of *Act. pectinata*. These are in the same plane as the section of the calyx of *Act polymorpha* represented in fig. 4, *i.e.* transverse to the synostosis of the radii *A*, *B* on the one side of the centre, and to the radius *D* on the other.

Fig. 5 represents a section, rather nearer the centre than fig. 4, passing vertically along the axial interradial canal (*a.i.c*); beneath the dorsal end are seen the vertical ascending fibres (S_2), which have a much deeper origin in the substance of the centrodorsal piece of this species than in *Act. polymorpha*. The diverging fibres are not seen, as they give rise by their calcification to the long basal ray (Pl. V. fig. 8, *S*); and this section passes through the depression at the central end of its ventral surface (Pl. V. fig. 8 a, *s*) in which the axial interradial canal terminates.

Fig. 6 is somewhat nearer the centre, but still shows the long vertical fibres (S_2) in the interradial plane, together with a portion of the central calcareous network and the axial radial canals (*a.r.c*) corresponding to the two radii *A*, *B*.

Fig. 7 is just beyond the centre, *i. e.* across the inner end of the first radial of *D*, so that no vertical fibres are visible, as they are only interradial in position. Two sets of them, however, are seen in fig. 8, which shows the first radial of *D* cut transversely rather further from the centre, so that the fibres (l) effecting its synostosis with the adjacent radials of *C* and *E* are cut obliquely; beneath these are seen the interradial ascending fibres (S_2), which diverge slightly at their upper extremities (S_1).

These diverging fibres and the upper ends of the vertical ones are the basis around which the calcareous material forming the rays of the basal star is deposited. As the ventral surface of the centrodorsal piece on which these rays rest is much higher at the centre than at the circumference, it is impossible to obtain horizontal sections in which these five rays are seen at all complete. Oblique sections, however, may be obtained in which one or more of them are cut along the greater part of their length. Two such sections, seen from their dorsal side, are represented in Pl. VIII. figs. 1 & 2; their lower left-hand portions lie nearer the dorsal surface of the calyx than the upper right-hand portions.

The centre of fig. 1 is occupied by the fibrous envelope *N* of the quinquelocular organ, from the dorsal portion of which cords (*n.c*) proceed to the cirrhi (*cir*). At the top and right of the figure are seen portions of three first radials (r_1), the central parts of which are lighter than the more peripheral parts, as the section here passes through the slightly developed unpigmented fibrous tissue (l) connecting the radials with the centrodorsal piece (*cd*), the peripheral portion of which consists of the same pigmented protoplasmic network as the substance of the radials.

Two of the synostoses between the latter are seen at the top of the figure; but they do not quite reach to the centre, where their place is occupied by the central ends of two of the rays of the basal star (S_1), the remaining three rays of which are visible in the lower part of the figure for the greater portion of their length. Two of them are also seen in the left or more dorsal portion of the next section (fig. 2), which also shows three synostoses (L) between the radials in the right or more ventral part of the figure.

The sections of these rays of the basal star appear very dark, not from the presence of pigment, which is entirely wanting in their fibrous basis, but because of the abundance and very close approximation of the fibres of this basis; these are the diverging and vertical fibres seen in Pl. VIII. figs. 3, 4, and more highly magnified in Pl. III. fig. 6 (S_1, S_2). Just in the same way, in Pl. VIII. fig. 3, the section appears much darker on the right-hand side, where it cuts the closely approximated connective-tissue fibres effecting the synostosis between two first radials transversely, than on the left-hand side, where it passes through the more open protoplasmic network of the individual segment of a single radial, D.

(§ 70) This great development of fibrous tissue along the interradial portions of the centrodorsal piece and of the pentagonal base of the calyx accounts for the fact, often mentioned already, that there is no pigment in the substance of the rays of the basal star (which is a more or less complete calcification of the central portions of these interradial fibrous masses), nor in the walls of the basal grooves on the centrodorsal piece, nor in those of the dorsal interradial furrows on the inferior surface of the pentagonal base, which are calcifications of the smaller lateral masses of long fibres running directly from the organic basis of the centrodorsal piece into that of the first radials (Pl. III. fig. 6, S_3). These lateral fibres have a common point of origin in the substance of the centrodorsal with the vertical and diverging fibres (S_1, S_2), around which the calcareous tissue of the basal rays is deposited. It is therefore easy to understand that the calcification may in some cases be so complete that the basal rays formed around the median fibres (S_1, S_2) may become completely united with the walls of the basal grooves formed around the lower ends of the two lateral fibrous masses (S_3); as is the case in the specimen of *Act. polymorpha* represented in Pl. VI. fig. 8, where two of the rays of the basal star (S) are so completely united with the floor and sides of the basal grooves in which they lie that the line of junction between them becomes indistinguishable.

The fact that the rays of the basal star are calcifications in connective tissue and not in the ordinary nuclear tissue which forms the organic basis of the other parts of the skeleton, also affords an explanation of the great variations in the extent to which the rays are developed. The general arrangement of the fibres constituting the interradial portions of the synostosis between the centrodorsal piece and the radial pentagon is essentially the same in *Antedon* as in *Actinometra*. In *Ant. rosacea* and *Ant. celtica* they never seem to undergo calcification, though this may take place in *Antedon Eschrichtii*, either only very slightly, as in the two specimens examined by myself (Pl. IV. fig. 10, *S*), or to a considerable extent, as in that figured by Lovén. In *Actinometra* also the extent of calcification of the rays of the basal star is very variable. In one specimen of *Act. polymorpha* scarcely any trace of them is visible (Pl. VI. fig. 11, *S*); in another they are short, but otherwise well developed (fig. 4, *S*); while in others they may extend very nearly to the outer angles of the radial pentagon (figs. 13, 18, 19, 22, 24, *S*).

In *Act. pectinata*, again, we have found them to be large and thick (Pl. V. fig. 8, *S*), while in the closely allied *Act. solaris* (Pl. V. fig. 3, *S*) they were slender rods, only imperfectly calcified here and there—the intervening portions of the dorsal interradial furrow seen in the prepared skeleton (*d.i.f*) being occupied in the fresh state by masses of fibrous tissue, which are removed by the action of the alkali used in preparation.

(§ 71) We have seen that the basal circlet of *Actinometra* is somewhat complicated in its nature, and consists of two entirely distinct elements, viz. a central rosette, which we may fairly suppose to be the result of the metamorphosis of the embryonic basal plates, as in *Antedon rosacea*, and five more or less completely ossified rays extending from it in a peripheral direction.

The rosette is situated on the ventral side of the quinquelocular organ, from the fibrous envelope of which proceed the primary basal cords. These are very short, and soon bifurcate, so as to give rise to ten secondary cords, which pass through the ten apertures ($v_1, v_2, \ldots z_1, z_2$) in the peripheral portion of the rosette in order to reach the central canals of the first radials.

As already remarked by Ludwig , we may fairly regard those elements of the skeleton in which the bifurcation of the primary basal cords occurs as homologous throughout the different genera of the Crinoids. This leads us to the conclusion that the rosette of *Antedon* and *Actinometra* is homologous with the united central ends (at least) of the basals of *Pentacrinus*, which are perforated by canals that lodge the five bifurcating fibrillar cords proceeding from the dorsal angles of the quinquelocular organ, and not from its ventral angles as in *Comatula*.

The question now arises, Where are we to seek for the homologues of the five rays of the basal star in most *Comatulæ*? Unfortunately the only type in which we find a condition any thing like that described above is a fossil one, the *Solanocrinus* of Goldfuss; so that it is difficult to ascertain the precise relation of its basals to the canals proceeding from the quinquelocular organ that was undoubtedly contained in the cavity of its deep centrodorsal piece.

The upper surface of the latter, according to Goldfuss[2], presents "five radiating elevations on which the pelvis articulates." They correspond to the interradial elevations on the ventral surface of the centrodorsal piece of *Antedon* and *Actinometra*.

The basals themselves vary in appearance in the different species. In *S. costatus* and *S. scrobiculatus* they are only "fünf schmale Strahlen die sich zwischen die Nähte der Rippenglieder einsenken;" but in *S. Jægeri* they are much wider, "so dass sie auf der ganzen Gelenkfläche zusammenstossen und hier fünf ausstrahlende Furchen zur Aufnahme

[1] Beiträge &c. *loc. cit.* p. 67. [2] Petref. Germ. *loc. cit.* p. 166.

der Säule bilden" (p. 168). This species, however, is possibly not a *Solanocrinus* at all, but the head of a stalked Crinoid.

In both these cases the peripheral ends of the basals appear on the external surface of the calyx, between the centrodorsal piece and the radial pentagon, although the extent to which they are visible is very different.

The long and narrow prismatic-shaped basals of *S. costatus* evidently represent the five rays of the basal star of *Actinometra.* The interradial elevations on the ventral surface of the centrodorsal piece are marked by five median grooves for the reception of the basals, just like the basal grooves of *Actinometra*; and these interradial elevations are continued beyond the margins of the radial areas, just like the small processes (*t*) in some species of *Actinometra* (Pl. VI. figs. 14, 15). They correspond with five longitudinal ridges on the outer surface of the columnar centrodorsal which separate the rows of cirrhus-sockets.

We do not, of course, know whether there was a rosette in *S. costatus.* I am inclined to think that this was not the case, as the central ends of the five basals are in contact with one another laterally for a short distance, instead of being united by narrow bars forming a basal bridge, as in *Actinometra*; and their internal or proximal faces were probably perforated by the opening of a short bifurcating canal lodging the fibrous cords on their way to the central canals of the first radials, as in the closely similar basals of *Pentacrinus asteria.* Hence these five basals as a whole would represent the circlet of compound basals in *Actinometra*, viz. the rosette together with the rays of the basal star. Whether, however, only the united central ends of the basals of *S. costatus* represent the embryonic basal plates, like the rosette of *Antedon* and *Actinometra*, or whether the whole star results from a metamorphosis of the embryonic basals, is a question which must remain in doubt, though the latter is by far the more probable supposition. Apart from the analogy of *Pentacrinus*, as the peripheral ends of the basal rays extend beyond the margin of the radial pentagon, it is hardly likely that they can be the result of calcification in the interradial portions of the synostosis between the radial pentagon and centrodorsal piece, as in *Actinometra* and *Antedon Eschrichtii.*

The calyx of the doubtful *S. Jægeri* presents a great advance upon that of *S. costatus* with respect to the development of the basals, which led Pictet[1] to propose the erection of this species into a separate genus. Instead of being long and narrow, and in contact only by their central ends, as in *S. costatus* and *S. scrobiculatus*, they are broad and wedge-shaped, and in contact along their whole sides, so as to form a complete calcareous disk entirely separating the radial pentagon from the centrodorsal piece.

This is occasionally their position in *Pentacrinus*, though there are but few species of that genus in which the basals are relatively so large and complete as in *Solanocrinus Jægeri.*

In *P. asteria*, and in the two fossil species *P. briareus* and *P. subangularis*, they are small and cuneiform and only in contact by their central ends, just as in *S. costatus*, so that the greater portion of the radial pentagon is in contact with the top stem-segment. In *P. Mülleri* they are in contact for about half their length, and then diverge, while in *P. Wyville-Thomsoni* they are completely united with one another along the

[1] *Op. cit.* p. 288.

whole length of their sides, so as entirely to cut off the radial pentagon from the top stem-segment, just as in *S. Jægeri*.

There can therefore be little doubt that the basals of *Pentacrinus* are homologous with those of *Solanocrinus*, and therefore analogous to the compound basals of *Actinometra*, which, as we have seen, are not entirely developed out of the embryonic basal plates. It would seem, in fact, as if in *Pentacrinus* and *Solanocrinus* the embryonic basal plates became directly transformed into the basals of the adult; while in *Comatula* they undergo metamorphosis into the central rosette by the absorption of the greater portion of their dorsal or primary tissue, and the development of a secondary ossification on the ventral side of the original plates.

In *Ant. rosacea* the metamorphosis is much more complete than in most *Antedons* and in *Actinometra*, in which new skeletal elements are developed by a more or less complete tertiary ossification in masses of connective tissue, that correspond precisely in position, and to a certain extent also in shape, with the basals of *Solanocrinus* and *Pentacrinus*. The latter being most probably direct products of the growth of the embryonic basals are therefore strictly homologous only with the rosette of *Actinometra*, although analogous in position to the whole circlet of compound basals in this genus, viz. to the rosette and basal star taken together.

(§ 72) It is interesting to observe the different position of the basals with regard to the chambered organ in *Comatula* and in the various species of the stalked Crinoids.

In *Comatula* this organ is situated in the cavity of the centrodorsal piece (Pl. VIII. fig. 3) which is on the dorsal side, not only of the radial pentagon, but also of the rosette or metamorphosed basals; and the nervous cords proceeding from its fibrillar envelope to enter the central canals of the first radials come off from its ventral angles.

The large centrodorsal piece of *Comatula* is developed by the growth of the top stem-segment of the Pentacrinoid larva. In *Pentacrinus*, which remains pedunculate throughout life, the top stem-segment is the youngest and smallest. Its central cavity is far too small to contain the quinquelocular organ forming the upper end of the central axis of the stem, which contains five longitudinal chambers expanding slightly at every nodal segment, where each of them gives off a single cirrhus-vessel[1].

There is no special increase in the diameter of these chambers in the top stem-segments, and they do not expand into the large chambers of the quinquelocular organ until near the level of the ventral surface of the basal circlet which surrounds the dorsal half of the chambered organ. The ventral portion of the latter is contained in the lower part of the central funnel-shaped space enclosed within the radial pentagon, where it is surrounded by a very dense calcareous network, through which the axial prolongation containing the superior continuations of the five chambers of the quinquelocular organ ascends, on its way to enter the visceral mass, just as in *Comatula*. In consequence of this relatively higher position of the chambered organ in *Pentacrinus* than in *Comatula*, the nervous cords which enter the central canals of the first radials come off from its dorsal angles, and not from the ventral ones as in *Comatula*.

In *Comatula*, therefore, the walls and floor of the cavity enclosing the chambered organ

[1] *Pentacrinus* and *Rhizocrinus*, loc. cit. pp. 43–46.

are formed almost entirely by what was once a stem-segment; while in *Pentacrinus* this cavity is a part of the central space enclosed within the radial and basal pentagons, which respectively form the ventral and dorsal portions of its side walls. Among the fossil *Apiocrinidæ* we find an intermediate condition between these two extremes. Thus in *Ap. mespiliformis,* as seen in Goldfuss's figure [1], the first radials are small, but the basals are very large and curved outwards, so as to enclose a large central cavity; this we may fairly suppose to have lodged a chambered organ, as Ludwig [2] has found that in *Rhizocrinus,* the modern representative of this family, the axis of the stem expands into a chambered organ just as described above in *Pentacrinus.* I have found the same to be the case in *Bathycrinus.*

This organ is contained in *R. lofotensis* in a large and apparently simple segment, described by Sars [3] as the expanded uppermost stem-segment. Pourtales[4], however, for reasons which will be discussed further on, regards it as composite and as representing the five basals. In this case the relative position of the chambered organ is precisely identical with that which we may suppose it to have occupied in *Ap. mespiliformis,* namely, on the dorsal side of the radial pentagon, but not within the uppermost stem-segment, as in *Comatula.* In *Ap. rosaceus* [5] the relative position of the chambered organ must have been very much as in *Pentacrinus,* though slightly higher; for the cavity in which it was contained was almost entirely enclosed between the enlarged first radials, while the basals only form its floor and the very lowest portion of its side walls. Lastly, in *Ap. Milleri* [6] the chambered organ must have lain altogether on the ventral side of the basals; the superior surfaces of which form by their apposition the floor of a cavity whose side walls are entirely composed of the adjacent inner faces of the contiguous first radials.

This condition is thus precisely the opposite of that which we find in *Comatula,* where the cavity containing the chambered organ is not only altogether outside the radial pentagon, but also on the dorsal side of the rosette or metamorphosed basals.

(§ 73) In the works both of Goldfuss and Miller may be found incidental suggestions that the "basis," or circlet of basals, and, indeed, the whole of the lower part of the calyx of the stalked Crinoids, may be regarded as representing expanded stem-segments, each broken up into five parts. Müller, however, was the first to put this idea into a definite form. He described the basals of *Pentacrinus* as a metamorphosed stem-segment [7], or as "zerfallene Theile eines obersten Stengelgliedes;" for they correspond in position with the five leaf-like figures on the articular surfaces of the stem-segments which mark the positions of the five longitudinal tendons.

The fibrous bundles composing these tendinous cords are separated from one another by a very regular calcareous network, which is deposited around and between them, somewhat as in the rays of the basal star of *Actinometra.* They are attached (by their

[1] Petref. Germ., Taf. lvii. fig. 1, H.

[2] "Zur Anatomie des *R. lofotensis,*" Zeitschr. f. wiss. Zool. Bd. xxix. p. 122.

[3] Crinoïdes vivants, *loc. cit.* pp. 4, 12.

[4] "On a new Species of *Rhizocrinus* from Barbadoes," Zoological Results of the Hassler Expedition, p. 28. Cambridge, U. S., 1874.

[5] Petref. Germ., Taf. lvi. fig. 3, G.

[6] Petref. Germ., Taf. lvii. fig. 2, D.

[7] "Bau des *Pentacrinus,*" loc. cit. pp. 16, 25.

upper ends) to the lower surfaces of the five basals in the same way as the ligaments of the arms are attached to the brachial segments, the fibres of the one passing gradually into the protoplasmic basis of the other. The basals cannot, however, be regarded as simply ossifications in this fibrous tissue of the same nature as the basal rays of *Actinometra*; for, as shown above, there is every reason to believe that they are developed, like the other elements of the skeleton, out of the embryonic basal plates; although, so far as position is concerned, they are precisely homologous with the calcareous deposits within the tendinous cords of the stem.

On the other hand, the basal rays of *Actinometra*, which are similar in position, though not in origin, to the peripheral portions of the basals of *Pentacrinus*, are of the same nature as the calcareous tissue of the leaf-like areas of the stem-segments, being simply the result of the deposition of calcareous material around and between connective-tissue fibres.

In many of the fossil *Articulate* Crinoids the lateral union of the basals with one another is so very complete that the lines of junction between them are not always visible, and the "basis" has therefore been described either as entirely absent or as replaced by the uppermost stem-segment, which, according to Müller's view, it is supposed to represent.

This is particularly the case in the *Apiocrinidæ* and in *Eugeniacrinus*. Miller, who was the first to describe the latter type [1], mistook the first radials of *E. caryophyllatus* for the basals, and described them as firmly anchylosed to what he supposed to be the "superior columnar joint." Goldfuss [2], however, rightly determined this last to be a part of the first radials, which are very much prolonged downwards, while, at the same time, he described the basals as replaced by the enlarged uppermost stem-segment, which articulates with the inferior surface of the elongated first radials. Rœmer [3] did not accept this view of Goldfuss's, although he recognized that the "superior columnar joint" of Miller was simply a dorsal prolongation of the first radials; but, like Miller, he described these last as the basals.

It is most probable that Goldfuss's view is the truer one, as in Hagenow's figure [4] of *Eugeniacrinus Hagenowii*, in which the first radials are not prolonged downwards as in *E. caryophyllatus*, the piece on which they rest, representing that which Goldfuss called the enlarged uppermost stem-segment of *E. caryophyllatus*, is seen to be distinctly composite; for its external surface is marked by five sutural lines, alternating in position with those between the first radials, and evidently indicating the lines of union of five basals.

The geological collection of the British Museum, which I have been able to examine, thanks to the kindness of Mr. Henry Woodward, contains a very interesting series of specimens from the Chalk which are labelled *Apiocrinus ellipticus*.

In some of them the basals form a complete ring, separating the radials from the upper stem-joint, which is very much enlarged. But in other specimens the basals appear

[1] *Op. cit.* p. 111. [2] Petref. Germ. *tom. cit.* p. 162. [3] Lethæa Geognostica, ii. Theil 4, p. 115.
[4] Min. Jahrb. *loc. cit.* ix. p. 13.

externally merely as small triangular pieces, not meeting laterally; so that they exhibit the same differences as the basals of *Pentacrinus* and of *Solanocrinus*. In many specimens the sutures between the basals, radials, and top stem-joint are clear and distinct; but in others there is no trace of them at all, just as in some examples of *Eugeniacrinus* and *Rhizocrinus*; but this is hardly a satisfactory reason for supposing the basals to be internal and concealed, as has been done in the case of the last-named genus.

Even in some species of *Pentacrinus* the basals appear to be very closely united to one another, and to assume the form of an uppermost stem-segment. Thus in *P. scalaris*, Goldfuss [1], there is no appearance whatever of small wedge-shaped basals, such as are found in *P. briareus* and in *P. asteria*; but, as remarked by the Messrs. Austin [2], they appear to be united into a single plate, which resembles an "enlarged columnar joint." The same was probably the case in the Jurassic genus *Isocrinus*, described by Von Meyer [3], though it is, of course, possible that in both these cases the basals may have been internal and concealed, as in *Comatula*.

I have endeavoured to show elsewhere [4] that in the recent *Rhizocrinus* we find a strikingly similar case to that presented by *Eugeniacrinus*, viz., the sutures between the basals, visible externally in one species and not in another, or, rather, *not invariably* in another. In *R. lofotensis* the first radials rest upon a large and expanded apparently simple segment, which was described by Sars [5] as the expanded uppermost stem-segment; and a small circular plate situated in the central vacuity between the first radials, with which, as well as with the enlarged uppermost stem-segment, it is closely connected, was regarded by him as representing the metamorphosed embryonic basals of *Comatula*.

Pourtales's observations [6], as well as my own subsequent ones, have led me to believe that the piece called the enlarged uppermost stem-joint of *R. loftensis* by Sars and Ludwig [7] is composed (if not entirely, at any rate in great part) of five closely anchylosed basals. Schlüter [8] is evidently not acquainted with the evidence on which this view rests, or he would scarcely suggest that *R. Rawsonii* might not be a *Rhizocrinus* at all, because its basals differ from those described in *R. loftensis* by Sars and Ludwig; although these two observers are not themselves in accordance as to which parts of the interior of the calyx are to be regarded as concealed basals.

Sir Wyville Thomson [9] takes the same view as Pourtales and myself; for he describes how "in *Rhizocrinus* the funnel-shaped piece formed by the coalescence of the basals with the fused first radials above and the dilated upper joint of the coalesced upper joints of the stem beneath, makes up a large part of the cup;" and his descriptions of the calices of *Hyocrinus* and *Bathycrinus*, both genera allied to *Rhizocrinus*, together with

[1] Petref. Germ. *tom. cit.* p. 173, Taf. lx. fig. 10, B.

[2] 'A Monograph on Recent and Fossil Crinoidea,' p. 121 (Bristol, 1845).

[3] "*Isocrinus* und *Chelocrinus*," Museum Senkenbergianum, p. 251 (Frankfurt, 1837).

[4] "*Pentacrinus* and *Rhizocrinus*," loc. cit. pp. 47–53.

[5] Crinoïdes vivants, *loc. cit.* p. 4.

[6] Hassler Expedition, *loc. cit.* pp. 28, 29.

[7] *Rhizocrinus lofotensis*, loc. cit. pp. 121, 122.

[8] *Op. cit.* p. 29. Schlüter was unfortunately unable to make himself acquainted with Pourtales's memoir.

[9] "Notice of new living Crinoids belonging to the Apiocrinidæ," Journ. Linn. Soc. Zool. vol. xiii. p. 48.

the analogies of *Apiocrinus* and *Eugeniacrinus*, strengthen Pourtales's view still more completely.

The occasional fusion of the upper stem-joints with the lower part of the calyx, as described above in the *Apiocrinidæ*, is an excellent illustration of Müller's idea respecting the correspondence between the basis and the stem-joints.

This correspondence, however, is by no means entitled to rank as a serial homology. The earliest condition of the basals shows them to be five separate plates developed in a spiral around the aboral cœlom of the Crinoid embryo[1]. They have distinct homologies in the apical system of the other Echinoderms[2]; while the stem-segments, surrounding the aboral cœlom much in the same way as the basal circlet, are simple undivided pieces from the first, and seem to be almost or quite unrepresented in the other Echinoderms.

(vi.) *The Second and Third Radials.*

(§ 74) The second radial of *Act. polymorpha* (Pl. VII. fig. 2), like that of *Ant. rosacea*, is an oval, somewhat discoidal plate, having two nearly parallel faces—one internal or proximal, articulating with the first radial, the other external or distal, articulating with the third radial. The internal face (fig. 2 a) closely resembles the external face of the first radial (Pl. VII. fig. 1 b), with which it articulates, being divided transversely by a large articular ridge (*i*) into a dorsal and a ventral portion; the former is entirely occupied by the fossa lodging the elastic ligament (*j*), which is particularly deep just below the opening of the central canal (*c.c*). From the ventral margin of this opening arise the two ridges which bound the intermuscular furrow (f_1), and are joined near their upper extremities by the transverse secondary ridges separating the large fossæ (*h*) that lodge the interarticular ligaments from those (*f*) lodging the flexor muscles of the ray; the latter are excavated in a pair of thin lamellæ, which extend upwards from the proper ventral margin of the plate, as is seen in a view of the distal face (fig. 2 b, *g*). Besides the above-mentioned ridges and fossæ, which correspond to similar ones on the distal face of the first radial, the proximal face of the second radial shows two lateral processes, in which shallow fossæ (*k*) are excavated. These processes represent the outer portions of the distal face, which is somewhat wider than the proximal one, as the lateral faces are not set at right angles to the two terminal ones, but form an oblique angle with the proximal face, so that the outline of the radial, when seen from the dorsal or ventral side, is trapezoidal in form (fig. 2 c, d). The shallow fossæ which are excavated in these lateral faces lodge the ligamentous substance by which the second radials are united with one another in pairs: the extent of this union is, as above remarked, very variable in different specimens, being generally greatest where the number of arms is largest (Pl. II. figs. 9, 11).

The external or distal face (fig. 2 b) is much simpler in character than the proximal one, as no muscles are attached to the vertical lamellæ which rise from its ventral margin above the articular face proper. This last is divided by a vertical ridge (*i*) that

[1] Götte, *loc. cit.* pp. 595, 620.

[2] P. H. Carpenter, "On the Oral and Apical Systems of the Echinoderms," Quart. Journ. Micr. Sci. xviii. (1878) pp. 371, 382.

passes round the opening of the central canal (*c.c*) into a pair of lateral fossæ (*h*), which give attachment to the large interarticular ligament connecting the second with the third radial. The proximal face is not quite vertical, but slightly inclined towards the distal one, so that the ventral face is not much more than an edge. When the piece is viewed from the ventral side, therefore (fig. 2 c), little else is visible but the fossæ for the muscles (*f*) and interarticular ligaments (*h*) of the proximal face and the intermuscular furrow (*f*) descending along its median line.

The second radials of var. 1 are very similar to those of the type, except that, as in the first radials, the muscular fossæ are relatively somewhat larger. In var. 2, however, they are very much smaller (Pl. VII. fig. 5 a, *f*); and there are no vertical lamellæ projecting from the ventral margin of the distal face (fig. 5 b), as is the case in the type. The lateral fossæ (*k*) lodging the ligamentous substance which connects the second radials with one another are somewhat more marked, as the union of the second radials in pairs is more complete than in the type, though not so complete as in varieties 1, 3, and 4.

The two latter also agree with var. 2 in the fact that the proximal and distal faces of the second radials are nearly parallel, and less inclined to one another than in the type and in var. 1; so that the fossæ for the muscles and interarticular ligaments are barely visible when the piece is seen from the ventral side (fig. 5 c), as there is a proper ventral face. Its median line is occupied by a continuation of the furrow on the ventral surface of the first radial (figs. 4 c, 5 c, *v.r.f*), while its lateral portions are divided up, in the same way as those of the first radial, into secondary ridges and furrows.

(§ 75) The third or axillary radial of *Act. polymorpha*, which gives attachment to two primary arms, presents three articular surfaces—an internal one corresponding to the distal face of the second radial, and two external ones, inclined to one another, with which the bases of the arms articulate.

The proximal face (Pl. VII. fig. 3 a) is precisely similar in character to the distal face of the second radial, being divided, like it, by a vertical ridge into two lateral fossæ (*h*) which lodge the interarticular ligaments. Its articular margin, when viewed from the dorsal side (fig. 3 d), is perfectly straight, and does not project in the middle as in *Ant. rosacea*; so that the possible amount of lateral movement between the second and third radials must be extremely slight. Two vertical lamellæ (*g*) project from the uppermost margin of the internal face; but they do not form part of the surface of articulation with the second radial, as they are excavated into fossæ on their outer side for the attachment of the proximal ends of the outer muscular bundles passing between the axillary radial and the lowest segments of the primary arms. The two inner muscular bundles are attached to the two sides of a projecting wedge-shaped process (*cl*) on the external or distal face, the "clavicular" of Schultze[1], which occupies the angle between the two obliquely placed articular faces for the basal arm-segments. These are of precisely the same character as the external faces of the first radials (fig. 3 b), consisting, besides the muscular fossæ (*f*) just mentioned, of two others for the interarticular ligaments (*h*), and of a large dorsal fossa (*j*) lodging the elastic ligament, and separated from the other two by a transverse articular ridge (*i*), in the centre of which is the opening of the central canal (*c.c*).

[1] *Loc. cit.* p. 5.

The median line of the ventral face (fig. 3 c) is occupied by a ventral radial furrow continuous with that on the ventral face of the first radial; it divides into two branches, one of which passes on either side of the clavicular, in order to be continued on to the basal arm-segments. The proximal end of this furrow is indicated by the deep notch separating the two vertical lamellæ which project upwards from the proper internal face (fig. 3 a, *g*), and through which the base of the clavicular is seen.

In the type and in var. 1 the lateral portions of the ventral face of the third radial are plain, and not sculptured; but in varieties 2–4 they are divided up by secondary ridges and furrows (fig. 6 c), just like the ventral faces of the first and second radials (figs. 4 c, 5 c). In these varieties also there are no vertical lamellæ projecting upwards from the ventral margin of the internal face (fig. 6 a), which is also the case in the external face of the second radial (Pl. VII. fig. 5 b), as the muscular bundles passing between the first and second radials, and between the third radials and basal arm-segments, are smaller than in the type. In var. 2 there would appear to be more power of lateral movement between the second and third radials than is the case in the type; for although, as in the type, there is no projection in the middle of the proximal articular margin of the third radial, yet the distal articular margin of the second radial shows a slight indication of such a median prominence (fig. 5 d), which is absent in the type. It would seem though, to be replaced to a certain extent by the greater thickness of the vertical articular ridge (*i*) around the opening of the central canal, which is seen, in Pl. VII. fig. 2 d, to project a little beyond the level of the dorsal surface of the radial; so that when the opposed ridges of the second and third radials are in contact with each other, the third may possibly have a very slight power of lateral movement upon the second, though by no means so great as in *Ant. rosacea*, in which the median prominence on the internal articular margin of the third radial is very marked.

The second and third radials of var. 2 differ from those of the type of *Act. polymorpha* and of all the other varieties in the very marked convexity of their dorsal surfaces, which renders them considerably higher than the first radials; so that when the whole calyx is viewed from the exterior, the inner circle of first radials, which are only very little concealed by the small centrodorsal piece, seems somewhat sunk within the outer circle formed by the second and third radials.

This marked convexity is well seen in Pl. VII. fig. 5, a, d, and fig. 6, b, d, especially when these figures are compared with those of the corresponding parts in the type (fig. 2, a, d, fig. 3, b, d).

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DESCRIPTION OF THE PLATES.

The following letters denote the same parts throughout all the Plates.

A, B, C, D, E. The five Radii or Ambulacra.

$A_1, A_2, B_1, B_2, C_1, C_2, D_1, D_2, E_1, E_2$. The ten Primary Arms.

a.c. Axial cœlom.

a.p. Axial prolongation.

a.i.c. Axial interradial canal.

a.r.c. Axial radial canal.

a.i.f. Axial interradial furrow.

a.r.f. Axial radial furrow.

An. Anal tube.

$b_1, b_2, b_3, b_6, b_{10}$. First, second, third, sixth, and tenth brachials.

b.b. Basal bridge.

b.f. Basal fold.

b.g. Basal groove.

$b.m_1$. Muscles between the radial axillary and the first brachials.

$b.m_2$. Muscles between the second and third brachials.

c.c. Central canal of the calcareous segments of the rays and arms.

c.c'. Central canal of the cirrhus-segments.

ch. Chambers of the quinquelocular organ.

cd. Centrodorsal piece.

cir. Cirrhus.

cd.c. Centrodorsal cœlom.

cl. Clavicular.

c.n. Calcareous network in the central vacuity of the pentagonal base of the calyx.

co.c. Commissural canals in the first radials.

d.i.f. Dorsal interradial furrow.

cv.c. Circumvisceral cœlom.

d.r.f. Dorsal radial furrow.

d_1, d_2, *d.a.* First, second, and axillary distichals.

ep. Epithelial wall of the alimentary canal.

F. Central funnel-shaped space enclosed within the pentagonal base.

f. Muscular fossæ.

g. Vertical lamellæ of the calcareous segments.

f_1. Intermuscular furrow.

g_1. Their superior margins.

f_2. Notch representing it in *Ant. celtica.*

g_2. Their inner lateral margins.

g_3. Ridge formed by the union of these in the first radials of *Ant. celtica.*

h. Fossæ lodging the interarticular ligaments.

i. Transverse articular ridge.

i.co. Interradial commissure.

i.e. Interradial elevations on the centrodorsal piece.

iv.c. Intervisceral cœlom.

j. Fossæ lodging the elastic ligaments.

k. Fossæ lodging the ligamentous substance between the sides of the second radials.

L. Ligamentous substance between the sides of the first radials.

l. Ligamentous substance between the first radials and the centrodorsal piece.

L'. Incompletely decalcified portions of the skeleton.

L_1. Interarticular and } ligaments between the first and second radials, or second and third
l_1. Elastic } brachials.

L_2. Interarticular ligaments between the second and third radials.

M. Mouth.

N. Fibrillar nervous envelope of the quinquelocular organ.

n. Axial nervous cords of the rays and arms.

o. Interradial spout-like processes of the rosette.

n'. Their branches.

o'. Interradial triangular processes.

n.c. Axial nervous cords of the cirrhi.

o.b. Ovoid bodies.

P. Peristome.

Pe. Uncalcified perisome between the radii.

p. Radial processes of the rosette.

p'. Small curved processes at the sides of a single basal.

p_1, p_2, *p.a.* First, second, and axillary palmars.

Q. Radial openings on the dorsal surface of the pentagonal base.

Q'. Notches on the inner margins of the dorsal faces of the first radials.
q. Radial depressions on the centrodorsal piece. *R*. Rosette.
r_1, r_2, *r.a.* First, second, and axillary radials. *r.ar.* Radial areas on the centrodorsal piece.
r.c'. Diverticulum from the radial cœlom into the substance of the first radial.
r.co. Intraradial commissure. *r.o.* Central opening of the rosette.
r.m. Muscles between the first and second radials. *r.s.* Radial space. *S.* Rays of the basal star.
S_1, S_2, S_3. Diverging, vertical, and lateral fibres effecting the interradial portions of the synostosis between the centrodorsal piece and the radial pentagon.
s. Depressions at the central ends of the rays of the basal star.
sp_1, *sp.a.* First and axillary suprapalmars. *Sy.* Syzygium.
t. Short processes at the angles of the centrodorsal piece.
U. Sockets for the attachment of the dorsal cirrhi.
u. Inner openings of the cirrhus-canals in the centrodorsal piece.
v.i.f. Ventral interradial furrow. *v.r.f.* Ventral radial furrow.
V, W, X, Y, Z. The five primary basal cords proceeding from the angles of the quinquelocular organ.
V_1, V_2, W_1, W_2, X_1, X_2, Y_1, Y_2, Z_1, Z_2. The ten secondary basal cords produced by the bifurcation of the primary ones.
v_1, v_2, w_1, w_2, x_1, x_2, y_1, y_2, z_1, z_2. The apertures in the basals through which the secondary cords pass.
v, v', w, w', x, x', y, y', z, z'. The corresponding apertures of the central canals on the internal faces of the first radials.

In Pl. II. figs. 9–11 indicate the position of the mouth (ventral) relative to the radial skeleton (dorsal).

* In Pl. V. fig. 4 indicates the passage of the ventral radial canal into the central calcareous network within the radial pentagon by two openings, instead of by only one as usual.

PLATE I.

Diagrams of the distribution of the ambulacra on the disks of different species of *Comatula*. The red lines mark the interradial intervals. Figs. 1–4 copied from Müller.

Fig. 1. *Antedon rosacea.*
2. *Actinometra solaris.*
Fig. 3. *Act. Wahlberghii.*
4. *Act. multiradiata.*

In figs. 5–16 the tentaculiferous grooves are marked by dark lines, and the non-tentaculiferous grooves by fainter lines.

Fig. 5.	*Act. solaris.*	Proportion of non-tentaculiferous arms,		$\frac{4}{10}$
6.	*Act. polymorpha*:	Type.	"	$\frac{7}{13}$
7.	"	"	"	$\frac{10}{18}$
8.	"	"	"	$\frac{6}{20}$
9.	"	Var. 1.	"	$\frac{11}{20}$
10.	"	Type.	"	$\frac{12}{25}$
11.	"	"	"	$\frac{15}{26}$
12.	"	"	"	$\frac{10}{28}$
13.	"	"	"	$\frac{15}{28}$
14.	"	Var. 2.	"	$\frac{10}{29}$
15.	"	Type.	"	$\frac{19}{31}$
16.	"	Var. 4.	All the arms tentaculiferous.	

Plate II.

Fig. 1. Diagram of the distribution of the ambulacra in a new *Actinometra* from the Philippines.

2. Superior or ventral aspect of the disk of *Act. polymorpha,* var. 2, the oral pinnules having been cut away near their bases. × 3.

3. Piece of an ordinary tentaculiferous arm of *Act. polymorpha,* from about the middle of its length, seen from above. × 4.

4. Terminal portion of the same arm. × 4.

5. Piece of the middle portion of a non-tentaculiferous arm, borne upon the same axillary as that represented in figs. 3 & 4. Ventral view. × 4.

6. Termination of the same arm. × 4.

7. Distichal, palmar, and lower brachial segments of one of the radii of *Act. polymorpha,* var. 4, showing the white line which occupies the middle of the dorsal surface of the skeleton. × 4.

8. Centrodorsal piece and one radius of a monstrous specimen of *Act. polymorpha,* showing the very irregular form of the centrodorsal piece (*cd*) and the imperfect condition of one of the palmar series, which consists simply of one axillary segment bearing brachials upon one of its distal faces, and two suprapalmars (sp_1, *sp.a*) upon the other. × 4.

9. Diagram of the calyx of a small thirteen-armed specimen of *Act. polymorpha*: Type. × 4.

10. A similar diagram of a larger specimen with 26 arms. × 3.

11. A similar diagram of a specimen of var. 3, with 39 arms. × 2.

The * in these three figures (9, 10, 11) indicates the position of the mouth on the ventral side of the disk relatively to the radial skeleton of the dorsal side.

Plate III.

Fig. 1. Terminal comb of an oral pinnule of *Act. pectinata.* × 20.

2. Oral pinnule of *Act. polymorpha,* Type. × 10.

3. Oral pinnule of *Act. polymorpha,* Var. 4. × 10.

4. Portion of a horizontal section through the synostosis of two first radials of *Pentacrinus Wyville-Thomsoni.* × 110.

5. Lower portion of a vertical section through the peripheral end of the synostosis of two first radials of *Act. polymorpha.* × 110.

6. Lower portion of a similar section, taken rather nearer the centre of the radial pentagon, showing the disposition of the fibres which effect the synostosis of the first radials with the centrodorsal piece, both in the radial (*l*) and the interradial planes (S_1, S_2, S_3). × 110.

7. Longitudinal section through one of the muscles ($b.m_2$) and interarticular ligaments (L_1) connecting the second and third brachials. × 110.

8–10. Cirrhi of *Act. polymorpha.* Type, and vars. 1 & 2.

8. Type. × 6. *a,* adult; *b,* very young; *c,* nearly mature.

9. Isolated cirrhus-segments of the Type. × 40. *a,* a basal segment; *b,* a terminal segment.

10. Cirrhus of var. 2. × 6.

11. Cirrhus of var. 1. × 6.

Plate IV.

Figs. 1–8 of *Ant. celtica.* All × 7.

Figs. 1 & 2. Centrodorsal piece, after removal of the cirrhi, as seen from its dorsal (fig. 1) and ventral (fig. 2) sides.

3 & 4. Pentagonal base of the calyx, as seen from its dorsal (fig. 3) and ventral (fig. 4) sides.

Fig. 5. Interior of the calyx, as seen after removal of the visceral mass.
6. Lateral view of the base of the calyx with the centrodorsal piece *in situ*.
7. Pentagonal base of the calyx of a smaller variety, as seen from its dorsal side.
8. Lateral view of the base of the calyx of the same variety, with the centrodorsal piece *in situ*.

Figs. 9–11 of *Ant. Eschrichtii*.

Fig. 9. Two united first radials, together with the portion of the rosette which is in connexion with them, as seen from within. × 7.
10. Pentagonal base of the calyx as seen from its dorsal side after removal of the rosette occupying its central cavity. × 3½.
11. Centrodorsal piece seen from its ventral side. × 3½.

Figs. 12–17 of *Ant. rosacea*, all × 7, except fig. 13, which is × 15.

Fig. 12. Isolated first radial. *a.* ventral, *b.* dorsal, *c.* internal aspect.
13. Abnormally developed rosette, with two spout-like interradial processes (*o*) and a basal bridge (*b. b.*) connecting the ends of two of the radial processes (*p*). × 15. *a.* ventral, *b.* dorsal aspect.
14. Lateral view of the base of the calyx with the centrodorsal piece *in situ*.
15. Centrodorsal piece seen from its ventral side.
16 & 17. Pentagonal base of the calyx as seen from its dorsal (fig. 16) and ventral (fig. 17) sides.

Plate V.

The figures all × 7, except fig. 8, which is × 15.

Figs. 1–4 of *Act. solaris*.

Figs. 1 & 2. Centrodorsal piece as seen from its dorsal (fig. 1) and ventral (fig. 2) sides.
3 & 4. Pentagonal base of the calyx as seen from its dorsal (fig. 3) and ventral (fig. 4) sides.

Figs. 5–9 of *Act. pectinata*.

Fig. 5. Interior of the calyx as seen after removal of the visceral mass.
6 & 7. Centrodorsal piece as seen from its dorsal (fig. 6) and ventral (fig. 7) sides.
8. An isolated compound basal. × 15. *a.* ventral, *b.* dorsal aspect.
9. An isolated first radial. *a.* ventral, *b.* dorsal, *c.* internal aspect.

Figs. 10–15 of *Act. robusta*.

Fig. 10. Internal aspect of an isolated first radial.
11–13. Two united first radials, together with those portions of the rosette which are in connexion with them, as seen from above (fig. 11), below (fig. 12), and within (fig. 13).

In these four figures (10–13) I. indicates a bristle passed along the axial radial canal; II. another passed along the axial interradial canal; and III. a third, entering the central canal by one of the apertures on the internal face (x'), and coming out through the aperture of the commissural canal (*co.c.*) on the lateral face.

Figs. 14 & 15. Centrodorsal piece as seen from its dorsal (fig. 15) and ventral (fig. 14) sides.

Plate VI.

All these figures are × 7, except figs. 6, 18, 19, 22, which are all × 15.

Figs. 1–11 of *Act. polymorpha*, Type. Figs. 1–6, from one specimen.

Fig. 1. Lateral view of the base of the calyx, with the centrodorsal piece *in situ*.
2. The same parts seen from the dorsal side.

Fig. 3. Ventral aspect of the centrodorsal piece.

4 & 5. Pentagonal base of the calyx as seen from its dorsal (fig. 4) and ventral (fig. 5) sides.

6. Two united compound basals as seen from their ventral side. × 15.

7, 8, & 9, from a second specimen.

7 & 8. Centrodorsal piece as seen from its dorsal (fig. 7) and ventral (fig. 8) sides. In fig. 8 three of the rays of the basal star are seen occupying the basal grooves (*b. g*), their proper connexion with the rosette having been broken.

9. Pentagonal base of the calyx as seen from its dorsal side after removal of the rosette and basal star.

10 & 11, from a third and abnormally developed specimen.

10. Centrodorsal piece seen from its ventral side.

11. Dorsal aspect of the pentagonal base of the calyx.

Figs. 12–15 of *Act. polymorpha*, var. 1.

Figs. 12 & 13. Pentagonal base of the calyx as seen from its ventral (fig. 12) and dorsal (fig. 13) sides.

14 & 15. Centrodorsal piece as seen from its dorsal (fig. 14) and ventral (fig. 15) sides.

Figs. 16–19 of *Act. polymorpha*, var. 2.

Figs. 16 & 17. Centrodorsal piece as seen from its dorsal (fig. 16) and ventral (fig. 17) sides.

18 & 19. Two united compound basals as seen from their ventral (fig. 18) and dorsal (fig. 19) sides.

Figs. 20–22 of *Act. polymorpha*, var. 3.

Figs. 20 & 21. Centrodorsal piece as seen from its dorsal (fig. 20) and ventral (fig. 21) sides.

22. An isolated compound basal as seen from its ventral (*a*) and dorsal (*b*) sides.

Figs. 23 & 24 of *Act. polymorpha*, var. 4.

Pentagonal base of the calyx as seen from its ventral (fig. 23) and dorsal (fig. 24) sides.

Plate VII.

In this Plate are shown the first, second, and third radials of the type of *Act. polymorpha* (figs. 1–3) and of var. 2 (figs. 4–6).

The different aspects shown are designated as follows:—*a*. Internal or proximal face; *b*. External or distal face; *c*. Ventral or superior face; *d*. Dorsal or inferior face.

Act. polymorpha, Type.

Fig. 1. First radial.

2. Second radial.

3. Third or axillary radial.

Act. polymorpha, var. 2.

Fig. 4. First radial.

5. Second radial.

6. Third or axillary radial.

Plate VIII.

All the figures are × 18. Figs. 1 & 2 of *Act. polymorpha*, Type.

Figs. 1 & 2. Two successive oblique sections through the base of a decalcified calyx, viewed from their dorsal side.

Fig. 1 is the more inferior, *i.e.* nearer the dorsal surface. Its left-hand lower portion shows the centrodorsal piece only, with its marginal cirrhi (*cir.*) which receive fibrillar cords (*n.c.*) from the central mass (N) enveloping the quinquelocular organ. Proceeding outwards from the centre are seen five dark rays (S_1), which represent the closely fibrillar organic basis of the five rays of the basal star. In the upper part of the figure two of them are very short, only their central ends being visible, as the section has here passed above the level of their outer ends through the substance of three first radials (r_1).

Fig. 2. In this section only two of the basal rays (S_1) are visible, as the greater part of it has passed above the level of the synostosis (l) between the first radials and the centrodorsal piece. In the centre are seen the chambers of the quinquelocular organ (ch), with their ventral openings into the vessels contained within the axial prolongation. At the right of the figure are seen the lower ends of the axial canals, both radial (*a.r.c.*) and interradial (*a.i.c.*); their cavities are generally crossed by transverse septa, which divide them up into two or three intercommunicating smaller ones. The interval between every two of these canals is occupied by one of the secondary basal cords (Y_2, Z_1, Z_2, &c.), produced by the bifurcation of the short primary cords (V, Y, &c.) proceeding from the angles of the quinquelocular organ. They are connected with one another laterally by interradial and intraradial commissures (*i.co.* & *r.co.*) and enter the central canals of the first radials (r_1) in successive pairs, so that the axial nervous cord (n) of each radius is composed of fibres derived from two primary basal cords (Y_2, Z_1, &c.), just as in *Antedon.*

Fig. 3. A vertical longitudinal section through a decalcified calyx, passing on the right through the synostosis of two first radials (A, B) and the fibrillar basis (S_2) of one of the basal rays, and on the left through the segments (r_1, r_2, *r.a.*) of radius D. The first of these is united to the centrodorsal piece by connective-tissue fibrils (l) similar to, but less abundant than, those in the interradial portion of the section, around which, in the natural condition, the calcareous material forming one of the basal rays is deposited. The passage of the ventral furrows (*v.r.f.*, *v.i.f.*) into the axial canals (*a.r.c.*, *a.i.c.*) is also well seen in this section. Its centre is occupied by the quinquelocular organ, from the ventral portion of which the axial prolongation (*a.p.*) rises into the circumvisceral cœlom (*c.v.c.*), which, together with the lower end of the wide axial cœlom (*a.c*), occupies the space between the ventral surface of the skeleton and the lower or dorsal wall of the convoluted alimentary canal. It is traversed by numerous connective-tissue septa, which divide it up into a system of spaces, communicating freely with those both of the intervisceral and of the axial cœlom (*iv.c.*, *a.c.*).

Fig. 4. Transverse section through the synostosis of two first radials (A, B) near the peripheral margin of the centrodorsal piece (*cd.*), showing the radial (l) and the interradial (S_2) fibres which effect the synostosis between it and the united first radials. The latter form the organic basis of one of the rays of the basal star.

Figs. 5–8. Four vertical sections, selected from a series, through a decalcified calyx of *Act. pectinata.*

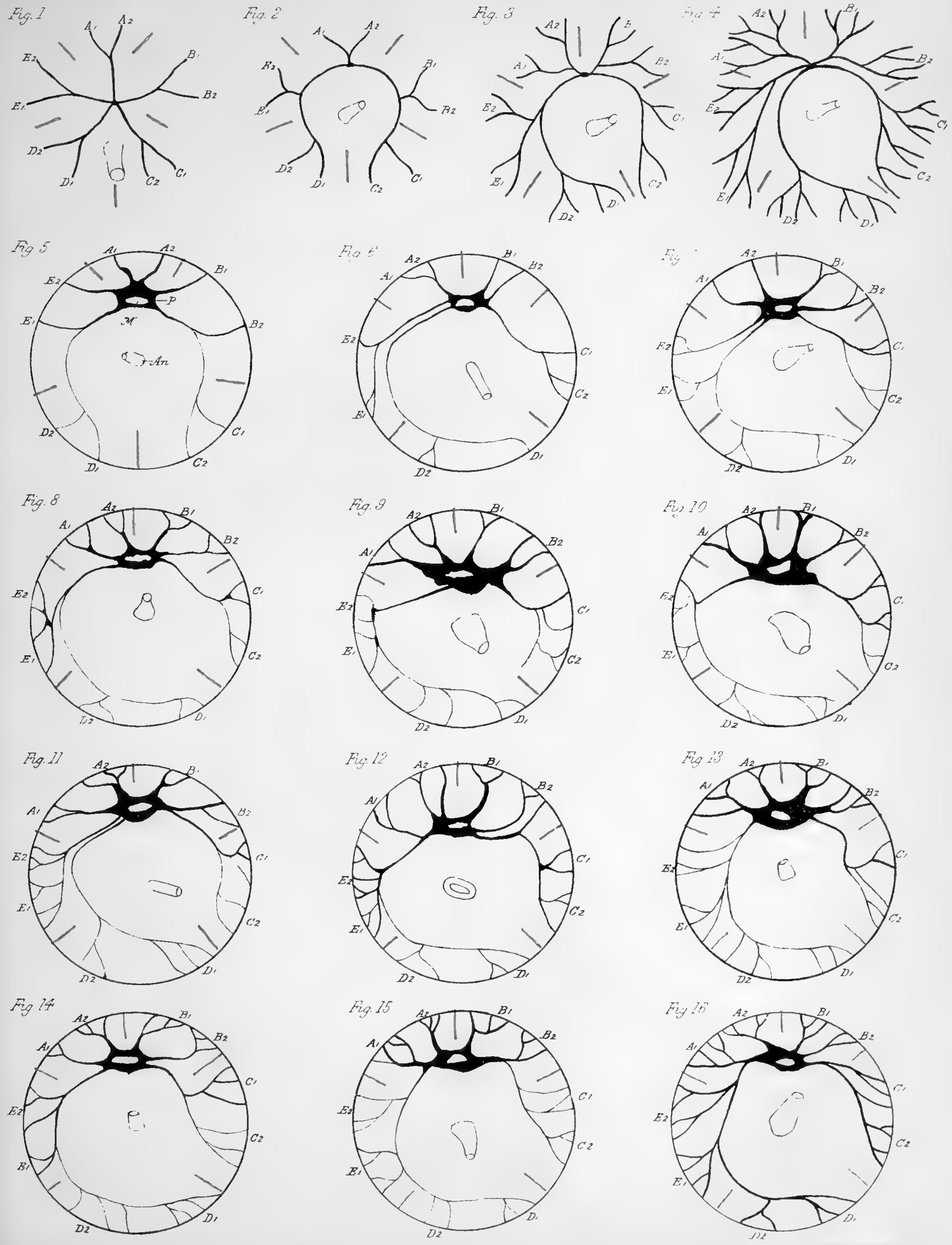
5. Section through the adjacent inner ends of two first radials (A, B), showing the axial interradial canal (*a.i.c.*) between them, and the open outer ends of the radial spaces (*r.s.*) between their dorsal surfaces and the ventral surface of the centrodorsal piece. The central ends of their axial nervous cords (*n.*) are cut very obliquely.

6. A section rather nearer the centre, showing the closed central ends of the radial spaces (*r.s.*) of the same two radii (A, B) and their axial canals (*a.r.c.*); also the four secondary basal cords which unite in successive pairs (Z_2, V_1 and V_2, W_1) to form their axial cords, cut obliquely.

7. A section from a little the other side of the centre, through the outer end of one of the chambers (ch) of the quinquelocular organ, corresponding to radius D. The radial spaces (*r.s*) of C and E are cut almost longitudinally; and above them, in the interior of the radials, are seen the axial nervous cords, with one of the two secondary basal cords

(X_1, Y_2) by which each is connected with the central nervous envelope of the quinquelocular organ. The other branches (X_2, Y_1) of the two primary cords (X & Y) combine to form the axial cord of the radius *D*. The inner end of its first radial is seen in the centre of the upper part of the figure (r_1), separated from those of *C* & *E* by the axial interradial canals (*a.i.c*).

Fig. 8. A section rather further from the centre of the calyx, showing the first radial of *D* cut transversely, with the closed central end of its radial space (*r.s.*). At the sides of the latter are the expanded dorsal ends of the axial interradial canals seen in fig. 7; they are received in depressions (*s*) at the central ends of the rays of the basal star, which are ossified around the vertical fibres (S_2) only, and not, like the stouter more peripheral portions of the rays, around both vertical and diverging fibres, as is seen in Plate III. fig. 6, S_1, S_2.



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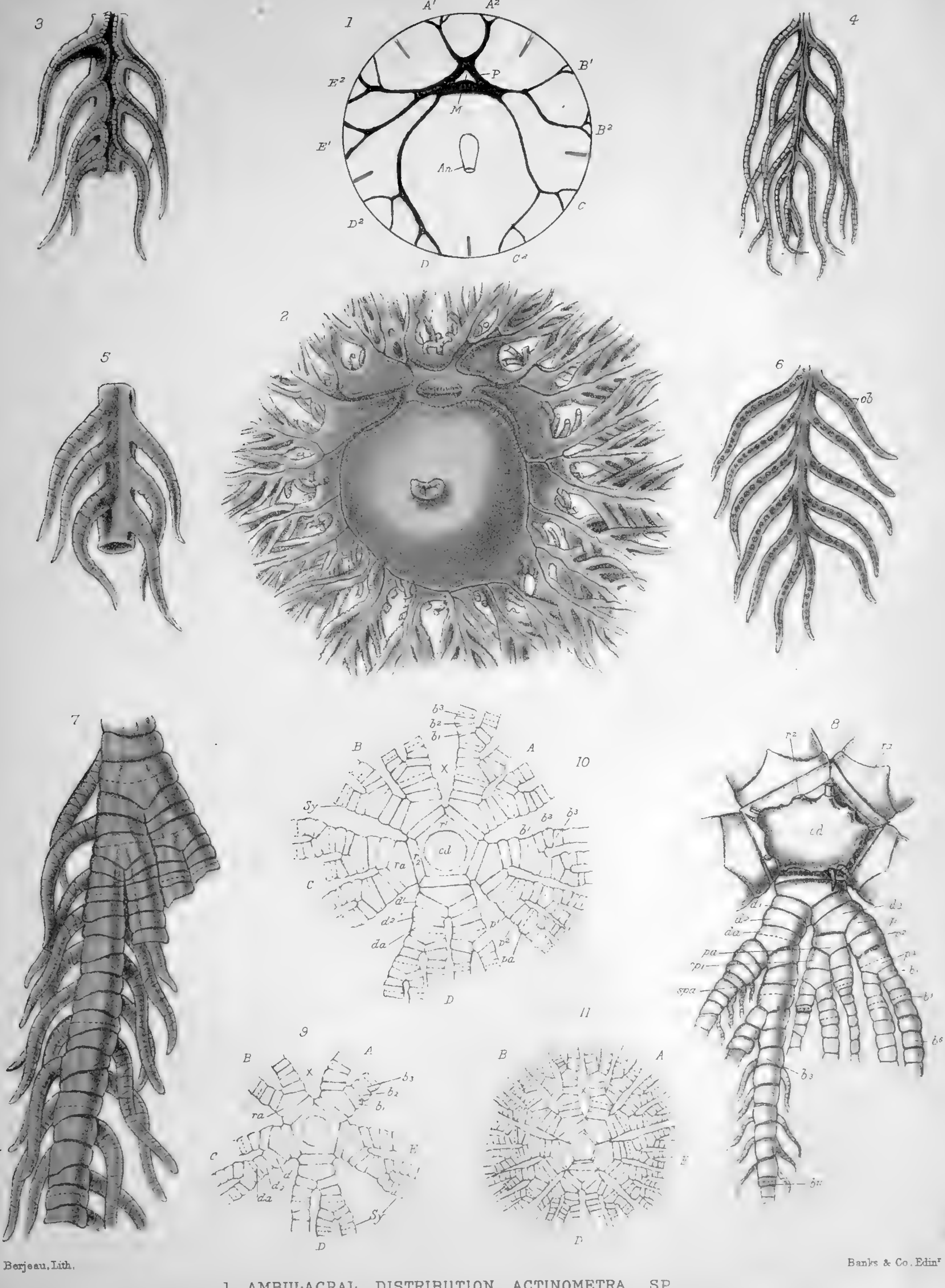
DIAGRAMS OF AMBULACRAL DISTRIBUTION, SPECIES OF COMATULA



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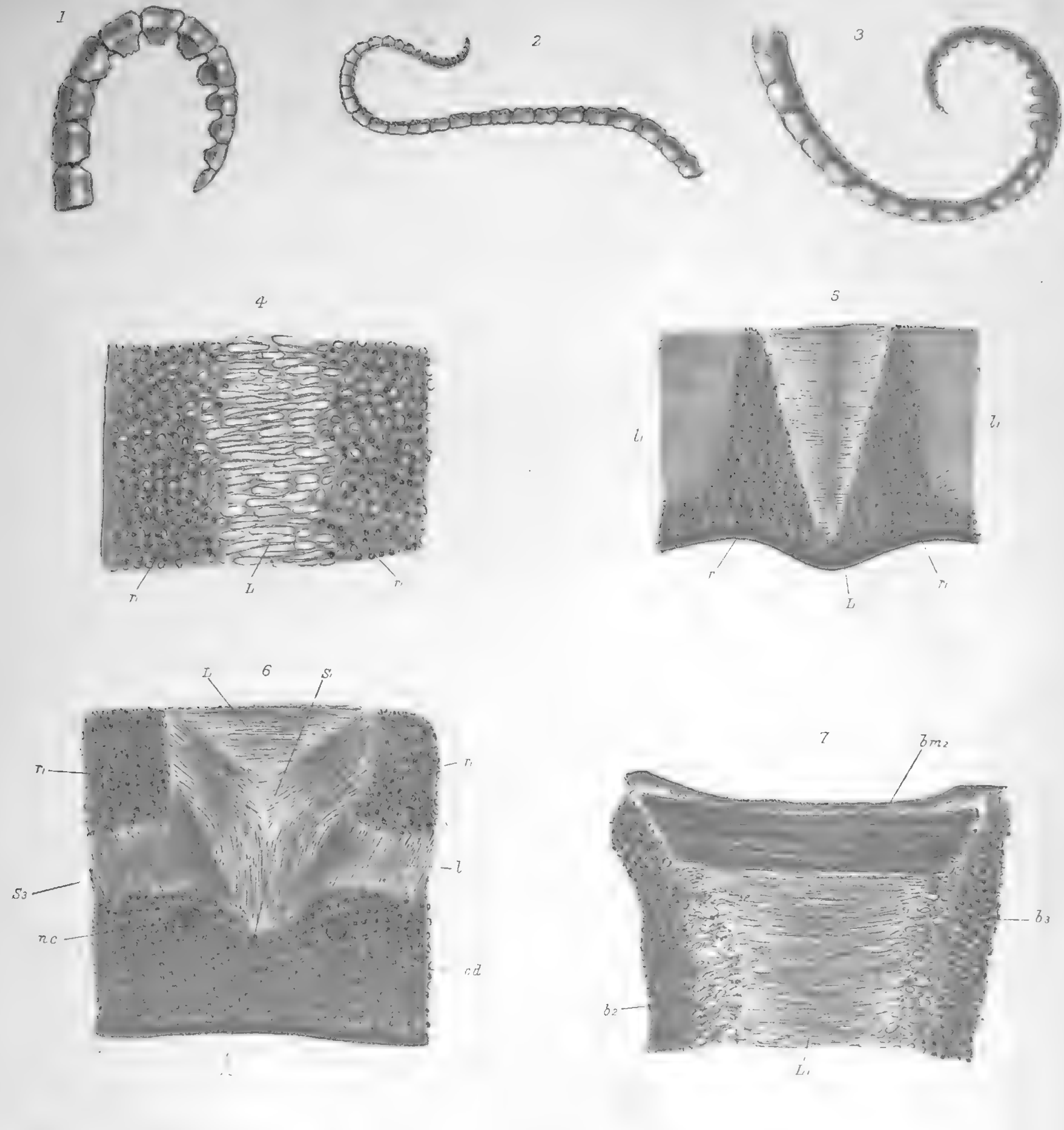
1. AMBULACRAL DISTRIBUTION ACTINOMETRA SP

2-11. DISK, ARMS, BRACHIAL SEGMENTS, CENTRODORSUM & CALYX OF ACT, POLYMORPHA.



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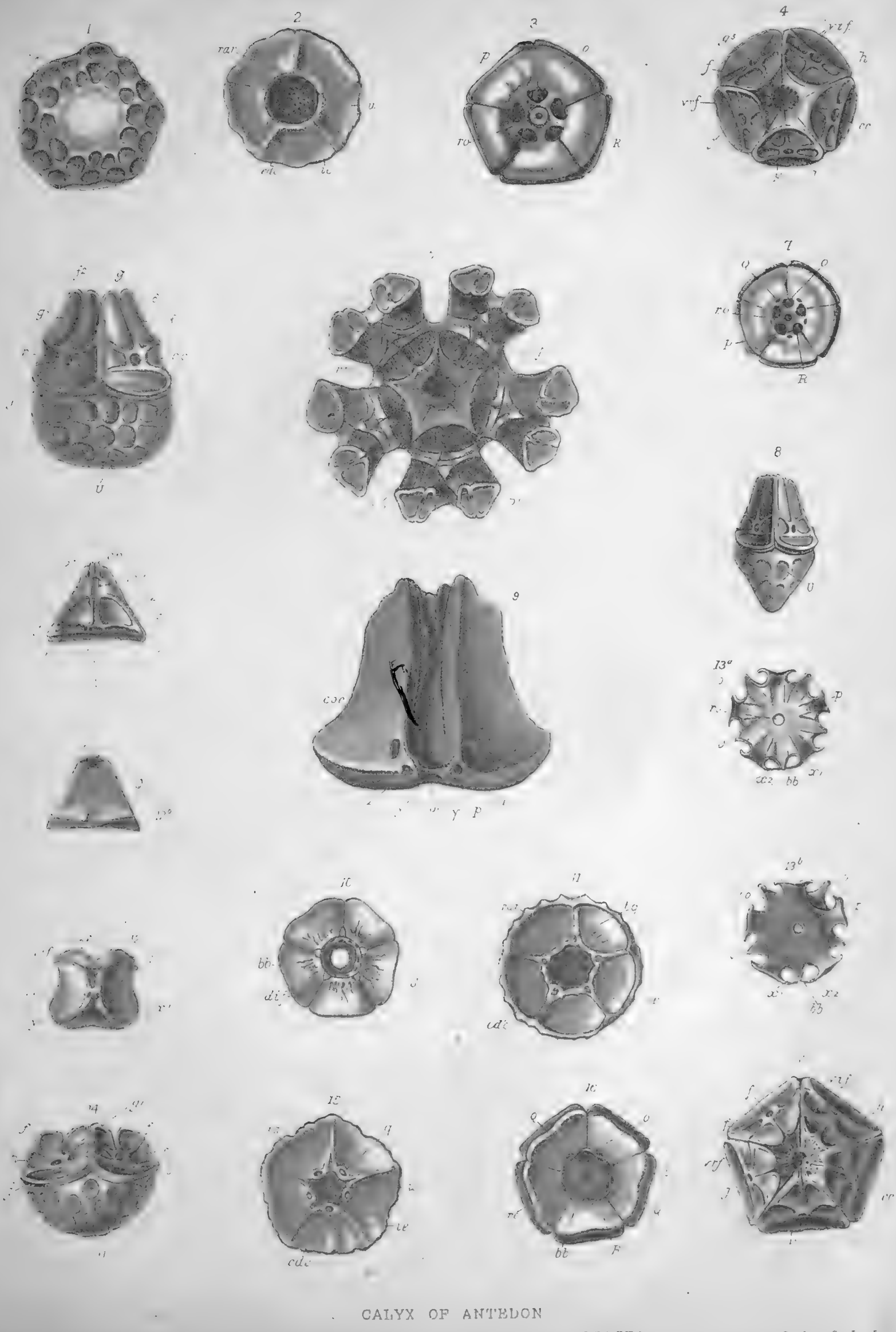
ORAL PINNULES, SECTS RADIALS, MUSCLES & CIRRHI OF
ACT. POLYMORPHA Type & Vars. 1-4 & Fig 4. SECT. RADIALS PENTACRINUS WYV. THOMSONI



CALYX OF ANTEDON

A. CELTICA, A. ESCHRICHTII & A. ROSACEA.

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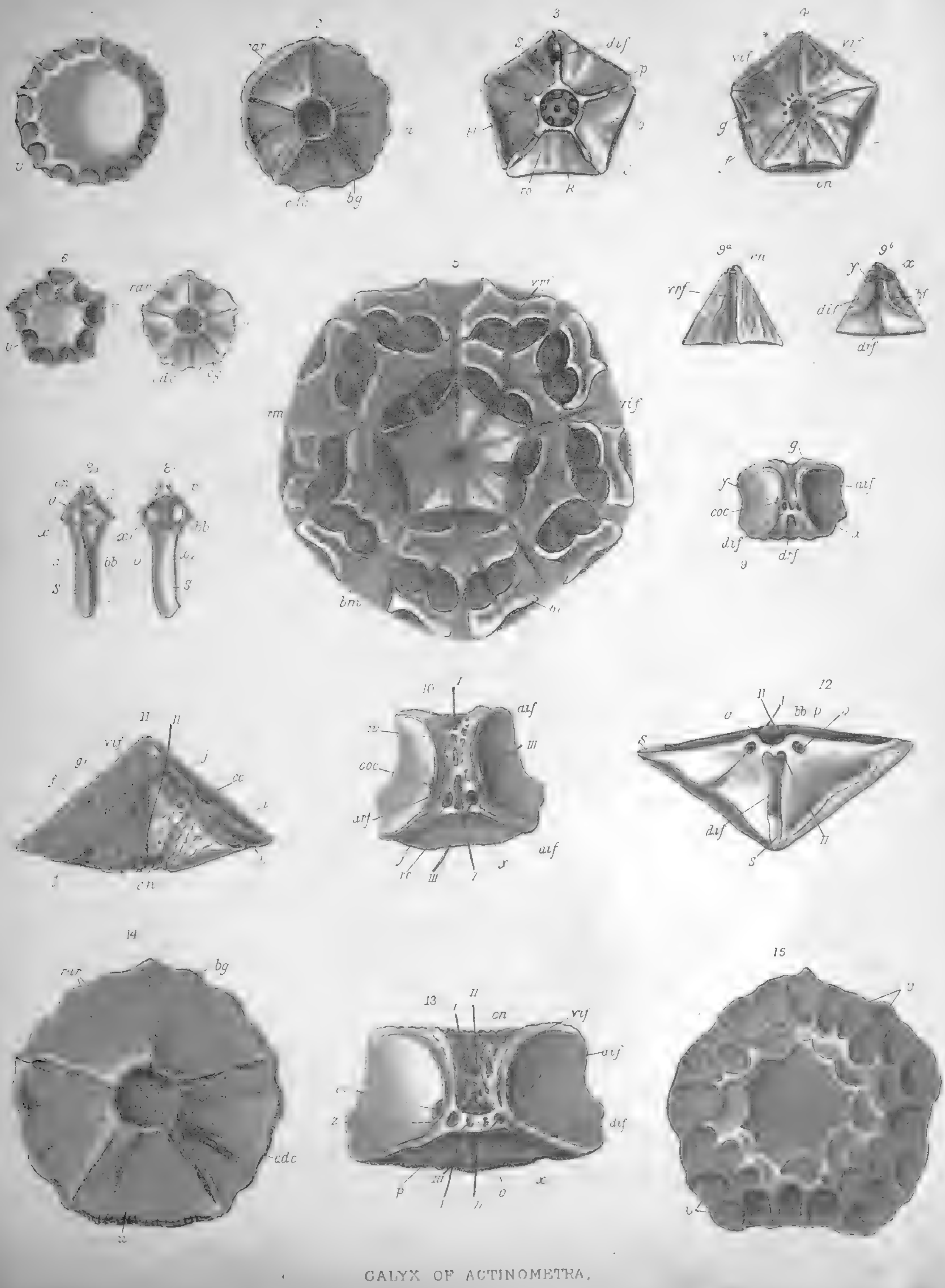
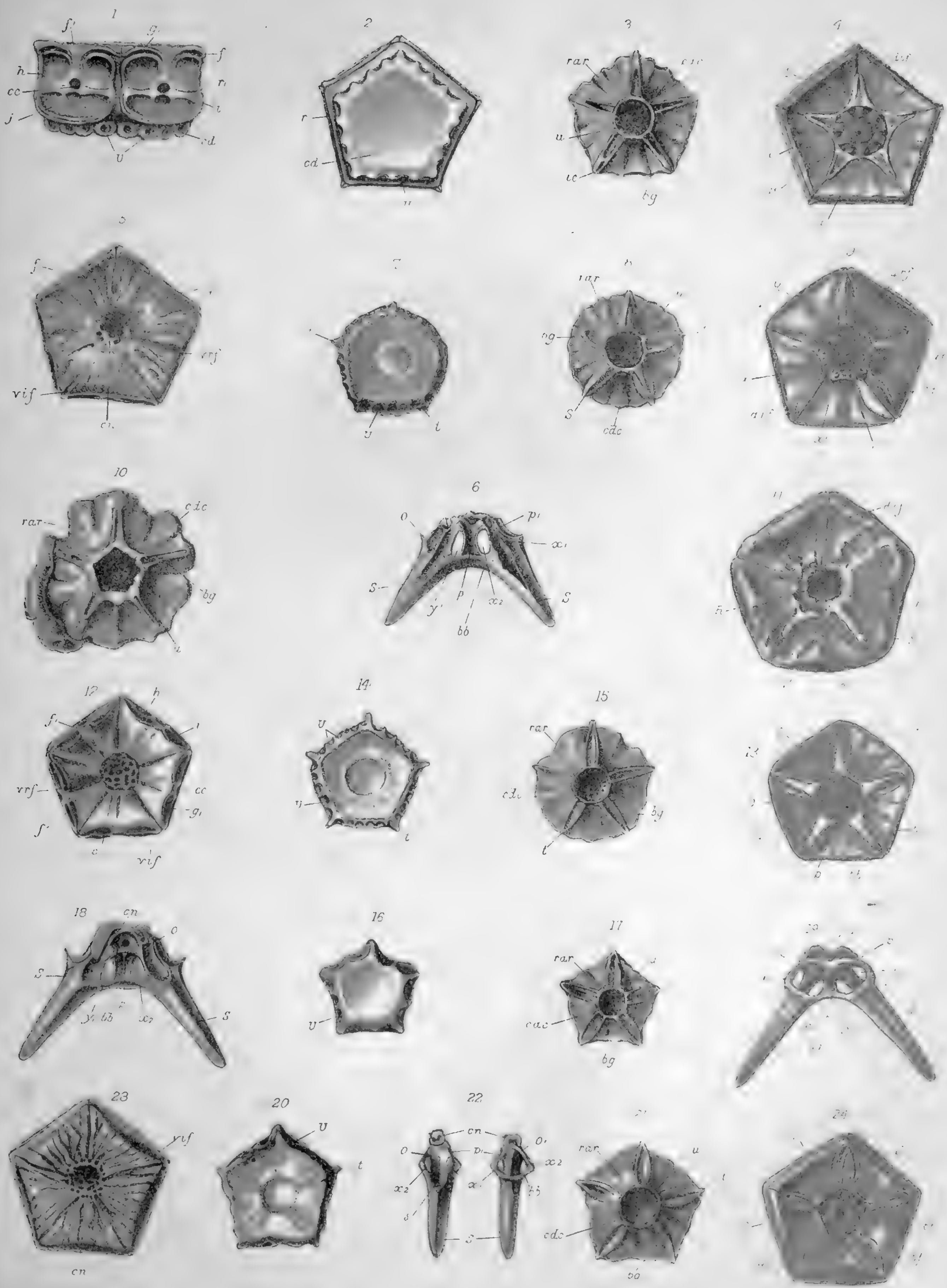


CALYX OF ACTINOMETRA,

A. SOLARIS, A. ROBUSTA & A. PECTINATA.

Bulas & Co. Edin[r]



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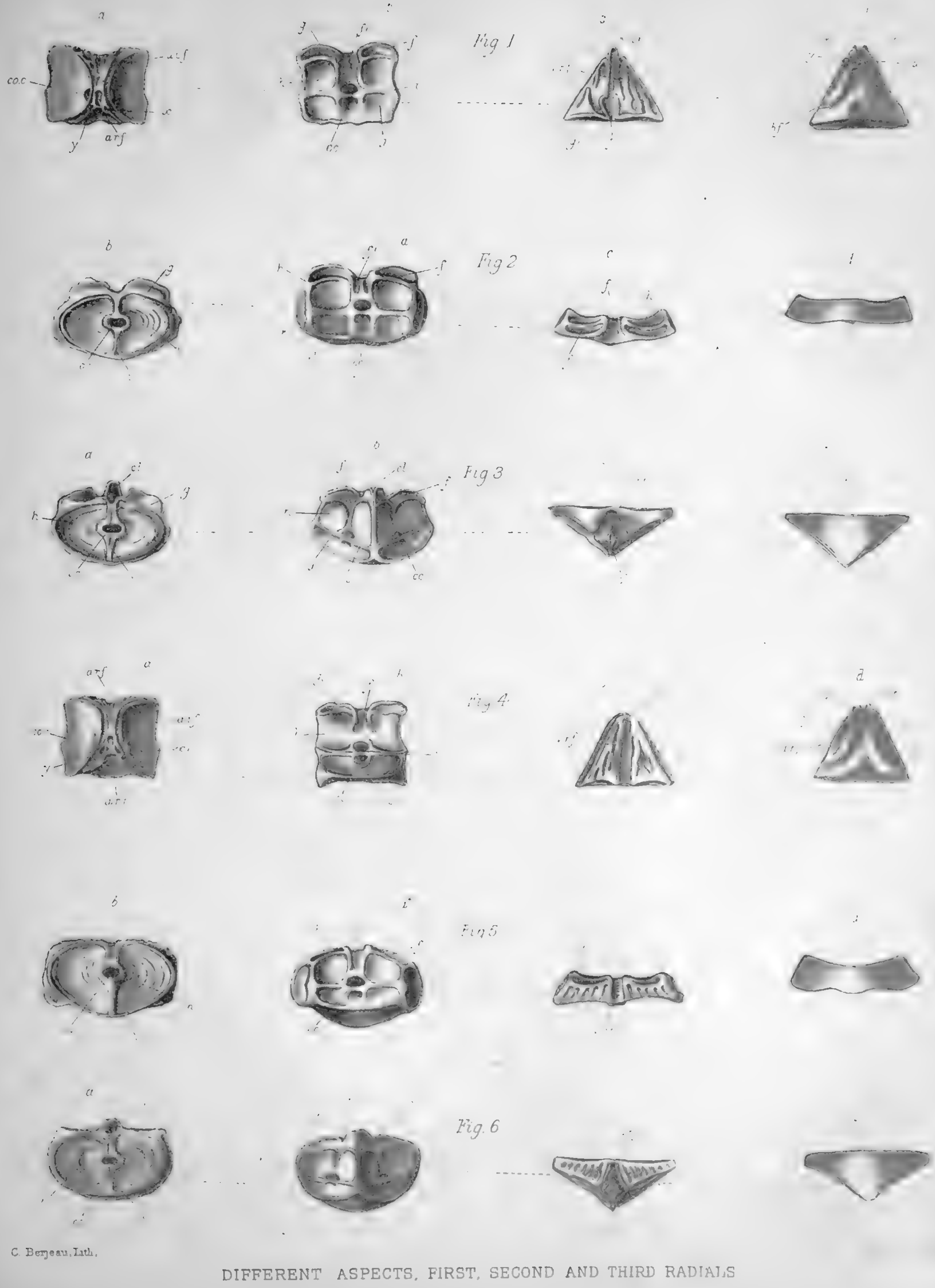
CALYX, BASALS AND CENTRODORSAL PIECE OF
ACTINOMETRA POLYMORPHA Type & Vars. 1-4



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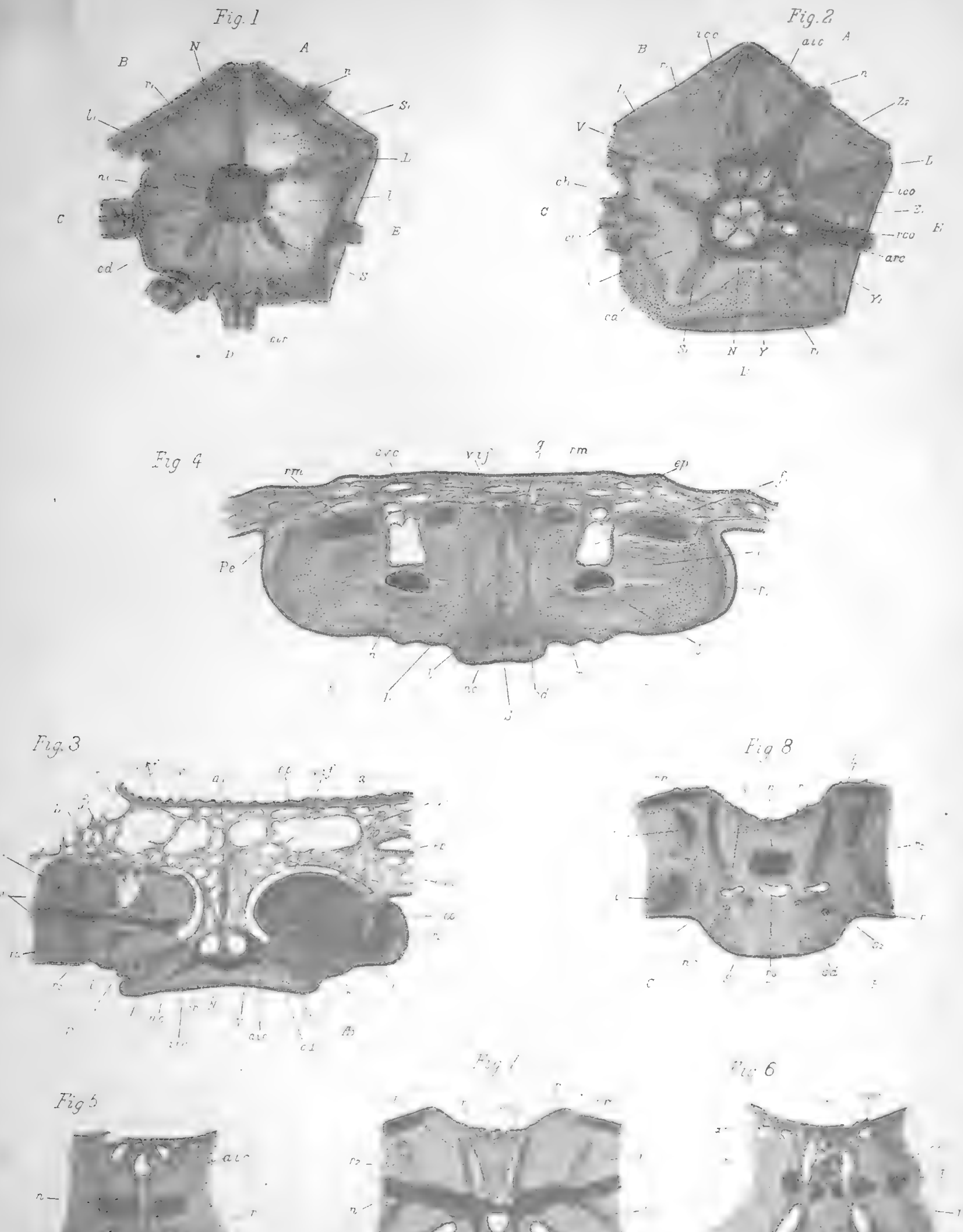
DIFFERENT ASPECTS, FIRST, SECOND AND THIRD RADIALS

ACTINOMETRA POLYMORPHA Type & Var 2



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SECTIONS CALYX. BASAL RAYS AND RADIALS, ACT. POLYMORPHA Type. AND. ACTINOMETRA PECTINATA

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