OBSERVATIONS

ON THE

NERVOUS SYSTEM

OF THE

ASTERIAS.

BY

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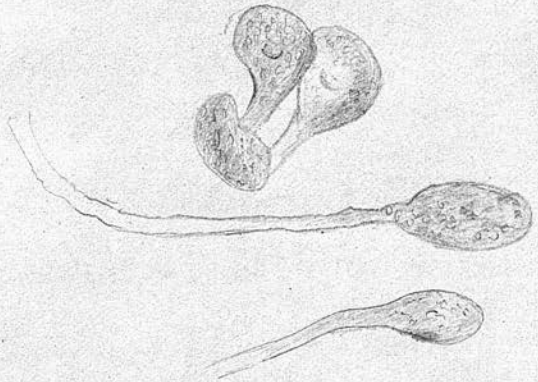
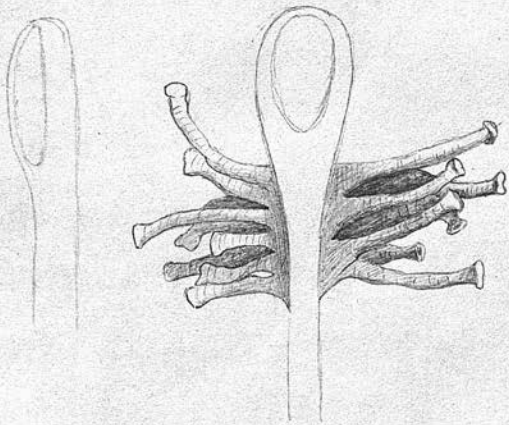
On the Nervous System of the Asterias.

This Nervous System has not, so far as I am aware, been as yet made a subject of microscopical investigation. Though much has been done in working out the Anatomy of the Radiata, and though observations on the Nervous System of Echinodermata have been conducted by many, especially by Müller in modern times, with great energy and care, yet the minute structure of this system remains still undetermined. This is accounted for by the fact that the object of those observers, who have been working at this subject, was, to ascertain the typical arrangement of the system in this Family. Although therefore little is found regarding the nervous system of these animals in books of Comparative Anatomy and Zoology, that little is sufficient to distinguish this type from those of the other Classes constituting the Animal Kingdom.

But since some authors seem to entertain doubts as to whether there is a Nervous System at all in these animals, more minute observations - such as





will decide the true Structure of what is pointed out to the nervous — Cannot be considered as fruitless or useless labour — But before entering into an account of some investigations lately made, it may be as well to glance briefly over the history of what is at present known of this subject —

Regarding the Asteroida Tiedemann stands as the first who described in 1816 a nervous system in these animals, consisting, according to him, of a delicate cord surrounding the mouth and giving off opposite each ambulacral groove three filaments, the middle one, the largest, running along the ambulacral groove and supplying in its course the tubes with feet on each side; and the other two, one on each side of the latter, passing into the interior to supply the viscera &c —. It was not until 1834 that Wagner pointed out ganglionic enlargements on that portion of the annular cord from which the three filaments, already mentioned, are given off. About the same time Ehrenberg described the small pigment spots, at the distal extremities of the ambulacral grooves, as organs of vision, in which, he held, that the nerve filament of the arm terminated. Other observations have since been made but comparatively lately

and it will be more convenient to mention them when treating of the subject afterwards. Many authors for a long period denied the existence of this Nervous System, and even yet, though its presence is granted by the greatest majority, there are a few who consider the whole as simply white fibrous tissue connecting the different vertebrae of the arms. On this point, however, we shall offer a few remarks subsequently. Regarding the organ of vision, considered as such by Ehrenberg, very few there are at the present time but look upon it as merely a mass of pigment, denying it any particular structure and even doubting the possibility of the nervous filament being traced to it. This brief sketch sufficiently proves the little that is known regarding this subject, and, at the same time, clearly shews how confused and uncertain Authors in general seem to be regarding even the few observations. It seems remarkable that no further investigations into the minute structure, have been made, since the subject is not only an interesting one, but may prove also of the greatest importance and use, in a Morphological point of view; seeing that, of all systems, the Neural is the one least subject to aberration. Having commenced some observations on the subject

(a). See Plate I.

last Summer with the kind assistance of Prof. Goodsir, and having, with short intervals, continued them up to the present time, I present them before you, though very imperfect and far from exhausting the subject, hoping that they may not prove altogether useless.

I have carried on my observations on the Urasters Rubens because it is the one most easily obtained. In this animal the nervous system exists as a ring situated on the outer margin of the perioral space, on its ventral surface (a) and since the portion of the ring, as more or less pointed, opposite the commencement of the ambulacral grooves, its shape is pentagonal, the animal having in general five arms. It lies immediately beneath the skin, which, in the this part of the body, is not calcareous and therefore offers it very little protection. But exposure to injury is only apparent, as the nerve ring and its branches are well provided for against harm by rows of spines situated around the perioral space and along the upper margins (ventral margins) of the ambulacral grooves — supposing the animal to be lying on its dorsal surface. The cord of the ring lies quite close to the terminations or proximal ends of the ambulacral

grooves and quite beneath the pointed projections formed by the junction of those calcareous plates, of two neighbouring arms, which bear the first row of spines. The skin over this part is closely bound down to the subjacent fibrous tissue of the perivisceral space, along the ciliated margin of the cord; so that, on attempting to reflect it, unless great care is taken, it is invariably broken off along this line. This close union of the integument to the subjacent fibrous tissue is continued inwards to the orifice of the mouth. It will also be found that on attempting to reflect the integument over the nerve ring, the greatest portion of the nerve substance ~~itself~~ comes away on the skin, proving it to be firmly adherent to the integument over it. The principal branch or prolongation of this nervous system, the ambulacral, lies along the middle of the arm, very deep in the ambulacral groove and generally concealed from view by the double row of alternate suckers or feet arranged along both sides of it. Not uncommonly, however, we find the animal with its feet parted or lying down to each side, thus displaying to the observer this branch resting at the line formed by the convergence of the suckers of opposite sides. As if it longed to shew and establish with certainty the fact

(a). See Plate II. a.a.

ofits having a nervous system and of its being, therefore, an animal of no mean organization. As this branch is of greater importance than is generally attached to it, we must notice, somewhat minutely its position as well as its protective apparatus. For this purpose we had better begin with an examination of the ambulacral groove. It may be said to be entirely formed by the, so called, vertebræ. These vertebræ are calcareous plates, of which, the principal portion of the ventral surface of the skeleton, is composed. They are united to the smaller pieces arranged in the form of ribs, which pass at first outwards and then arch upwards and inwards, roofing the canal space or cavity of the arm by terminating in a calcareous network. Diagramatic views are given, of this portion of the skeleton, in Plates II as seen on a transverse section of an arm. And in Plate III as seen from above. The latter illustrating, principally, the relation each vertebra bears to the others; and the former its connection with the smaller bones and the manner in which it forms the ambulacral groove. They seem each to consist of two calcareous plates which are flat and comparatively broad when seen in a transverse section (a) but having narrow margins on their dorsal and ventral

(a). See Plate III. aaaaa.

(b). See Plate II and III b.

(c). See Plate II. c.

(d). Plate II. d.

aspects.[a] They are irregularly Quadrilateral and rest against each other, by the narrow margin of their upper or dorsal ends, in such a manner, that their lower or ventral extremities diverge from each other. These dorsal ends are firmly united by a transverse fibrous ligament, which may be termed the superior ligament.[b] Somewhat lower down than this a second stronger ligament crosses between the two vertebral plates, forming by one aspect, the floor or roof of the ambulacral groove according as the animal is lying on its dorsal or ventral surface; and by the other, closing in the space above it for the water vessels which supplies the vesicles and feet with ~~water~~ fluid.[c] On this superior ligament, therefore, or below it the ambulacral nerve[d] lies as it passes along the groove. I suspect that this ligament has been mistaken for the nerve, by those who hold that the nervous system of the Starfish consists simply of white fibrous tissue. A mistake exceedingly easy to make, for, since on examination of this portion of the animal under the microscope for the nervous structure, unless great care is taken in hardening it, some of this ligament is very apt to be also taken up and will obscure every thing else, as to make any one at first doubt its being nerve at all. This may readily occur, even

(a). See. (Siebold's Anatomy of the Invertebrata - Echinodermata
Page 82 - §79 - Note (a)).

though the structures are properly hardened, if it so happens that in reflecting the skin you remove the ligament as well. I must acknowledge that, when I first began to work at this, I was, for a long time, very much confused by the presence of this tissue. It may, on the other hand, be possible that these authors have searched for the nervous system on the superior surface of the upper ligament of the vertebrae, in the interior of the arch; where Spix and Konrad[a] affirm it have seen nerve filaments, but where most decidedly they will find nothing more than connective fibrous tissue. The portion of the vertebra between these ligaments are each bent slightly upon itself, or as it incline towards the centre or body and thus to rest on its proximate neighbour but to be overlapped by its distal one.

Below the attachments of the inferior ligaments the vertebral plates diverge from each other more suddenly, so as to make a small Knee-shaped bend; & by this divergence the annulated groove is formed. These portions of the plates present small groovings or furrows, which, when in contact with corresponding ones in neighbouring vertebra, become foramina for the passage of the feet. These foramina, like the feet,

(b). Plates II and III. g.

(c). Plates II. and III h.

(d). Plates II. and III. i

are in two rows, one alternating with the other.[a] At their ventral or lower extremities each vertebral plate rests upon a calcareous mass, which, in common with two or generally three other vertebræ, it is united by means of a joint.[b] These masses which are of an irregular shape, with their outer margin or facette bevelled off from above downwards and inwards towards the medial line of the arm, give attachment by their lower surface to two long spines which are moveable, apparently, in a sort of ball and socket joint. They generally have at their apex minute radiating spinules, and are admirably adapted for roofing over the ambulacral groove and thus protecting its contents from external injury. From this point the skeleton takes an outward course. Another piece[c], somewhat similar to the previous one, and, like it, having oblique articulating facettes, supports two spines, but connects by joints the previously described piece to a thick calcareous mass[d] which is triangular in shape when viewed in a vertical section but somewhat flattened off when looked upon from above. This piece supports three thick, bluntly acuminated, comparatively short spines. Masses similar to the one preceding this are articulated with external facette and these again unite with similar ones, for=

). See Plate II. f.

among the so called ribs, which at last terminate in a kind of calcareous network beautifully seen on the inner side of the dorsum of the arm. The joints between these several calcareous pieces are apparently united by cartilage and have ligamentous-like bands around them, holding them in position. In the latter structure I detected narrow, fusiform, nucleated cells, somewhat resembling those of the uterus but much smaller. Of this, however, I am not certain. These joints seem principally adapted for assisting in the adduction and abduction of the ventral plates to and from the mesial line so as either to enlarge the breath of the ambulacral groove and thus allow of freer movement to the feet or to diminish it in order that the spines may more completely cover it.

The skin after passing from the nerve to the feet may readily enough be traced from the latter to the base of the spines; and, from specimens I have examined, which had all the calcareous portion removed by dilute Hydrochloric acid, I am inclined to think, is continuous, though modified, along their surface also.[a]

Such is the protective apparatus and the relation the nerve branch bears to it. But it may be

argued that all these strong provisions against injury, are only to insure the safety of the nucleus and that the protection it offers to the nerve is only of secondary importance. Granting, however, that the groove is an admirable recess for the contracted nucleus, yet, seeing that the nerve lies deepest in the groove, and that it is, as I think I shall be able to shew, a structure of much greater importance than simply nervous filament, and, in addition, since the homologous branch in those fleshy Echinoderms, as ~~the~~ Ophiura and Ophiocoma, is protected not by such complicated apparatus but by continuous and permanent calcareous plates - I am inclined to believe that its principal function is that of preserving this structure. Besides, I found that, on destroying a portion of this nerve, which can be easily done without injuring the nucleus, these latter no longer performed their function properly, if at all. This sufficiently proves that here, the structure requiring greater protection, is the nervous.

Of the other branches of this nervous system, I shall say nothing at present - taking them up while treating of the microscopical structure of parts. To which we must now turn our attention.

(a). Plate I. g.

(b). Plate I. f.

c. Plate I. a. b.

From the observations I have made and often repeated in order to insure as much as possible, correctness and certainty; it would appear that not only does the perioral ring and its ganglionic enlargements contain nerve cells; but also the so called branches, running along the ambulacral grooves. ~~have nerve cells.~~ For convenience of description, then, this nervous system may be said to consist of five ganglia[a], placed on the ventral surface of the animal, opposite and close to the commencement of the ambulacral grooves - each ganglion being connected to each neighbour on either side by inter ganglionic cords[b], and sending along its corresponding ambulacral groove a prolongation of its substance, which may be termed, for distinction, the ambulacral cord[c]. Müller, however, describes it in an entirely different manner - noticing first, the ambulacral cord and considering it to divide at the outer margin of the perioral space into two smaller prolongations which diverge and become continuous with those of the other ambulacral cords. His reason for adopting this description is that the ambulacral cords, being twice the thickness of the perioral ring, are the true centres of the system; and the other cords, merely the connecting media by which

the movements and actions of the animal are harmonized. In support of this view he states that those species of star-fishes which break their arms to pieces on being handled, may be prevented doing so by slipping through the ring so as to sever the connection existing between the ambulacral cords and thus to destroy their harmony. Prof. Goodsir, last Summer in his Lectures on Comparative Anatomy supported the same view.

But in describing these different parts we shall adopt the former division into Ganglia, Inter-ganglionic and Ambulacral Cords.

The Ganglions are apparently, merely, a collection of nerve cells clustered together and forming a union, as it were between the inter-ganglionic and ambulacral cords. Filaments pass from this outwards and also to the different Cords in connection with it and some may likewise be detected passing inwards to the perivisceral space. Tiedemann, it will be recollected, describes two branches coming off from the Ganglion, one on each side of the ambulacral cord and passing inwards to supply the Stomach and other viscera. For a long time I could not find these branches, but, if the ganglions be thoroughly freed from all the flesh and spines about it, and if then the skin be gently

(a). Lectures on Comparative Anatomy - Summer of 1856 - by Prof: Goodsir.

reflected over it from the convex ~~side~~ to the outer side, these branches will be seen as very small filaments diverging outwards and very soon passing backwards into the interior of the animal through small foramina in the calcareous plates. They are, however, exceedingly delicate.

The inter ganglionic cords consist of a series of cells arranged pretty nearly in a line and sending filaments to the outer side of the perioral space and also in the direction of the cord itself. They are not, however, numerous. Prof. Goodsir states that minute branches pass outwards from this part to supply, he thought, the suckers situated round the perioral space (a). The filaments rendered visible by the microscope do most probably supply these suckers but I can find no distinct branches, visible to the naked eye, going from this part of the nervous system.

The circumoesophageal cord is by far the most conspicuous because the most extensive and because, as has been stated, it is longer than the inter ganglionic cords. In all the descriptions of this cord found in books it is supposed to consist, or the reader is left to infer that it is made up, of a bundle or ribband of nerve filaments sent off from the ganglion and splitting

(a). Siebold's Comparative Anatomy of the Invertebrata - Page 82 - § 80. Note (1).

itself in its descent along the arm, by supplying lateral twigs to the feet on each side. Such is Tiedemanns account of it - Rymer Jones in his Manual of Comparative Anatomy merely Quotes the preceding - Siebold after mentioning the ring adds that "the main nervous trunks are given off from this and pass to the other end of the body along the medium line of the rays" And Edward Forbes also in his History of the Starfishes repeats Tiedemann's account and says also that "the existence of ganglions in the nervous system of these animals is generally regarded as doubtful". Krohn describes it as sometimes having a longitudinal furrow as if consisting of double cords, but I think this is only apparent, for I have often seen the double cords turn out on more careful examination to depend merely on colour - pigment being deposited in the skin along each side of a central semi translucent streak, which is the cord lying immediately beneath the skin integument. The cause of this appearance seems, therefore, to be the arrestment of the deposit of pigment in that part of the skin covering the nerve cord; the streak along each side of this is easily made out to belong to the skin and not to the nervous system. Last Summer Prof: Goodsir described these cords as "not mere nerves but five series of

ganglionic cords - each cord being beaded or enlarged at the spot where branches pass off" - Again, at another part he says - "In the arteries the nerve cords contain a brown pigmental streak extending down their inferior surface - Each cord is invested by a fine membrane & consists of fine filaments running longitudinally, others transversely and contains also a gelatinous material which appears to be cellular". Thus, though he does not decidedly state having seen any of the cells, Prof. Goodsir was the first to teach that these cords consisted of something more than simple nerve filaments - Examined microscopically it is found to consist of a central line of cells having filaments passing from them to either side and others also along the line of the cells - These cells lie in the very centre of the cord and, when examined with a power of about 200 diameters, present the appearance given in Plate IV Fig 1. The cells in this as well as in other parts of the system are apparently chiefly unipolar - although I have often seen bipolar ones - In Plate IV Fig 2 we have some of these taken from another specimen and greatly magnified - Two are seen to be bipolar and the other two apparently unipolar - The greatest number of these cells are seen as if isolated owing to their filaments having broken off but with careful focussing you generally

manage to see the part of the cell from which it has been detatched. Prof: Goodsir believes that the so called uni polar nerve cells will probably be found to contain really a many poles - one of which is of the ordinary size while the others are much smaller connecting it with the other cells - The difficulty of explaining the manner in which these cells perform their functions in perfect harmony with each other, if they are considered as uni polar - leads him to adopt the above hypothesis - These cells are granular in their interior and are sometimes with the greatest difficulty distinguished from the surrounding granular mass in which they lie imbedded. This is owing to the great delicacy of their walls. Therefore - before examining them microscopically they must be hardened and this brought to the desired point. Various were the means tried for this purpose - Different Strengths of the solution of Chromic acid pure Spirits of Wine - very weak solution of Creasote - Corrosive sublimate and many others all unavailably - that is to say although I could satisfy myself that I saw nerve cells yet these were so indistinct that I could not possibly ascertain their Connection with each other or their form as to whether they were uni or bipolar. In preparing the animal for examination there are two great difficulties to be overcome which are always met with in the micros-

copious investigation of nervous structure - namely -
1st to harden the true nervous tissue that it may be capable of bearing a little pressure and secondly 2d to get rid of that mass of connective fibrous tissue which is always found round these structures, especially in the Invertebrates above all in the Starfishes, that the true nervous tissue may be seen clearly and distinctly - I had before tried Acetic Acid to render the latter tissue transparent but found it to make the nervous structure equally clear and structureless - The best, I found at last to be, a modification of Lockhart Clarke's plan - His method consists in keeping the nervous structure in a mixture of 3 parts of spirits of wine and one of Acetic Acid for one hour - then, removing it into pure spirit where it remains for the same time after which it is put into Turpentine in order that the latter may displace the spirit and render the structure as transparent as possible. This mode, however, does not exactly suit the nervous tissue of the Starfish and the plan I follow is - After having procured different sized Starfishes, lively and healthy - I proceed to separate that portion of the animal which has the system - This is done by cutting with a strong pair of scissors along the arms between the two rows of spines situated on the border of the Ambulacral groove - re=

peating this on both sides of all the arms and making these incisions meet at the union of the Arms. The dorsum of the Animal is then removed along with the Cæcal appendages, the ovaries, the stomach &c nothing remains on the ventral surface save the feet, nervous system and perioral space pierced by the mouth. I tried dissecting the nervous system out of the grooves and then putting it alone in the reagents but I found it impossible doing this a thing impossible, when the Animal is in the recent state, without injuring the structures so much as to render it almost useless for investigations. Having cut up one or more animals in this manner they must be put in the mixture of spirit and Acetic Acid for about two hours and then removed to pure spirits for about one hour, after which they must be used as soon as possible, for I dont think they improve by being kept in the spirits. The media used to put the parts in during investigations may be either turpentine, if you wish to mount the preparations in Canada Balsam, or the mixture of Acetic acid and spirit. It does not answer in the case of the Starfish to steep the whole in Turpentine, as advised by L. Clarke, for then it becomes too transparent. Since I have given the above, it may not be amiss in my describing the best manner of removing por-

tions of the nervous system of the animal for examination. At first I endeavoured to take up the nervous structure after having reflected the skin but found subsequently that, all the while, I had been examining a mass of the inferior ligament. The nerve cord is so close below the skin and is so firmly attached with that when the latter is reflected the greatest portion of the cells and filaments are found to come away along with it, the rest remaining on the ligament. It appears, therefore, absolutely necessary, to examine it through the skin as it lies upon it. For this purpose a small portion of the arm must be cut off the length of the cord you wish to place under the microscope - from which reflect skin - and cord and you will find this much easier and more satisfactory than if you removed it from the entire arm. In doing this the feet need not be plucked out but may be pushed aside or as not to interfere with the proceedings. I fear I have dwelt too long on this part of the subject - but as some others may wish to examine the nervous system of these animals - I thought ~~I had better~~ might thereby, spare them a considerable amount of useless trouble.

The branches of the Ambulacral cord are those described as passing out from either side

(a). Plate I. a. b.

(b). When a very strong current is passed along the cord for, say five or ten minutes the animal almost always casts off that sec-

to the feet. They are anything but distinct and I cannot say positively that I have seen them. But sometimes on examining a highly coloured animal you may see a delicate streak of pigment running outwards from the cord and upwards along each cylinder of the rachis deep indicating the distribution of a nerve filament. If, again, you press to either side forcibly the double row of feet you will always find the cord lose its straight outline and become wavy or thrown into ragged on either side by some of its branches being put on the stretch. That the feet are supplied by this cord may, I think, also, be proved in an indirect manner from experiments made with Galvanism. Thus - if the two wires from a Galvanic battery be placed one at each extremity of the cord of an arm, and not completing the Galvanic current until the shock and irritation resulting from these wires touching the nervous parts have subsided - the effect will be, sudden and strong contraction of all the rachis from the proximal to the distal extremity of the arm. Thus remaining so long as the current is continued and for some time after if the current be strong; but if, on the other hand, that be weak - the first contraction will after some time be followed by extension of the feet again. If, however,

the wire on the distal end be removed to about the middle of the cord, waiting until the irritation caused by it has subsided before completing the current, the result will be, similar contraction of the muscles on that portion of the arm contained between the wires - and also to some extent of those fibres on the other portion nearest the middle wire - the rest remaining at their ease - supporting, however, the distal wire who still in its previous situation - let a cut be made across the cord in the centre or let a portion of it be in any way destroyed and the current, when completed, will cause strong contraction of that portion of it next to the proximal wire - and only very partial contraction of those on the distal side - This slight shortening of the distal muscles may be explained by supposing that from the proximal wire to the destroyed portion of the cord the Galvanic current is conducted onwards by the nerves as well as by the moist integument - but that beyond this to the distal wire the skin alone is the conductor and acts, therefore, comparatively slightly on the contractile muscular fibres of the cylinders of the feet. If the wires be put on the integument instead of the cord - the feet contract in the same manner though nothing like so suddenly nor so strongly - the skin, itself, likewise

Contracting between the points and also the stalks of the Pedicillaria. I have already mentioned that on destroying a portion of the cord the nucleus near that portion shrunk and ~~so that~~ remaining for a very long period. The length of time, however, I could not ascertain because the animals always died before they got a fair chance of recovery - not from the injury inflicted, but simply from the difficulty of keeping these animals alive in the room. This is unfortunate as it would be interesting to observe, whether any change occurred in the nutrition of that portion of the arm beyond the injured part.

These experiments may, I think, fairly prove or at least go very far in proving three very important things. First that the Ambulacral cord is really a nervous structure and not white fibrous tissue alone, as some Authors would assert. Secondly - that the peripheral terminations of the greatest number of the filaments coming off from this cord, are in the feet - and Thirdly that this Cord cannot consist only of nerve filaments but must contain in it nerve cells or centres - because, on cutting it across the middle, the greatest majority of the feet of the distal portion continue perfectly normal in function. The first and third, however, do not require any such proof, as they may be seen; &

stem R. the second will also soon be made out as distinctly -- So much for the branches to the feet.

On reflecting carefully with the forceps the skin and nervous system of those animals that have been steeping for a long time in spirits, I have often seen very small delicate fibres going directly inwards as if passing between the inferior ligaments of neighbouring vertebræ - And if they are nerve filaments at all, it seems very probable that they go to the supply of the muscles - for, most likely, these receive a different set of nerves from those going to the feet - since they do not act simultaneously but alternately with the feet. This is, however, a mere hypothesis.

We must now consider briefly the last of this system - Namely the terminations of the cerebral cords and the pigment deposited on it, - Considered by Ehrenberg as Eye spots. The cord can be easily followed down to the extremity of the arm where it may be seen to enlarge slightly into a bulb-like swelling - on any, some portion, or on the whole surface, of which, the pigment may be deposited - I have seen it sometimes at the base of the bulb, so as to have a large portion of it projecting beyond, of the colour of the cord. In other instances I have observed it more

(a). Shad a very good preparation of one of these eye spots - just up in Canada Balsam - Has a profile view of the bulb and exhibits the modifications of the skin admirably; but unfortunately it became spoiled with Keeping - Plate XII. However, is a drawing of it -

at the centre – but generally at the point of the bulbous enlargement – or covering its whole surface (as) – The pigment is of a more or less dark red colour and seems to lie upon the ventral aspect of the nervous structure. As the integument runs along the distal portion of the cord it is continued over this pigment deposit in a modified condition becoming perfectly clear and apparently denser. It rests on a kind of calcareous deposition at the very extremity of the Ambulacral groove and is surrounded by the same kind of spines as already described. The animal can so close these spines as entirely to conceal the eye spot from view – and, on the other hand, when moving, the arms or that part of the body fronting the direction in which the animal is going, have generally their extremities slightly bent upon their dorsal surfaces in such a way that the eye spots are directed straight in the line of the progression – The pigment is contained in the deposited in conical papilla like projections which are arranged in transverse lines crossing the bulb – I have been able to trace filaments to the under surface of the pigment but have not as yet detected nerve cells although I have often seen ~~bodies~~ granules very similar to nuclei – The nerve also to some extent is generally more or less tinged

(a). Forbes. E. History of the Starfishes - Page 102.

(b). Since writing this I have succeeded once or twice in getting under the microscope, a front of view of the belt and the appearance was irregularly shaped pigment masses - more or less pointed and having in the Centre a clear space which, by means of gradually altering the focus - appear to be pits and are most probably those mentioned by Prof. Godrich. One of the preparations contains a portion of the eye spot representing this structure and in Plate VII. d. I have endeavoured to represent them -

with the colouring matter. Goodsir examined these eye spots in the Chitella cuticata but found them "to consist in that animal of a red cushion with pits on its surface" (a) It seems to me that this pigmented structure, to a certain extent, resembles the compound eye of insects in arrangement - for it may not be improbable that each papilliform projection is equivalent to the simple eye of an insect. But it will require a great deal more of investigation and I have been able to devote only a very short period to this portion of the structure (b) - There are, however, some curious facts regarding the reproduction of the arms which may be worth the statement. In examining specimens of starfishes which have lost one or more of its arms at different periods previous to capturing them - I found, that the first thing towards the reproduction of the lost part, was a short projection or prolongation from the portion of the nerve cord that had remained behind - This nerve process ~~is~~ much thinner than the cord and had developed almost simultaneously at its dorsal aspect a thick, soft tubercle of skin - apparently used as a protection as well as support. Very soon after this the red pigment is found deposited at the end of the prolongation and it is only subsequent to this

that the feet and spines appear. This would seem to indicate the necessary presence of a nerve structure or something equivalent to it for the guidance or determination, as it were, of the different nutritive functions of each part in such a manner as to lead to the production of different tissues.

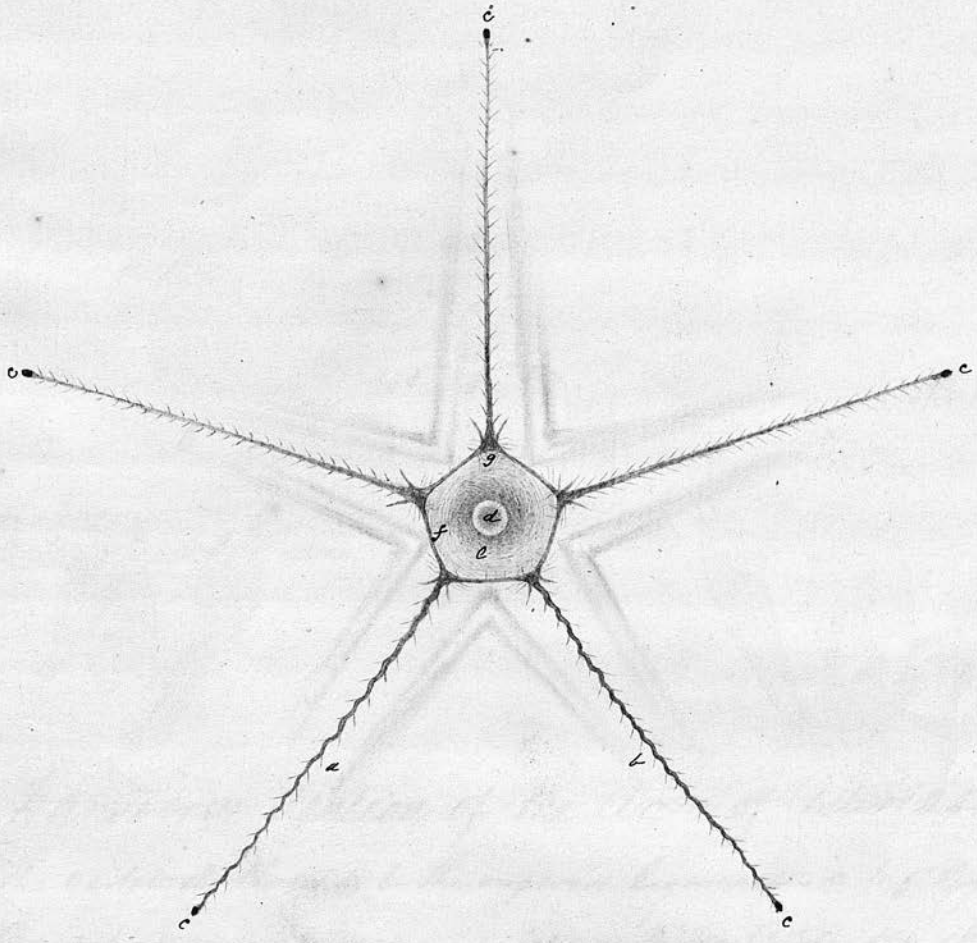
If these observations prove hereafter to be correct, I have some hope that they will be found of some value. Even now they are interesting seeing that this is the lowest Order of Animals in which a nervous system has been discovered - And such being the case we are led to look at the lower animals as lower in organization for a system simpler in the construction - since we know from the structure of this one that it is somewhat complicated -

The arrangement of the Constituents of this nervous system would also bear out the idea that as the simplest Animal consists of a cell performing at once the functions of Nutrition - reproduction - And - Innervation and that as the first two of these appear to become complicated in the higher organisms - by one cell being first - especially devoted to either function and - subsequently - by the multiplication of this cell and their further development or transformations - of these so also the nervous system appears to be in its simplest known typical form composed principally of cells; it now remaining

for further observations to make out, whether these cells, as we descend in organic life, become more and more separate (that is have fewer and fewer connecting medea or filaments) and gradually diminish in number until we arrive at last at the unicellular organisms in which all these functions are centered —

With these remarks I conclude my observations on a subject which has, for a long time past, afforded me great pleasure during my spare hours and, although far from being completed owing to other duties preventing me devoting that amount of time requisite for such investigations — I trust that they will, at least, call attention to the fact that this is a subject well worth the energies of observers in order that the ultimate structure of the nervous system of these Animals may be thoroughly made out —

Plate I



Diagramatical View of Nervous System of Asterias.

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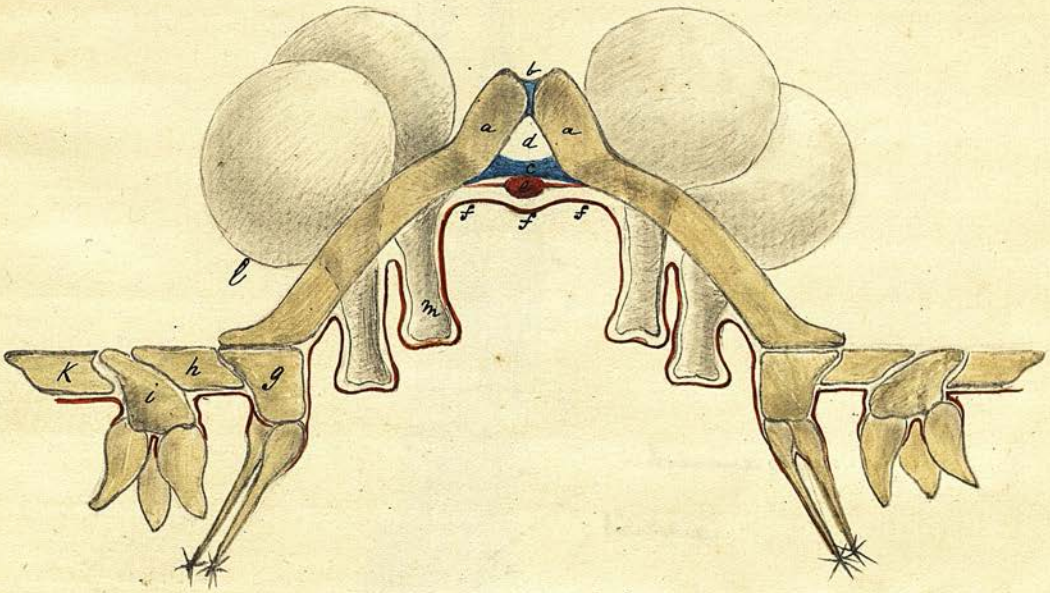
a. & b. Ambulacral Cords having the wavy appearance produced by pushing aside the feet on each side.

c.c.c.c.c. Eye spots at the distal extremities of Ambulacral Cord

d. Oral Orifice – e Perioral Space – f Interganglionic Cord. g. Ganglion

Plate II



Transverse Section of the Arm of Asterias

a. The Vertebral Plates – b the superior ligament – c Inf^r Ligament. &
d. Canal for water vessel supplying vesicles. e. Nerve Cord. f.f.f. Skin – g
g. h. i. K Calcareous masses – l. Vessels – m. Test.

Plate III

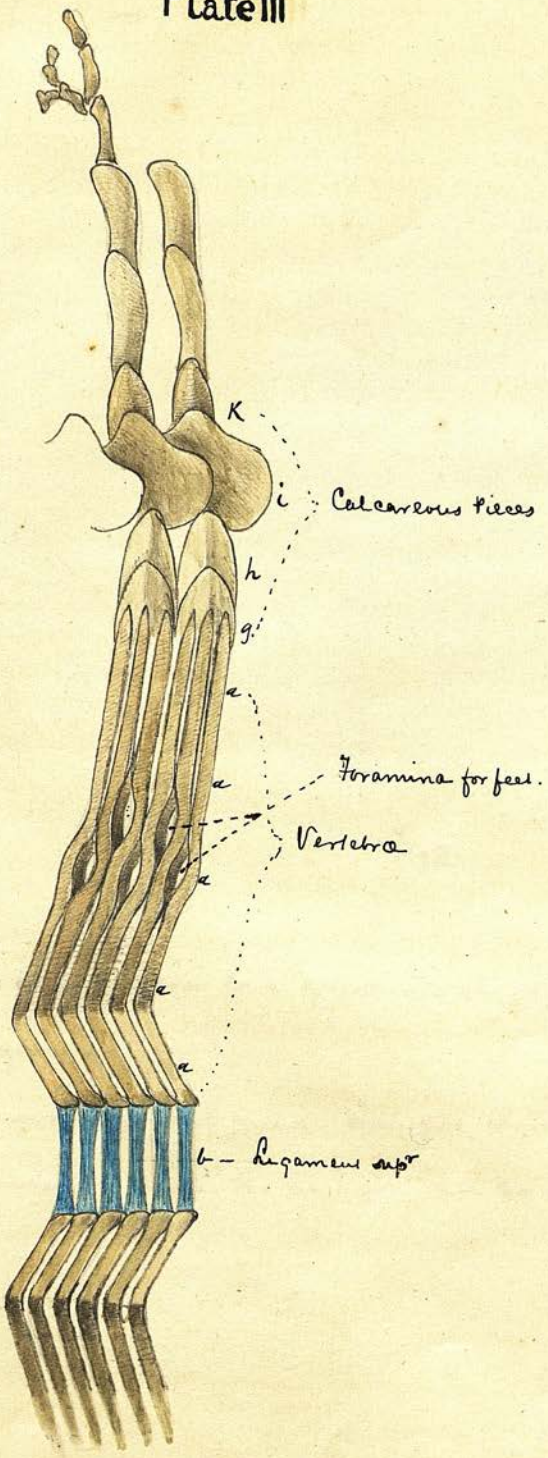

K
i
Calcareous pieces
h
g
a
a
Foramina for feet.
Vertebra
a
a
a
b – Ligament sup.r

Plate IV

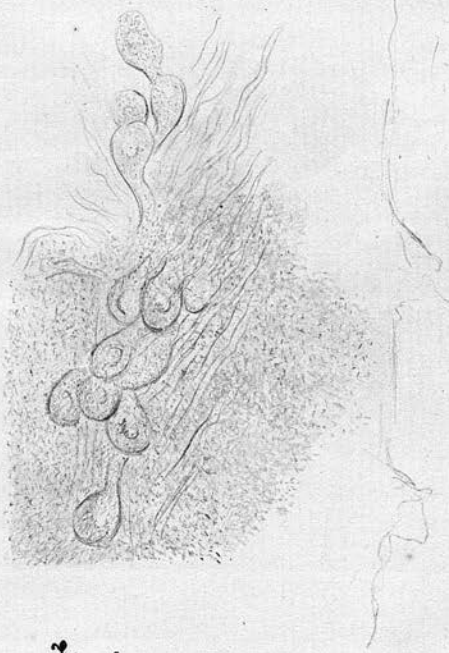


Fig: I

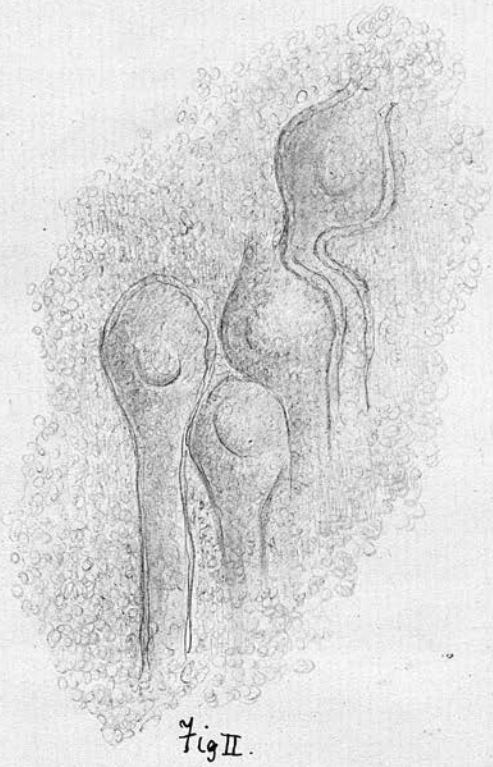
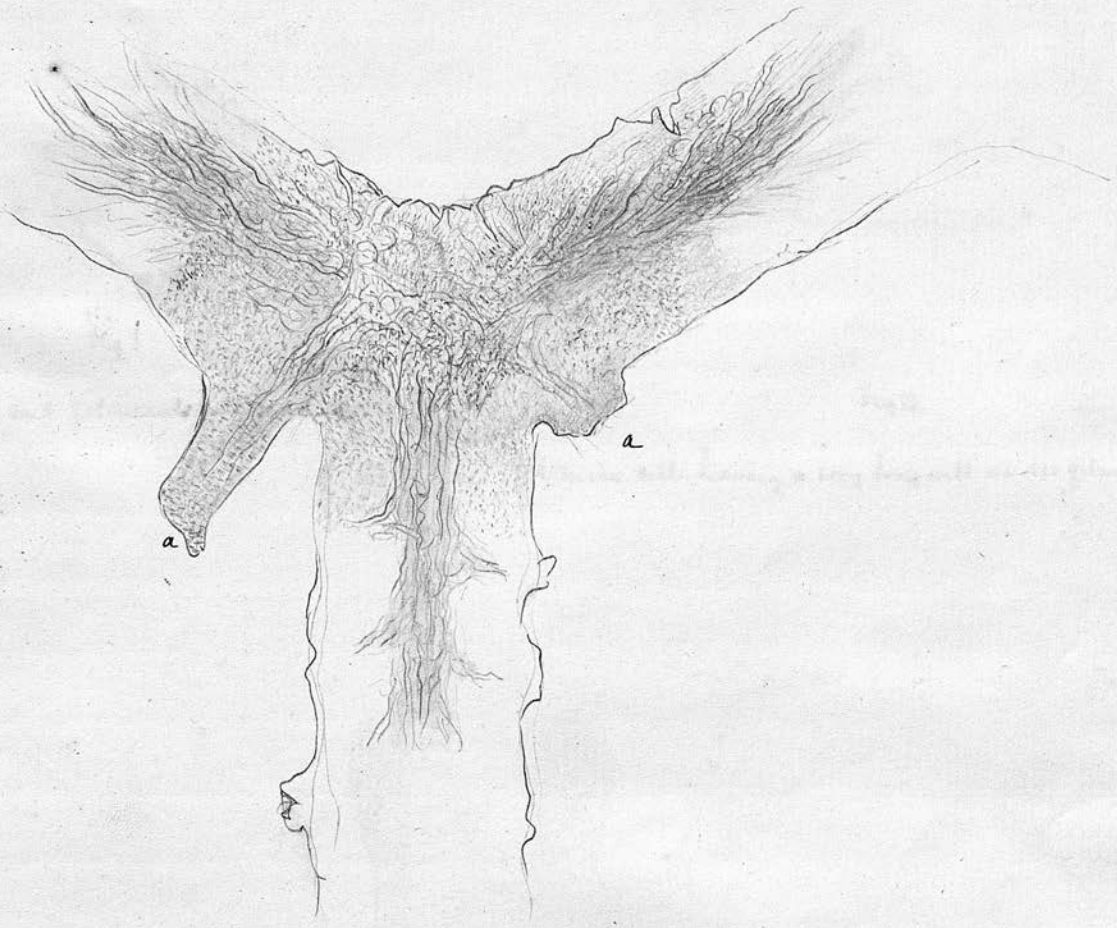


Fig II.

Fig: 1. Nucleated unipolar cells in ambulacral Cord of Asterias - also filaments - the whole imbedded in a mass of granules -

Fig. II. The same as above but from a different rip Cineus - Magnified about 1000 diam. They are imbedded in a mass of nuclei like masses - thus are bipolar and two unipolar

Plate V.



Piece of integument reflected from the Ganglion - Interganglionic cords and the Ambulacral Cord. Filaments are seen running in each direction of the cords and other distributed by the perivisceral ring ~~to~~ within or without the nerve ring - Cells are also seen in the ganglionic enlargement -

a. Lateral branches of the visceral first described by Tiedemann -

Plate VI

Fig I

ther Cells and filaments well marked.

Fig II

A nerve cell having a very long well marked filament.

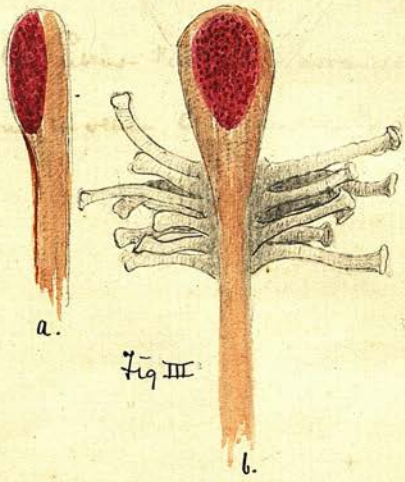


Fig III

Distal termination of the Acetabulocral cord with the Eye-like pigment deposit ~~[illegible]~~

a. Lateral view.

b. Front view.

Plate VII

Fig I -

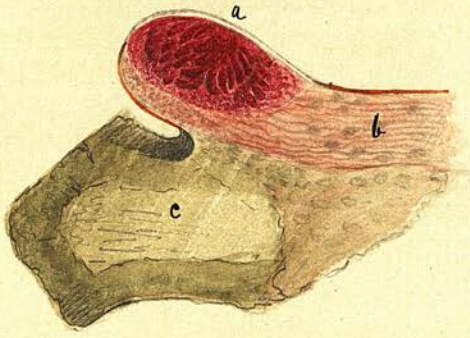


Fig: II.

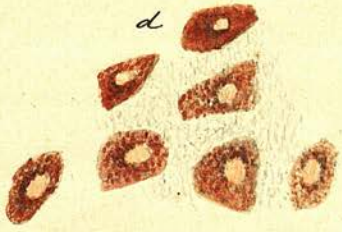


Fig I. Ventral view of Eye spot of Urastes Rubens - Pigment is arranged in papilliform conical projections under which the filaments (b) may be seen - c Calcareous Cushion on which it rests -

Fig II. d. Pigment masses - as seen in a front or ventral view of the bulb - apparently having a clear pit-like depression in its centre -