On the Innervation of the Cerata of some Nudibranchiata.[1]

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With Plates XXXII, XXXIII, and XXXIV.

A FEW years ago (1889) one of us read a paper at the Newcastle-on-Tyne meeting of the British Association "On the Structure and Functions of the Cerata in Nudibranchiata," in which these dorso-lateral processes were regarded as being probably epipodial outgrowths. In other papers[2] published since, we have compared the conditions of these structures in various genera of Nudibranchs, and have tried to show that they are all modifications of simple lateral epipodial ridges. Garstang also, in papers[3] published about the same time, came independently to the same conclusions from the examination of a somewhat different series of forms.

Pelseneer[4] and others, however, have lately contended that

[1] Read (in abstract) before Sect. D of British Association, Cardiff, August 24th, 1891.

[2] Herdman, 'Quart. Journ. Micr. Sci.,' vol. xxxi, p. 41; and Herdman and Clubb, 'Trans. Biol. Soc. Liverpool,' vol. iv, p. 131.

[3] 'Journ. Mar. Biol. Assoc.,' N. S., vol. i, No. 2, p. 173; and No. 4, p. 399.

[4] 'Bulletin Scientif.,' 1888, p. 182; and 1890, p. 138.

processes, be they "epipodia" or "pleuropodia," are truly pedal structures, like the lateral processes in the Rhipidoglossa, in the sense of being innervated from the pedal centres.

The present knowledge of the matter from literature, restricting the question now to the cerata of Nudibranchs, is as follows.

Alder and Hancock,[1] in their admirable anatomical plates, figure, in the case of Tritonia, large nerves to the dorsal integument, which are shown arising from the "branchial" [pleural] ganglia, while the pedal ganglia give off only the nerves to the foot proper, and two small nerves to the skin of the sides of the body. In Goniodoris they show practically the same arrangement, and also in the case of Fiona. In Eolis, however, large nerves from the pedal ganglia are shown supplying the skin of the sides of the back where the cerata arise.

Bergh, in his important series of detailed papers on the minute anatomy of these forms, figures what we take to be epipodial nerves in various Nudibranchs. In his "Beiträge z. Mon. d. Polyceraden," No. 1,[2] he describes in the case of Euplocamus croceus the "n. pallialis" arising from the visceral part of the cerebro-visceral ganglionic mass, and giving off branches to the cerata. Again, in his "Die Cladohepatischen Nudibranchien" he describes[3] the "n. pleuralis" (or "lateralis"), evidently the same nerve as the "pallialis" mentioned above, as arising in Eolids from the pleural part of the cerebro-pleural ganglia.

Vayssière figures[4] in Marionia (a form closely related to the common Tritonia) a nerve from the pleural portion of the cerebro-pleural mass on each side, and also an accessory smaller

[1] "Monograph of the British Nudibranchiate Mollusca,' Ray Society, 1845—1855.

[2] 'Verh. d. k. k. Zool. Bot. Ges. Wien,' Bd. xxix, 1879, p. 599.

[3] 'Zoolog. Jahrb.,' Bd. v, 1890.

[4] 'Atlas d'Anatomie comparée des Invertébrés,' Paris, 1888, pl. ix, fig. 3. Vayssière has also described ('Arch. Mus. Marseilles,' t. ii, p. 96) the nerves supplying the large "parapodia" in Notarchus and Aplysia as arising from the lateral posterior borders of the pedal ganglia.

nerve from the pedal ganglion on each side, going to the lateral integument from which the cerata arise. On the right side the latter nerve supplies also the reproductive aperture and neighbouring parts. Finally, Pelseneer, in his last note which we have just received, states that in all cases the cerata are supplied by the pleural ganglia, and he gives as an example Janus (Antiope) cristatus.[1]

The results of these former investigations, then, depending entirely, we believe, upon minute dissection, are puzzling, and seem sufficiently contradictory to indicate the need of corroboration or correction; so we have set ourselves to trace all these nerves afresh by means of serial sections of such of the types as we could obtain, with the results given below.

The species we have sectionised and examined are Polycera quadrilineata, Ancula cristata, Dendronotus arborescens, Hermæa dendritica, Facelina coronata, and Tergipes despectus. Most of the specimens were procured alive either from the Liverpool Marine Biological Station on Puffin Island, or from Hilbre Island near Liverpool. They were killed and fixed with Kleinenberg's picric acid, stained with picro-carmine, passed through graduated alcohols, embedded in paraffin, and cut with the Cambridge rocking microtome. For the specimens of Hermæa dendritica which we used we are indebted to the kindness of Mr. W. Garstang, M.A., now Berkeley Fellow at the Owens College, Manchester. These specimens were collected near Plymouth, were plunged for a moment, while alive, into glacial acetic acid, were then transferred to a saturated solution of corrosive sublimate for half an hour or so, after which they were put through increasing strengths of alcohol up to 90 per cent. in the usual way. They were afterwards stained and sectionised like the other forms.

We shall describe the facts we have been able to make out in regard to the origin and distribution of the nerves in each form separately under the headings of the genera, beginning with those in which the cerata seem to be in their simplest

[1] 'Bull. Scientif.,' t. xxiii, p. 440.

condition, and working up to those in which they are more complicated.

Polycera.

In Polycera quadrilineata the cerebral and pleural ganglia are completely fused to form a cerebro-pleural mass on each side, of which the anterior part is cerebral and the posterior pleural. The "epipodial"[1] nerves are found arising, one on each side, from the ventral and posterior part of this mass (Pl. XXXII, fig. 2, *ep. n.*), i. e. distinctly from the pleural ganglia; and they eventually run along the sides of the back to supply the ceratal lobed ridges found in this species.

In one of our series we have a specimen cut into 300 sections, and we find, on the right side of the body, the epipodial nerve arising, as above described, in the 91st section, in the region of the reproductive aperture (see Pl. XXXII, fig. 2), and then running forwards[2] through ten sections to the 81st, in the region of the eyes (Pl. XXXII, fig. 1, *ep. n.*), where it suddenly bends round ventrally, and can then be traced backwards through the same series of sections (81 to 91).

In the 90th and 91st sections (Pl. XXXII, fig. 2) the cut end of the nerve is seen lying dorsally and externally to the point of origin from the ganglion, but free in the body-cavity. It can be traced back in this same free condition to about the 120th section, when it sinks gradually into the mesodermal body-wall. The nerve then continues to pass backwards in a dorso-lateral position, lying just over the lateral edge of the ovo-testis, which overlies the liver in this part of the body (Pl. XXXII, fig. 3, *o. t.*). In about the 160th section the ceratal (epipodial?) ridges begin to be more prominent, and a few sections further on (No. 165) a branch is seen arising from

[1] Throughout the present paper we shall continue, in the anatomical descriptions, to call these nerves epipodial, without considering now the question of whether the parts they supply are to be regarded as "epipodial," "pleuropodial," or not "podial" at all.

[2] Possibly in consequence of the retracted position of the nerve collar, due to contraction of the animal at death.

the nerve, and running upwards dorsally into one of the two large lobes or projections on the ridge (see Pl. XXXII, fig. 3, *ep. n.'*), while the main nerve continues its course backwards in the body-wall at the base, giving off small branches, which are distributed to the ridge above. The first large dorsal or ceratal branch from the main nerve is found in the anterior part of the branchial region, and is therefore nearly in the middle of the length of the body. Our epipodial nerve is probably nerve 7 of Alder and Hancock's Fam. I, pl. xvii, fig. 12, arising from the "branchial" ganglia, and going to the skin of the back.[1]

Figs. 2 and 3 on Pl. XXXII incidentally show some other points, especially, in fig. 2, the cartilages and muscles of the odontophore (*cart., m.*) and scattered teeth of the radula (*r.*), the glands of the foot (*f.*) the blood-spaces of the body-wall (*b. s.*), and the reproductive vestibule (*r. a.*); and in fig. 3 the ovo-testis (*o. t.*), the liver (*l.*), the branchiæ (*br.*) with their blood-spaces, and the structure of a ceras with its large unicellular glands in the ectoderm.

Ancula.

In Ancula cristata the pleural ganglia are distinct from the cerebral (Pl. XXXII, figs. 4, 5, and 7).

In a specimen cut into about 500 sections we find in about the 106th section or so from the anterior end six distinct ganglia (the cerebral, pleural, and pedal pairs) surrounding the œsophagus (Pl. XXXII, figs. 4 and 5). A few sections further back the cerebrals disappear, and then (in the 113th section, Pl. XXXII, fig. 6) the epipodial nerves are found arising from the dorsal edge of the pleural ganglia. They run dorsally and outwards and then posteriorly, lying free in the body-cavity.

Soon after leaving the ganglion each epipodial nerve gives off its first branch dorsally. This branch enters the mesoderm of the dorsal body-wall, and can be traced back through over

[1] In this same figure Alder and Hancock show on the left side a small accessory nerve (8) to the side of the body, arising from the pedal ganglion.

100 sections to one of the first pair of cerata, which it enters (in 231st section in this series), and is then distributed.

Fig. 8 (Pl. XXXII) shows the main nerve (*ep. n.*) in a compartment of the body-cavity, the dorsal branch (*b.*) in the body-wall, and twigs from the latter (*c.*) passing up into the ceras above. In about the 240th section (see Pl. XXXII, fig. 9) the epipodial nerve, still in the body-cavity, gives off a small branch, which is distributed to the lateral body-wall. In the 258th section the branch to the second ceras arises. The epipodial nerve has now become more dorsal in position, and it soon leaves the body-cavity and sinks into the body-wall, where it gives off small branches to the dorsal integument and to the branchiæ. In about the 312th section the branch of the third ceras is given off, and the main nerve, now very small, runs back a little further, and then breaks up into the delicate twigs which supply the fourth and fifth pairs of cerata.

In another small specimen of Ancula cristata we find the epipodial nerves arising from the dorsal surfaces of the pleural ganglia, just posterior to the cerebrals (see Pl. XXXII, fig. 7, *ep. n.*) on both sides in the 96th section. The nerves then run back in the body-cavity to section 130, where they give off their first dorsal branches to the first pair of cerata.

Some of the sections of Ancula show the histology of the ganglia well (see Pl. XXXII, figs. 5, 6, 7). There is a connective tissue sheath, which becomes thicker where a nerve leaves, and is then continued along the nerve (see fig. 6, *p. n.* and *sh.*). The large nerve-cells are distributed round the periphery of the ganglion, while the centre is occupied by small cells and interlacing delicate nerve-fibres.

Dendronotus.

Bergh[1] states that in Dendronotus arborescens the cerata are supplied by nerves arising from the pleural ganglia; but we find in addition an interesting anastomosis of a branch

[1] "Die Nudibran. d. 'Willem Barents,'" Bijdragen tot de Dierkunde, 'Nat. Artis Mag.,' Amsterdam, 13e Afl., 1886, p. 28.

origin of the primary pleural and pedal nerves from the ganglia, and is immediately below the most anterior pair of cerata.

The dorsal epipodial nerves also give off small branches to the cerata and to the neighbouring integument, and then the four nerves continue their course backwards to supply the more posterior cerata (see Pl. XXXIV, fig. 26).

In regard to the pleuro-pedal anastomosis described above, it is interesting to note that Pelseneer has found that a junction (the cervical plexus) between nerves having distinct origins from the pleural and the pedal ganglia is effected in Pneumonoderma, and other gymnosomatous Pteropods,[1] and also in Aplysia.[2]

Hermæa.

In Hermæa dendritica (the opportunity of examining which we owe to the kindness of our friend Mr. Garstang) we find the epipodial nerve arising from the ventral external edge of the pleural ganglion. The anterior part of this nervous system is bilaterally symmetrical (see Pl. XXXIII, fig. 20, which shows the cerebral, the buccal, and the anterior ends of the pedal ganglia surrounding the œsophagus), but posteriorly it becomes very unsymmetrical, as was noticed by Bergh,[3] and as figs. 21 to 25 show.

The flattened expansion of the lateral edge of the body at the base of the cerata in this form is largely occupied by the lobes of the ovo-testis, their ducts, and the ducts of the hepatic cæca (Pl. XXXIII, figs. 20 and 25).

The origin of the epipodial nerve is shown in fig. 21, which is two sections posterior to fig. 20. The nerve turns upwards dorsally at once (fig. 22, *ep. n.*). It is surrounded by a very distinct connective-tissue sheath, which is seen connecting the pieces of the nerve in fig. 23. When it reaches the level of the

[1] 'Arch de Biologie,' t. vii.

[2] "Report on the 'Challenger' Pteropods," part 3, 'Zool. Chall. Exp.,' part lxvi, pp. 43 and 88; also 'Bulletin Scientif.,' 1888, p. 195.

[3] "Beit. z. Kennt. d. Æolid.," viii, 'Verhdl. Zool. Bot. Gesell. Wien,' 1885, p. 5.

top of the œsophagus, and the dorsal surface of the base of the cerata, the nerve splits into two branches, a dorsal and a ventral (fig. 24, *ep. n.*), which proceed outwards into the cerata respectively above and below the lobes of the ovo-testis.

The otocyst lies between the pleural and the pedal ganglia, just underneath and internal to the origin of the epipodial nerve (fig. 21, *o. c.*).

Fig. 20, besides giving the general relations of nervous system, body, and cerata, shows the enormous number of glands (fig. 20, *gl.*) embedded in the anterior part of the foot.

Tergipes.

Fig. 17 on Pl. XXXIII gives a transverse section of Tergipes despectus to show the relative sizes and positions of the few large cerata and the small body. It is a little behind the middle of the body, posterior to the stomach and nervous system, and the greater part of the cavity of the body is occupied by the very large lobes of the ovo-testis.

The only nerves which we find going to the cerata in this species arise from the pedal ganglia. Fig. 10 (Pl. XXXIII) shows part of a section in which the pedal ganglia connected by their commissure lie under the œsophagus; the cerebrals are no longer visible, they are in sections further forward. The epipodial nerve is seen on the left side arising from the dorsal surface of the pedal ganglion, and running outwards under a part of the stomach which occurs here. The next two sections (figs. 11 and 12) show the nerve passing outwards to enter into close relations with the pleural ganglion of that side, from which, however, it remains perfectly distinct. On reaching the lateral body-wall the nerve turns upwards and runs dorsally (Pl. XXXIII, figs. 13 and 14) between the stomach and the body-wall towards the base of one of the cerata (Pl. XXXIII, figs. 15 and 16), to which it gives off a branch and then passes on backwards in a dorso-lateral position.

These sections of Tergipes despectus show well some other points in structure. The lobes of the ovo-testis (figs. 17

and 18) contain ova and spermatozoa in various stages of development. In most cases single lobes are not hermaphrodite, but occasionally both ova and developing spermatozoa are to be found in the same lobe. In fig. 18 the upper lobe is a purely female one and the lower is entirely male, while the small piece of a third seen at the left side contains large and small ova and also spermatic cells.

Glands are very abundant in the integument of this minute species. Fig. 17 shows the large mass of ovate glands above the foot, and the numerous small glands scattered all over the surface of the cerata; these latter are seen more highly magnified in figs. 13 and 19. The connection between the hepatic cæca in the cerata and the median portion of the liver in the body is seen in fig. 17 on the right side, and the opening of the hepatic cæcum into the cnidophorous sac at the apex of the ceras is shown in fig. 19. This opening is surrounded by muscle-fibres which encircle the lower half of the cnidophorous sac. The cnidocysts are large and distinctly nucleated (Pl. XXXIII, fig. 19, *cn. c.*), and the cnida are of elongated ellipsoidal form.

Eolis (Facelina).

In Eolis (or Facelina) coronata we find that, as Alder and Hancock showed long ago for Eolis papillosa, the chief nerves to the cerata arise from the pedal ganglia; but there is also, on one side at least, a smaller accessory epipodial nerve which is pleural in origin.

The numerous large cerata arise from the body in Facelina coronata in clumps (Pl. XXXIV, figs. 28 and 32). This is especially well shown in fig. 28, where on the left side of the figure the section shows a large basal projection from the body common to half a dozen cerata. In this basal mass we find muscle-bundles and connective tissue, the ducts from the hepatic cæca, and the epipodial nerves going to the cerata. This basal region of a clump of cerata is separated off from the body proper by a line of longitudinal and oblique muscle-fibres (Pl. XXXIV, figs. 28 and 31, *musc.*), through which the nerves have to pass.

The chief epipodal nerve (figs. 28 and 29, *ep. n.*) is found to arise from about the middle of the dorsal and external edge of the large pedal ganglion on each side, and to curve outwards and ventrally (fig. 29). After a short course it passes through the muscular layer of the body-wall and is distributed to the clumps of cerata (fig. 28).

In addition to the main epipodial nerve we have found also, on the left side only, a small nerve which arises from the ventral and posterior part of the cerebro-pleural mass, just below the eye (see Pl. XXXIV, fig. 28, right side of figure), and runs ventrally (fig. 28, *acc. ep. n.*) till it gets opposite the middle of the buccal mass, and then passes outwards through the layer of muscle-fibres (see fig. 31, *acc. ep. n.*) to reach the base of a clump of cerata. This nerve may, therefore, be regarded as pleural in its nature; it is distinctly anterior in its origin to the main epipodial nerves springing from the pedal ganglia, and so far as we can find it supplies only the most anteriorly placed clump of cerata on its own side.

There can be no doubt as to the ganglia from which the main epipodial nerves arise. Not only do their relations to one another and to the other ganglia and to the œsophagus (see Pl. XXXIV, fig. 29) show clearly that they are the pedals, but we have also traced from them the ordinary pedal nerves (fig. 31, *p. n.*) going to the foot. These pedal nerves arise from the ventral surface of the ganglia two or three sections in front of the origin of the main epipodial nerves, and two or three sections behind where the small accessory epipodial nerve arises from the left pleural. They are in the same section with the otocysts (Pl. XXXIV, fig. 31, *o. c.*) which lie on the upper surface of the pedal ganglia.

These figures of Facelina coronata show some other points of interest. The numerous sections of the cerata show the relations between the cnidophorous sac and the hepatic cæcum (fig. 28); and the opening of the latter into the ducts in the body (figs. 28 and 31, *n. h. cæ.*), and also the position of the cnida in distinct cnidocysts, which are epithelial cells turned in from the ectoderm on the apex of the ceras, as we have shown

in former papers.[1] The relations of the buccal mass, odontophore, and œsophagus to the nervous system, and the constitution of the body-wall are also shown. Figs. 29 to 31 show the histology of the ganglia. The largest nerve-cells, as in other forms, are here on the surface. Fig. 30 shows the posterior surface slice of the right cerebral ganglion from the next section to that drawn in fig. 29. It is entirely composed of large polygonal cells with huge reticulated nuclei, each of which has a single very distinct nucleolus, which, again, sometimes has a distinct central spot (as in the cell marked *n. c.* in fig. 30). Fig. 29 shows on the left side at the top the next section of that cerebral ganglion, passing forwards, and it is also nearly all large cells; while the pedal ganglia below in the same figure, and also in fig. 31, show that the central parts of the ganglia are composed of small rounded or fusiform cells and interlacing delicate nerve-fibres. These fibres and the small cells come to the surface where a commissure or a nerve leaves the ganglion (see pedals of fig. 31).

Conclusion.

We have shown, then, by the examination of this series of types, that instead of the cerata of Nudibranchs being always innervated by the pleural ganglia, as Pelseneer supposes,[2] or always supplied by pedal nerves, as we had expected to find when we commenced the investigation, there are, in fact, various arrangements of the nerve-supply. The dorso-lateral processes of the body-wall which we call cerata may be supplied entirely by the pleural ganglia (e. g. Polycera and Ancula), or chiefly by the pleural with a small supply from the pedal by means of a pleuro-pedal anastomosis (Dendronotus), or entirely by the pedal ganglia (Tergipes), or chiefly by the pedal ganglia with a small independent accessory supply from the pleural (as in Facelina).

If, then, we take the nerve-supply as a sure indication of

[1] 'Quart. Journ. Micr. Sci.,' vol. xxxi, p. 41; and 'Trans. Liverpool Biological Society,' vol. iv, p. 131.

[2] 'Bulletin Scientif.,' t. xxiii, p. 439, Aug. 18th, 1891.

homology, we arrive at the remarkable result that these processes of the body-wall are not all of the same nature; and that whereas in Tergipes, and possibly also in Facelina, they may be considered as pedal in origin, and as homologous with the epipodia of an ordinary rhipidoglossate Gastropod, such as Trochus (where the epipodial ridges and processes are supplied, according to Pelseneer, by nerves arising from the dorsal part of the pedal ganglia), in Polycera, Ancula, and others, they must be regarded as totally distinct structures of pallial[1] origin. This seems to be a clear case of reductio ad absurdum.

We have in a former paper tried to show that these processes, whether ridges or papillæ or lobes, parieto-cerata as in Dendronotus and Tritonia, or hepato-cerata as in Eolis and Doto, are all really modifications of the same thing; and although it might conceivably be argued that the parieto-cerata (pleural) of Ancula might be different in their nature and origin from the hepato-cerata of Eolis (mainly pedal), still no one would be likely to suggest that the cerata of Tergipes (pedal) and of Hermæa (pleural) are not homologous structures. And in addition there are the intermediate conditions found in Dendronotus and in Marionia,[2] linking together the purely pedal and the purely pleural methods of innervation.

Consequently we are inclined to consider that in this case the nerve-supply cannot be taken as a sure indication of the homology, and that possibly the innervation has undergone modification in accordance with changes in the position, size, and relation to other organs of these ceratal processes in the Nudibranchiata. The cerata, which we still regard as homologous structures throughout the series of Nudibranchiata, must, from their great differences in size, shape, colours, stinging properties, and contents, be of very varied importance to

[1] I. e. from the integument dorsal to the foot, and supplied by the pleural ganglia, whether there is a distinct "pallium" present or not.

[2] Where, according to Vayssière, the main epipodial nerves are pleural; but there are also smaller accessory nerves from the pedal ganglia.

their possessors; and it may readily be imagined that when such modifications have taken place as led to the appropriation of important organs like large blood-sinuses, huge hepatic cæca, and cnidophorous sacs, it would not be unlikely for nerves in the neighbourhood to be diverted from their original positions and become drawn up into the cerata.

The condition of Facelina, where there is what may be the commencement of a pleural supply, and in Dendronotus, where the anastomosis may be the remains of an original pedal supply, suggest at least the possibility of the following as an explanation; viz. (1) that these ceratal outgrowths may be truly epipodial, homologous with the epipodia of Trochus, starting at first as pedal structures supplied with nerves from the pedal ganglia; and (2) may have secondarily acquired, possibly as the result of changes in form, position, and relations to other organs, a supplementary nerve-supply from the adjacent integumentary nerves arising from the pleural ganglia; and (3) this supplementary supply, while remaining subordinate in Facelina, may in other forms have gradually come to supplant the original epipodial (pedal) nerves, which (on this view) have now completely disappeared in such forms as Polycera and Ancula, and are only represented in Dendronotus by the pleuro-pedal anastomosis. This is, however, only a suggestion, which we do not feel able to support or press further at present. We may possibly be able to get evidence for or against it from the examination of the nerve-supply in some additional forms of Nudibranchs, which we hope soon to undertake.

If, then, the cerata of Nudibranchs cannot all be said to be true epipodia innervated by the pedals, we have shown, at least, (1) that it is equally impossible to regard them all as pallial outgrowths supplied by the pleural ganglia, and (2) that possibly they may have been epipodial in origin, although there is now in some a connection with pleural nerves.

EXPLANATION OF PLATES XXXII, XXXIII, and XXXIV,

Illustrating Messrs. W. A. Herdman's and J. A. Clubb's paper "On the Innervation of the Cerata of some Nudibranchiata."

The figures were drawn from the sections, as seen under Swift's 1-inch (× 50) and $\frac{1}{6}$-inch objectives (× 300), with the occasional use of Zeiss's $\frac{1}{12}$-inch oil immersion for the more minute details. The following abbreviations are used for the reference letters:

b. m. Buccal mass. *b. w.* Body-wall. *br.* Branchiæ. *b. s.* Blood-sinus. *b. c.* Blood-corpuscles. *buc. g.* Buccal ganglion. *cer. g.* Cerebral ganglion. *c.* Hepatic cells. *c. t.* Connective tissue. *c. m.* Circular muscles. *cn. c.* cnidocyst. *cn. s.* Cnidophorous sac. *ep. n.* Epipodial nerve. *e.* Eye. *ec.* Ectoderm. *f.* Foot. *gl.* Glands. *h. c.* Hepatic cæcum. *l. m.* Longitudinal muscles. *l.* Liver. *m.* Muscle-fibres. *n. c.* Nerve-cell. *n. sh.* Nerve-sheath. *œs.* Œsophagus. *o. t.* Ovo-testis. *o. c.* Otocyst. *p. g.* Pedal ganglion. *pl. g.* Pleural ganglion. *p. n.* Pedal nerve. *r.* Part of radula. *r. a.* Reproductive aperture. *ren.* Renal organ. *st.* Stomach. *sh.* Sheath of ganglion or nerve.

PLATE XXXII.

Fig. 1.—Transverse section of Polycera quadrilineata at level of eye (section 81 of series), showing relation of cerebral ganglia (*c. g.*) to buccal mass and body-wall, and the anterior loop of the epipodial nerve (*ep. n.*). × 50.

Fig. 2.—Another transverse section of same series, ten sections further back, in region of reproductive aperture, showing cerebro-pleural and pedal ganglia, with the origin of the epipodial and of various pedal nerves, and also the epipodial nerve in section in its course backwards. × 50.

Fig. 3.—Dorso-lateral part of another transverse section of the same series (No. 166), in the region of the branchiæ, to show the epipodial nerve in the body-wall over the edge of the ovo-testis, and a branch of it entering one of the ceratal processes. × 300.

Fig. 4.—Transverse section (No. 106) of Ancula cristata, showing the three pairs of ganglia surrounding the œsophagus. × 50.

Fig. 5.—Part of adjoining section, showing the ganglia more highly magnified. × 300.

FIG. 6.—Part of section (No. 113), six further back, showing the origin of the epipodial nerve (*ep. n.*) from the dorsal edge of the pleural ganglion. The cerebrals are not present so far back. × 300.

FIG. 7.—Part of similar section of another specimen (section No. 96), showing the origin of the epipodial nerve on each side, from dorsal edge of pleural ganglion immediately behind the cerebral, a small piece of the posterior end of the cerebral ganglion being present on the left side. × 300.

FIG. 8.—Upper half of transverse section (No. 231 of same series as Figs. 4, 5, and 6) in the region of the first pair of cerata, showing the main epipodial nerve in the body-cavity, its first branch in the dorso-lateral body-wall, and twigs going up from that into the ceras on the right side. × 50.

FIG. 9.—Diagram of Ancula cristata, from the left side, showing the origin and distribution of the epipodial nerves.

PLATE XXXIII.

FIG. 10.—Part of a transverse section of Tergipes despectus, showing the origin of the epipodial nerve from the dorsal surface of the pedal ganglion. × 300.

FIG. 11.—Part of the next section, showing the epipodial nerve lying under part of the stomach-wall where it runs outwards from the pedal towards the pleural ganglion. × 300.

FIG. 12.—Part of the next section, showing the epipodial nerve lying in contact with the pleural ganglion. × 300.

FIG. 13.—Adjoining section, showing epipodial nerve passing from close to pleural ganglion to inner surface of body-wall, so as to pass up to ceras above. × 300.

FIG. 14.—Next section (54th from anterior end), showing nerve passing up dorsally between stomach and body-wall. × 300.

FIGS. 15 and 16.—Neighbouring sections to last, showing branches of nerve passing up to ceras. × 300.

FIG. 17.—Transverse section of the whole body of Tergipes despectus behind the middle, to show the relative sizes of cerata and body, and the junction of hepatic cæca with liver in body. × 50.

FIG. 18.—Part of the ovo-testis in same region of body as last section, showing both ova and spermatozoa in various stages. × 300.

FIG. 19.—The tip of one of the cerata in the same region, showing the communication between the hepatic cæcum and the cnidophorous sac. × 300.

FIG. 20.—Transverse section of Hermæa dendritica, near the anterior end (Section 61st of the series), showing the relations of the cerata to the body, and the cerebro-pedal and buccal ganglia surrounding the œsophagus. × 300.

FIG. 21.—Part of the second section, further on, showing the origin of the epipodial nerve from the ventral part of the cerebro-pleural ganglion. × 300.

FIG. 22.—Part of next section, showing the epipodial nerve free from the ganglia. × 300.

FIG. 23.—Part of next section, showing the epipodial nerve turning up dorsally; the nerve is in part out of the plane of the section, but the connective-tissue sheath connects the pieces. × 300.

FIG. 24.—Part of next section, showing the epipodial nerve at the base of one of the cerata dividing into a dorsal and a ventral (rather the larger) branch, the latter of which runs down round a lobe of the ovo-testis. × 300.

FIG. 25.—Part of the next section (No. 67), including the basal part of one of the cerata, showing the dorsal and ventral branches of the epipodial nerve. × 300.

PLATE XXXIV.

FIG. 26.—Diagram of Dendronotus arborescens, showing the origin and distribution of the dorsal and lateral epipodial nerves.

FIG. 27.—Diagrammatic scheme of the anterior part of the nerves in last figure, showing in lateral view their origin from the ganglia, their branches, and the anastomosis between *a* and *c*, the result being that the lateral epipodial nerve has a pedal element in it, while the dorsal epipodial nerve is entirely pleural in origin.

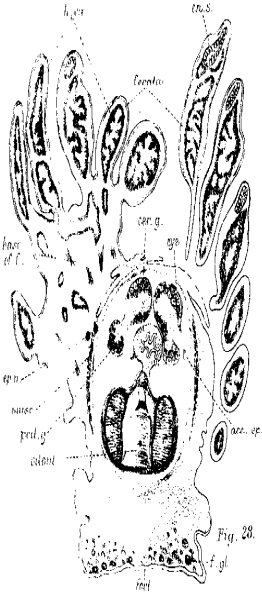
FIG. 28.—Transverse section of Eolis (Facelina) coronata in the region of the eye, showing on one side, below the eye, the point of origin of the accessory epipodial nerve from the ventral part of the cerebro-pleural ganglion; and also showing a part of the accessory epipodial nerve free from the ganglia. This also shows well on the other side the common base to a clump of cerata; the hepatic cæca and cnidophorous sacs are seen in the cerata. × 50.

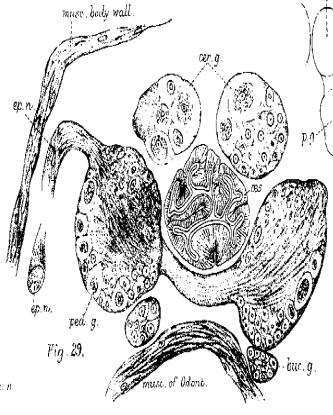
FIG. 29.—Part of a section a little further back, more highly magnified, showing structure of cerebral and pedal ganglia, and the chief epipodial nerve arising from the latter. × 300.

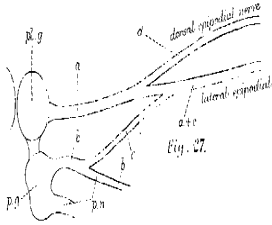
FIG. 30.—Surface section of cerebral ganglion from section adjoining last, showing the large superficially placed nerve-cells, with reticulated nuclei. × 300 (enlarged).

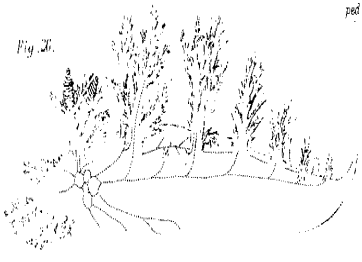
FIG. 31.—Part of a section through region of the otocysts, showing an ordinary pedal nerve (*p. n.*) arising from the pedal ganglion, just a few sections in front of where the chief epipodial nerve (*ep. n.* in Fig. 29) arises from the same ganglion. This section also shows the accessory epipodial nerve on the other side (*acc. ep. n.*) passing through the muscular layer of the body-wall to reach the base of a clump of cerata. Figs. 28 and 31 show the course of this nerve from the ganglion to the point of distribution to the cerata. × 300.

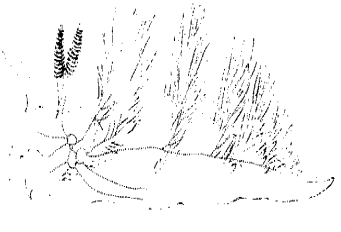
FIG. 32.—Diagram of Facelina coronata, from left side, showing the origin and distribution of the epipodial nerves.

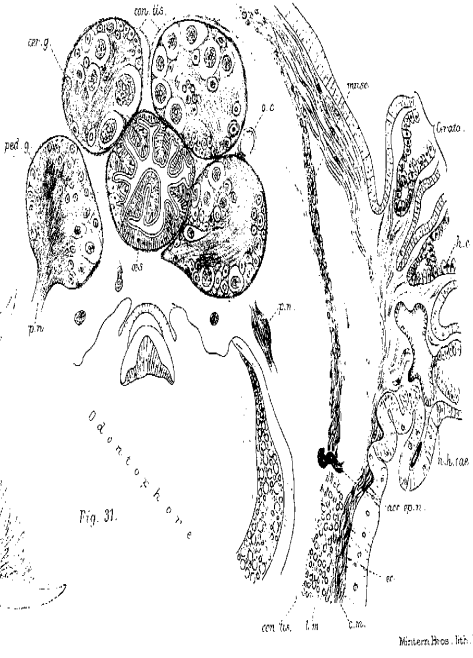












Mintern Bros. lith. London.