of the visceral hump, in the centre of which the shell-sac existed for a brief period.

In Clausilia, according to the observations of Gegenbaur, the primitive shell-sac does not flatten out and disappear, but takes the form of a flattened closed sac. Within this closed sac a plate of calcareous matter is developed, and after a time the upper wall of the sac disappears, and the calcareous plate continues to grow as the nucleus of the permanent shell. In the slug Testacella (fig. 69, C) the shell-plate never attains a large size, though naked. In other slugs, namely, Limax and Arion, the shell-sac remains permanently closed over the shell-plate, which in the latter genus consists of a granular mass of carbonate of lime. The permanence of the primitive shell-sac in these slugs is a point of considerable interest. It is clear enough that the sac is of a different origin from that of Aplysia (described in the section treating of Opisthobranchia), being primitive instead of secondary. It seems probable that it is identical with one of the open sacs in which each shell-plate of a Chiton is formed, and the series of plate-like imbrications which are placed behind the single shell-sac on the dorsum of the curious slug, Plectrophorus, suggest the possibility of the formation of a series of shell-sacs on the back of that animal similar to those which we find in Chiton. Whether the closed primitive shell-sac of the slugs (and with it the transient embryonic shell-gland of all other Mollusca) is precisely the same thing as the closed sac in which the calcareous pen or shell of the Cephalopod Sepia

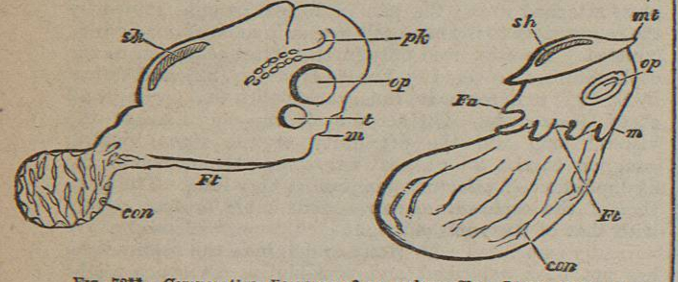

FIG. 72**.—Comparative diagrams of an embryo Slug, Limax (left), and an embryo Cuttle-fish, Loligo (right). *sh*, internal shell; *pk*, embryonic renal organ (Stiebel's canal) in Limax; *mt*, edge of the mantle-flap in Loligo; *op*, cephalic eye; *t*, cephalic tentacle; *m*, position of the mouth; *Ft*, the foot; *Fu*, the hinder part of the foot drawn out to form the funnel of Loligo; *con*, the contractile yelk-sac or hernia-like protrusion of the mid-region of the foot, corresponding to the line of closure of the blastopore in Limnæus. *N.B.*—The blastopore in the embryo of Loligo, which, like that of a bird, is much distorted by excess of food-yelk, *does* close at the extremity of the yelk-sac *con*. (Original.)

and its allies is formed, is a further question, which we shall consider when dealing with the Cephalopoda. It is important here to note that Clausilia furnishes us with an exceptional instance of the *continuity* of the shell or secreted product of the primitive shell-sac with the adult shell. In most other Mollusca (Anisopleurous Gastropods, Pteropods, and Conchifera) there is a want of such continuity; the primitive shell-sac contributes no factor to the permanent shell, or only a very minute knob-like particle (Neritina and Paludina). It flattens out and disappears before the work of forming the permanent shell commences. And just as there is a break at this stage, so (as observed by Krohn in Marsenia = Echinospira) there *may* be a break at a later stage, the nautiloid shell formed on the larva being cast, and a new shell of a different form being formed afresh on the surface of the visceral hump. It is, then, in this sense that we may speak of primary, secondary, and tertiary shells in Mollusca, recognizing the fact that they *may* be merely phases fused by continuity of growth so as to form but one shell, or that in other cases they *may* be presented to us as separate individual things, in virtue of the non-development of the later phases, or in virtue of sudden changes in the activity of the mantle-surface causing the shedding or disappearance of one phase of shell-formation before a later one is entered upon.

The development of the aquatic Pulmonata from the egg offers considerable facilities for study, and that of Limnæus has been elucidated by Lankester, whilst Rabl has with remarkable skill applied the method of sections to the study of the minute embryos of Planorbis. The chief features in the development of Limnæus are exhibited in the woodcuts (figs. 3, 4, and 72***). There is not a very large amount of food-material present in the egg of this snail, and accordingly the cells resulting from division are not so unequal as in many other cases. The four cells first formed are of equal size, and then four smaller cells are formed by division of these four so as to lie at one end of the first four (the pole corresponding to that at which the "directive corpuscles" *dc* are extruded and remain). The smaller cells now divide and spread over the four larger cells (fig. 3); at the same time a space

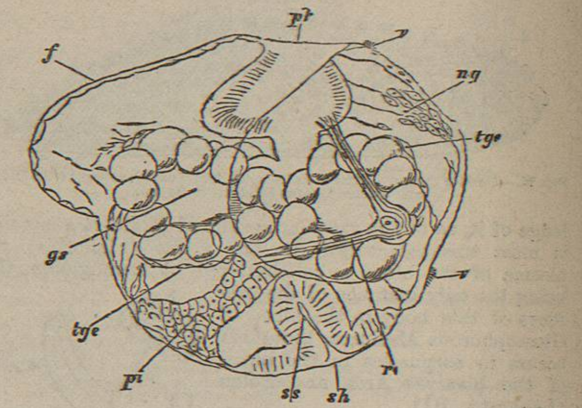

FIG. 72***.—Embryo of *Limnæus stagnalis*, at a stage when the Trochosphere is developing foot and shell-gland and becoming a Veliger, seen as a transparent object under slight pressure. *ph*, pharynx (stomodæal invagination); *v*, *v*, the ciliated band marking out the velum; *ng*, cerebral nerve-ganglion; *re*, Stiebel's canal (left side), probably an evanescent embryonic nephridium; *sh*, the primitive shell-sac or shell-gland; *pi*, the rectal peduncle or pedicle of invagination, its attachment to the ectoderm is coincident with the hindmost extremity of the elongated blastopore of fig. 3, C; *tge*, mesoblastic (skeletotrophic and muscular) cells investing *gs*, the bilobed arch-enteron or lateral vesicles of invaginated endoderm, which will develop into liver; *f*, the foot. (Original.)

—the cleavage cavity or blastocœl—forms in the centre of the mulberry-like mass. Then the large cells recommence the process of division and sink into the hollow of the sphere, leaving an elongated groove, the blastopore, on the surface (fig. 3, C, and fig, 4, G). The invaginated cells (derived from the division of the four big cells) form the endoderm or arch-enteron; the outer cells are the ectoderm. The blastopore now closes along the middle part of its course, which coincides in position with the future "foot." One end of the blastopore becomes nearly closed, and an ingrowth of ectoderm takes place around it to form the stomodæum or fore-gut and mouth. The other extreme end closes, but the invaginated endoderm cells remain in continuity with this extremity of the blastopore, and form the "rectal peduncle" or "pedicle of invagination" of Lankester (see also the account and figures (fig. 151, A) of the development of the bivalve Pisidium), although the endoderm cells retain no contact with the middle region of the now closed-up blastopore. The anal opening forms at a late period by a very short ingrowth or proctodæum coinciding with the blind termination of the rectal peduncle (fig. 72***, *pi*).

The body-cavity and the muscular, fibrous, and vascular tissues are traced partly to two symmetrically-disposed

"mesoblasts," which bud off from the invaginated arch-enteron, partly to cells derived from the ectoderm, which at a very early stage is connected by long processes with the invaginated endoderm, as shown in fig. 3, D. The external form of the embryo goes through the same changes as in other Gastropods, and is not, as was held previously to Lankester's observations, exceptional. When the middle and hinder regions of the blastopore are closing in, an equatorial ridge of ciliated cells is formed, converting the embryo into a typical "Trochosphere" (fig. 4, E, F).

The foot now protrudes below the mouth (fig. 4), and the post-oral hemisphere of the Trochosphere grows more rapidly than the anterior or velar area. The young foot shows a bilobed form (fig. 4, D, *f*). Within the velar area the eyes and the cephalic tentacles commence to rise up (fig. 4, D, *t*), and on the surface of the post-oral region is formed a cap-like shell and an encircling ridge, which gradually increases in prominence and becomes the freely depending mantle-skirt. The outline of the velar area becomes strongly emarginated and can be traced through the more mature embryos to the cephalic lobes or labial processes of the adult Limnæus (fig. 70).

This permanence of the distinction of the part known as the velar area through embryonic life to the adult state is exceptional among Mollusca, and is therefore a point of especial interest in Limnæus. None of the figures of adult Limnæus in recent works on Zoology show properly the form of the head and these velar lobes, and accordingly the figures here given have been specially sketched for the present article. The increase of the visceral dome, its spiral twisting, and the gradual closure of the space overhung by the mantle-skirt so as to convert it into a lung-sac with a small contractile aperture, belong to stages in the development later than any represented in our figures.

We may now revert briefly to the internal organization at a period when the Trochosphere is beginning to show a prominent foot growing out from the area where the mid-region of the elongated blastopore was situated, and having therefore at one end of it the mouth and at the other the anus. Fig. 72*** represents such an embryo under slight compression as seen by transmitted light. The ciliated band of the left side of the velar area is indicated by a line extending from *v* to *v*; the foot *f* is seen between the pharynx *ph* and the pedicle of invagination *pi*. The mass of the arch-enteron or invaginated endodermal sac has taken on a bilobed form (compare Pisidium, fig. 151), and its cells are swollen (*gs* and *tge*). This bilobed sac becomes *entirely* the liver in the adult; the intestine and stomach are formed from the pedicle of invagination, whilst the pharynx, œsophagus, and crop form from the stomodæal invagination *ph*. To the right (in the figure) of the rectal peduncle is seen the deeply invaginated shell-gland *ss*, with a secretion *sh* protruding from it. The shell-gland is destined in Limnæus to become very rapidly stretched out, and to disappear. Farther up, within the velar area, the rudiments of the cerebral nerve-ganglion *ng* are seen separating from the ectoderm. A remarkable cord of cells having a position just below the integument occurs on each side of the head. In the figure the cord of the left side is seen, marked *re*. This paired organ consists of a string of cells which are perforated by a duct. The opening of the duct at either end is not known. Such cannulated cells are characteristic of the nephridia of many worms, and it is held that the organs thus formed in the embryo Limnæus are embryonic nephridia. The most important fact about them is that they disappear, and are in no way connected with the typical nephridium of the adult. In reference to their first observer they are conveniently called "Stiebel's canals." Other Pulmonata possess, when embryos, Stiebel's canals in a more fully-developed state, for instance, the common slug Limax (fig. 72**, *pk*). Here too they disappear during embryonic life. Further knowledge concerning them is greatly needed. It is not clear whether there is anything equivalent to them in the embryos of marine Gastropoda or other Mollusca, the ectodermal cells called "embryonic renal organs" in some Gastropod embryos having only a remote resemblance to them. The three pairs of transient embryonic nephridia of the medicinal leech, the ciliated cephalic pits of Nemertines, and the anterior nephridia of Gephyræans, all suggest themselves for comparison with these enigmatical canals.

Marine Pulmonata.—Whilst the Pulmonata are essentially a terrestrial and fresh-water group, there is one genus of slug-like Pulmonates which frequent the sea-coast (Peronia, fig. 72), whilst their immediate congeners (Onchidium) are found in marshes of brackish water. Semper (33) has shown that these slugs have, in addition to the usual pair of cephalic eyes, a number of eyes developed upon the dorsal integument. These dorsal eyes are very perfect in elaboration, possessing lens, retinal nerve-end cells, retinal pigment, and optic nerve. Curiously enough, however, they differ from the cephalic Molluscan eye (for an account of which see fig. 118) in the fact that, as in the vertebrate eye, the filaments of the optic nerve penetrate the retina, and are connected with the surfaces of the nerve-end cells nearer the lens instead of with the opposite end. The significance of this arrangement is not known, but it is important to note, as shown by Hensen, Hickson, and others, that in the bivalves Pecten and Spondylus, which also have eyes upon the mantle quite distinct from typical cephalic eyes, there is the same relationship as in Onchidiadæ of the optic nerve to the retinal cells (fig. 145). In both Onchidiadæ and Pecten the pallial eyes have probably been developed by the modification of tentacles, such as coexist in an unmodified form with the eyes. The Onchidiadæ are, according to Semper, pursued as food by the leaping fish Periophthalmus, and the dorsal eyes are of especial value to them in aiding them to escape from this enemy.

Class II.—SCAPHOPODA.

Characters.—Mollusca Glossophora with the FOOT adapted to a BURROWING life in sand (figs. 73, 74, *f*). The body,

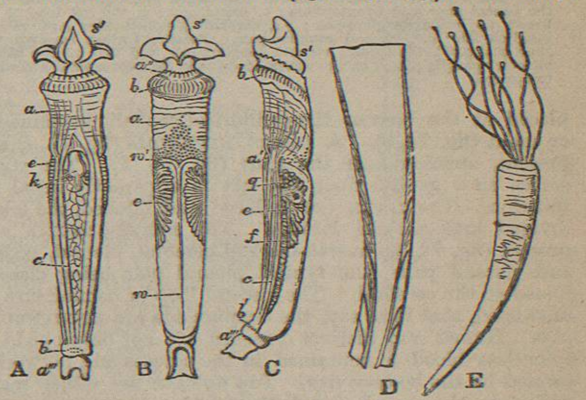

FIG. 73.—*Dentalium vulgare*, Da C. (after Lacaze Duthiers). A. Ventral view of the animal removed from its shell. B. Dorsal view of the same. C. Lateral view of the same. D. The shell in section. E. Surface view of the shell with gill-tentacles exserted as in life. *a*, mantle; *a′*, longitudinal muscle; *a″*, fringe surrounding the anterior opening of the mantle-chamber; *a‴*, the posterior appendix of the mantle; *b*, anterior circular muscle of the mantle; *b′*, posterior do.; *c*, *c′*, longitudinal muscle of mantle; *e*, liver; *f*, gonad; *k*, buccal mass (showing through the mantle); *q*, left nephridium; *s′*, club-shaped extremity of the foot; *w*, *w′*, longitudinal blood-sinus of the mantle.

and to a much greater extent the mantle-skirt and the foot, are elongated along the primitive antero-posterior (oro-anal) axis, and retain, both externally and in the disposition of internal organs, the archi-Molluscan BILATERAL SYMMETRY. The margins of the mantle-skirt of opposite sides (right and left) meet below the foot and fuse by concrescence; only a small extent in front and a small extent behind of the mantle-margin is left unfused. Thus a CYLINDRICAL FORM is attained by the mantle, and on its surface a TUBULAR shell (incomplete along the ventral line in the youngest stages) is secreted (fig. 73, D). The FOOT is greatly elongated, and can be protruded from the anterior mantle-aperture. It has a characteristic clavate form (fig. 74, *f*).

The pair of typical CTENIDIA are symmetrically developed in the form of numerous gill-filaments (fig. 74, A, *g*)

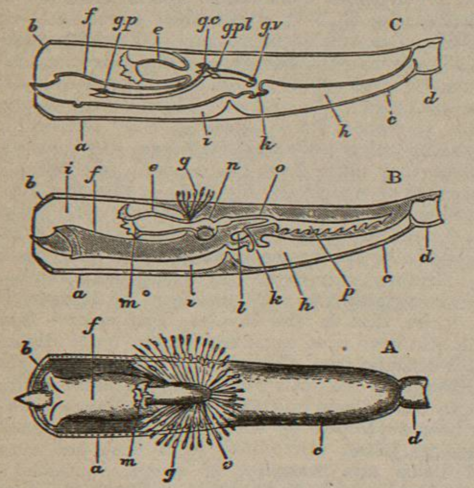

FIG. 74.—Diagrams of the anatomy of Dentalium. A. The anterior portion of the tubular mantle is slit open along the median dorsal line, and its cut margins (*a*) reflected so as to expose the foot, snout, and gills. B. Lateral view with organs showing as though by transparency. C. Similar lateral view to show the number and position of the nerve-ganglia and cords. *a*, the mantle-skirt; *b*, anterior free margin of the same; *c*, hinder extension of the mantle-skirt; *d*, the appendix of the mantle-skirt separated by a valve from the peri-anal portion of the sub pallial chamber, *h*; *e*, the snout or oral process; *f*, the foot; *g*, the ctenidial filaments; *h*, the peri-anal part of the sub-pallial chamber; *i*, the peri-oral part of the same chamber; *k*, the anus; *l*, the left nephridium; *m*, the mouth surrounded by pinnate tentacles; *n*, the buccal mass and odontophore; *o*, œsophagus; *p*, the left lobe of the liver; *g.p*, pedal ganglion-pair; *g.c*, cerebral ganglion-pair; *g.pl*, pleural ganglion-pair; *g.v*, visceral ganglion-pair. Possibly further research will show that *g.pl* is the typical visceral ganglion-pair, and that *g.v* is a pair of olfactory ganglia placed on the visceral loop as in the Lipocephala according to Spengel.

placed at the base of the cylindrical cephalic prominence or snout (fig. 74, *e*). A pair of NEPHRIDIA (fig. 74, *l*) are present, opening near the anus (fig. 74, *k*). The right serves as a genital duct, the left is apparently renal in function. The LIVER (*p*) is large and bilobed, the lobes divided into parallel lobules. The NERVE-GANGLIA are present (fig. 74, C) as well-marked cerebral, pleural, pedal, and visceral pairs the typical pleural pair being closely joined to the cerebral. The visceral loop or commissure is untwisted, that is to say, the Scaphopoda are EUTHYNEUROUS. HEART and distinct VESSELS are not developed; a colourless blood is contained in the sinuses and networks formed by the body-cavity. The GONADS are either male or female, the sexes being distinct.

The embyro is remarkable for developing five ciliated rings posterior to the ciliated ring and tuft characteristic of the trochosphere larval condition of Molluscs generally. These rings are comparable to those of the larva of Pneumodermon (fig. 84), and like them disappear.

The class Scaphopoda is not divisible into orders or families. It contains only three genera: *Dentalium*, L. (figs. 73, 74); *Siphonodentalium*, Sars.; and *Entalium*, Dfr.

They inhabit exclusively the sand on the sea-coast in depths of from 10 to 100 fathoms.

It is worthy of remark that the Scaphopoda constitute among the Glossophora a parallel to the sand-boring forms so common among the Lipocephala (such as Solen and Mya). This parallelism is seen in the special mode of elongation of the body, in the form of the foot, and in the tubular form of the mantle brought about by the concrescence of its ventral margins, as in the Lipocephala mentioned. The cylindrical shell of Dentalium is also comparable to the two semi-cylindrical valves of the shell of Solen; or, better, to the tubular shell of Aspergillum and Teredo. Nevertheless, it is necessary to consider the Scaphopoda as standing far apart from the Lipocephala, and as having no special genetic but only a homoplastic relationship to them, in consequence of their possessing a well-developed odontophore, the characteristic organ of the Glossophora never possessed by any Lipocephala.

Class III.—CEPHALOPODA.

Characters.—Mollusca Glossophora with the FOOT primarily adapted to a FREE-SWIMMING mode of life. The archi-Molluscan BILATERAL SYMMETRY predominates both in the external and internal organs generally, though in many cases (especially the smaller forms) a one-sided displacement of primitively median organs and a suppression of one of the primitively paired organs is to be noted.

An ANTERIOR, MEDIAN, and POSTERIOR region of the FOOT can be distinguished (fig. 75, (4), (5), (6)), corresponding to but probably not derived from the pro-, meso-,

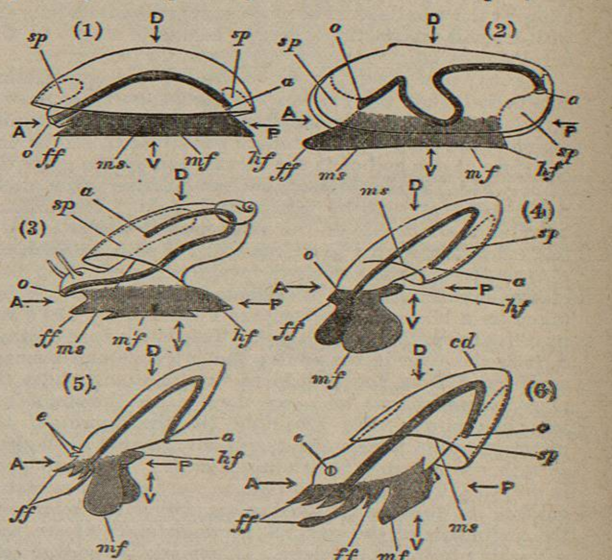

FIG. 75.—Diagrams of a series of Molluscs to show the form of the foot and its regions, and the relation of the visceral hump to the antero-posterior and dorso-ventral axes. (1) A Chiton. (2) A Lamellibranch. (3) An Anisopleurous Gastropod. (4) A Thecosomatous Pteropod. (5) A Gymnosomatous Pteropod. (6) A Siphonopod (Cuttle). A, P, antero-posterior horizontal axis; D, V, dorso-ventral vertical axis at right angles to A, P; *o*, mouth; *a*, anus; *ms*, edge of the mantle-skirt or flap; *sp*, sub-pallial chamber or space; *ff*, fore-foot; *mf*, mid-foot; *hf*, hind-foot; *e*, cephalic eyes; *cd*, centro-dorsal point (in 6 only).

and meta-podium of Gastropoda. The fore-foot invariably has the HEAD MERGED into it, and grows up on each side (right and left) of that part so as to surround the mouth, the two upgrowths of the fore-foot meeting on the dorsal aspect of the snout,—whence the name Cephalopoda. In the more typical forms of both branches of the class, the peri-oral portion of the foot is drawn out into paired arm-

like processes, either very short and conical (Clio, Eurybia), or lengthy (Pneumodermon, Octopus); these may be beset with suckers or hooks, or both. The mid-foot (fig. 75, *mf*) is expanded into a pair of muscular lobes right and left, which either are used for striking the water like the wings of a butterfly (Pteropoda), or are bent round towards one another so that their free margins meet and constitute a short tube,—the siphon or funnel (Siphonopoda). The hind foot is either very small or absent.

A distinctive feature of the Cephalopoda is the ABSENCE of anything like the TORSION of the visceral mass seen in the Anisopleurous Gastropoda, although as an exception this torsion occurs in one family (the Limacinidæ).

The ANUS, although it may be a little displaced from the median line, is (except in Limacinidæ) approximately median and posterior. The MANTLE-SKIRT may be aborted (Gymnosomatous Pteropoda); when present it is deeply produced posteriorly, forming a large sub-pallial chamber around the anus. As in our schematic Mollusc, by the side of the anus are placed the single or paired apertures of the NEPHRIDIA, the GENITAL APERTURES (paired only in Nautilus, in female Octopoda, female Ommastrephes, and male Eledone), and the paired CTENIDIA (absent in all Pteropoda). The VISCERAL HUMP or dome is elevated, and may be very much elongated (see fig. 75, (4), (5), (6)) in a direction almost at right angles to the primary horizontal axis (A, P in fig. 75) of the foot.

A SHELL is frequently, but not invariably, secreted on the visceral hump and mantle-skirt of Cephalopoda; but there are both Pteropoda and Siphonopoda devoid of any shell. The shell is usually light in substance or lightened by air-chambers in correlation with the free-swimming habits of the Cephalopoda. It may be external, when it is box-like or boat-like, or internal, when it is plate-like. Very numerous minute pigmented sacs capable of expansion and contraction, and known as CHROMATOPHORES, are usually present in the integument in both branches of the class. The GONADS of both sexes are developed in one individual in some Cephalopoda (Pteropoda), in others the sexes are separate.

SENSE-ORGANS, especially the cephalic eyes and the otocysts, are very highly developed in the higher Cephalopoda. The osphradia have the typical form and position in the lower forms, but appear to be more or less completely replaced by other olfactory organs in the higher. The normal NERVE-GANGLIA are present, but the connectives are shortened, and the ganglia concentrated and fused in the cephalic region. Large special ganglia (optic, stellate, and supra-buccal) are developed in the higher forms (Siphonopoda).

The Cephalopoda exhibit a greater range from low to high organization than any other Molluscan class, and hence they are difficult to characterize in regard to several groups of organs; but they are definitely held together by the existence in all of the encroachment of the fore-foot so as

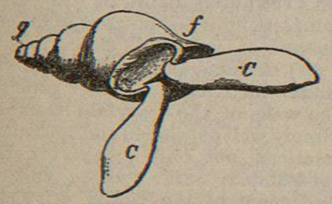

Fig. 76.

Fig. 77.

FIG. 76.—*Spirialis bulimoides*, Soul., one of the Limacinidæ enlarged (from Owen). *C C*, pteropodial lobes of the mid-foot; *f*, operculum carried on the hind-foot; *g*, spiral shell.
FIG. 77.—Operculum of Spirialis enlarged.

to surround the head, and by the functionally important BILOBATION OF THE MID-FOOT.

Two very distinct branches of the Cephalopoda are to be recognized: the one, the Pteropoda, more archaic in the condition of its bilobed mid-foot, including a number of minute, and in all probability degenerate, oceanic forms of simplified and obscure organization; the other, the Siphonopoda, containing the Pearly Nautilus and the Cuttles, which have for ages (as their fossil remains show) dominated among the inhabitants of the sea, being more highly gifted in special sense, more varied in movement, more powerful in proportion to size, and more heavily equipped with destructive weapons of offence than any other marine organisms.

FIG. 77*a*.—*Cymbulia Peronii*, Cuvier (from Owen). *C*, *C*, the expanded pteropodial lobes or wing-like fins of the mid-foot.

Branch *a*.—*PTEROPODA*.

Characters.—Cephalopoda in which the mid-region of the foot is (as compared with the Siphonopoda) in its more primitive condition, being relatively largely developed and drawn out into a pair of wing-like muscular lobes (identical with the two halves of the siphon of the Siphonopoda) which are used as paddles (see figs. 76-86). The hind-region of the foot is often aborted, but may carry an operculum (figs. 76, 77). The fore-region of the foot (that embracing the head) is also often rudimentary, but may be drawn out into one or more pairs of tentacles, simulating cephalic tentacles, and provided with suckers (figs. 84, 85).

Though the visceral hump is not twisted except in the Limacinidæ (fig. 76), there is a very general tendency to one-sided development of the viscera, and of their external apertures (as contrasted with Siphonopoda). The ctenidia are aborted, with the possible exception of the processes (fig. 85, *c*) at the end of the body of Pneumodermon. The vascular system resembles that of the Gastropoda. The nephridium is a single tubular body corresponding to the right nephridium of the typical pair of the archi-Mollusc. The anal aperture is usually placed a little to the left of the median line, more rarely to the right. In the Limacinidæ it has an exceptional position, owing to the torsion of the visceral mass, as in Anisopleurous Gastropoda.

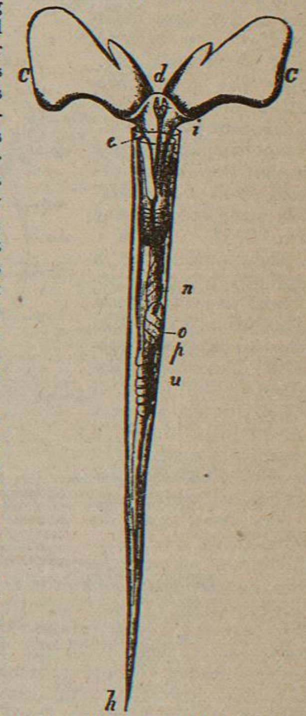

FIG. 78.—*Styliola acicula*, Rang. sp. enlarged (from Owen). *C*, *C*, the wing-like lobes of the mid-foot; *d*, median fold of same; *e*, copulatory organ; *h*, pointed extremity of the shell; *i*, anterior margin of the shell; *n*, stomach; *o*, liver; *u*, hermaphrodite gonad.

Jaws and a lingual ribbon are present as in typical Glossophora, the dentition of the ribbon and the number of jaw-pieces presenting a certain range of variation. Sense-

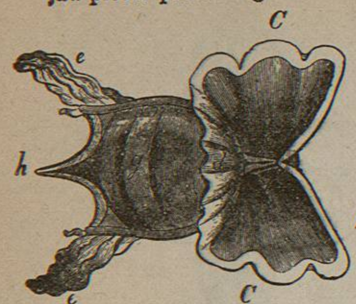

Fig. 79.

Fig. 80.

FIG. 79.—*Cavolinia tridentata*, Forsk. from the Mediterranean, magnified two diameters (from Owen). *a*, mouth; *b*, pair of cephalic tentacles; *C*, *C*, pteropodial lobes of the mid-foot; *d*, median web connecting these; *e*, *e*, processes of the mantle-skirt reflected over the surface of the shell; *g*, the shell enclosing the visceral hump; *h*, the median spine of the shell.

FIG. 80.—Shell of *Cavolinia tridentata*, seen from the side. *f*, postero-dorsal surface; *g*, antero-ventral surface; *h*, median dorsal spine; *i*, mouth of the shell.

organs are present in the form of cephalic eyes in very few forms (Cavolinia, Clione, and in an undescribed form discovered by Suhm during the "Challenger" Expedition); otocysts are universally present. The osphradia are present in typical form, although the ctenidia are aborted; only one osphradium (the right of the typical pair) is present (fig. 87). The gonads are both male and female in the same individual. The genital aperture is single. Copulatory organs, often of considerable size, are present (fig. 86, *z*).

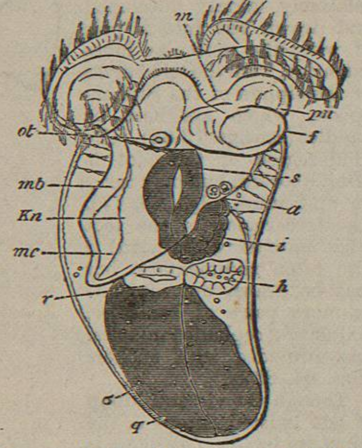

FIG. 81.—Embryo of *Cavolinia tridentata* (from Balfour, after Fol.). *a*, anus; *f*, median portion of the foot; *pn*, pteropodial lobe of the foot; *h*, heart; *i*, intestine; *ot*, otocyst; *q*, shell; *r*, nephridium; *s*, œsophagus; *σ*, sac containing nutritive yelk; *mb*, mantle-skirt; *mc*, subpallial chamber; *Kn*, contractile sinus.

The mantle-skirt is present in one division of the Pteropoda (Thecosomata), and in these an extensive subpallial chamber is developed, the walls of which in the absence of ctenidia have a branchial function. In a second division (Gymnosomata), which comprises forms highly developed in regard to the processes of the fore-foot, the mantle-skirt is aborted. A shell is developed on the surface of the visceral hump and mantle-skirt of the Thecosomata, whilst in the Gymnosomata, which have no mantle-skirt, there is in the adult animal no shell. The embryo passes through a trochosphere and a veliger stage (fig. 81), provided with boat-like shell, except in some Gymnosomata in which the Trochosphere with its single velar ciliated band becomes metamorphosed into a larva which has three additional ciliated bands but no velum (resembling the larva of the Scaphopod Dentalium); this banded larva does *not* form a larval shell (fig. 84).

The Pteropoda are divided into two orders.

Order 1.—Thecosomata.

Characters.—Pteropoda provided with a mantle-skirt, and with a delicate hyaline shell developed on the surface of the visceral hump and mantle-skirt; visceral hump, and consequently the shell, spirally twisted in one family, the Limacinidæ; shell often with contracted mouth and dilated body, its walls sometimes drawn out into spine-like processes, which are covered by reflexions of the free margin of the mantle (Cavolinia, figs. 79, 80).

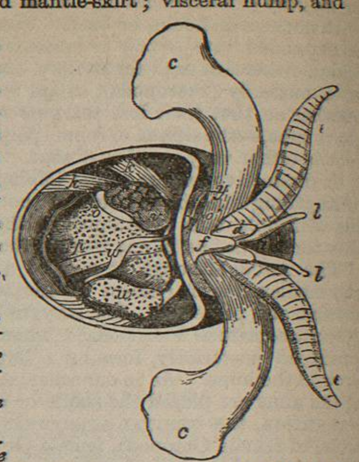

FIG. 82.—*Theceurybia Gaudichaudii*, Soul., (from Owen). Much enlarged; the body-wall removed. *a*, the mouth; *c*, the pteropodial lobes of the foot; *f*, the centrally-placed hind-foot; *d*, *l*, *e*, three pairs of tentacle-like processes placed at the sides of the mouth, and developed (in all probability) from the fore-foot; *o′*, anus; *y*, genital pore; *k*, retractor muscles; *o* and *p*, the liver; *u*, *v*, *w*, genitalia.

Family 1.—*Cymbuliidæ.*
Genera: *Tiedemannia*, Chj.; *Halopsyche*, *Theceurybia* (figs. 82, 83), *Cymbulia*, P. and L. (fig. 77*a*).
Family 2.—*Conulariidæ* (fossil).
Genus: *Conularia*, Mill.
Family 3.—*Tentaculitidæ* (fossil).
Genera: *Tentaculites*, Schlth.; *Cornulites*, Schlth.; *Coleoprion*, Sandb.
Family 4.—*Hyaleidæ.*
Genera: *Triptera*, Q. and G.; *Styliola*, Les. (fig. 78); *Balantium*, Lch.; *Vaginella*, Dand.; *Cleodora*, P. and L.; *Diacria*, Gr.; *Pleuropus*, Esch.; *Cavolinia*, Gioni. (figs. 79, 80, 81).
Family 5.—*Thecidæ.*
Genera: *Theca*, Low; *Pterotheca*, Salt.
Family 6.—*Limacinidæ.*
Genera: *Eccyliomphalus*, Porti.; *Heterofusus*, Flg.; *Spirialis*, E. S. (fig. 76); *Limacina*, Cuv.

Order 2.—Gymnosomata.

Characters.—Pteropoda devoid of mantle-skirt and shell; tentacular processes of the fore-foot well developed and provided with suckers.

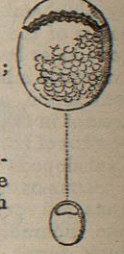

FIG. 83.—Shell of *Theceurybia norfolkensis*; the lower figure shows the natural size.

Family 1.—*Pterocymodoceidæ.*
Genus: *Pterocymodoce*, Kef.
Family 2.—*Clionidæ.*
Genera: *Cliodita*, Q. and G.; *Clionopsis*, Trosch.; *Clione*, Pall. (fig. 86).
Family 3.—*Pneumodermidæ.*
Genera: *Trichocyclus*, Esch.; *Spongobranchia*, d'Orb.; *Pneumodermopsis*, Kef.; *Pneumodermon*, Cuv. (fig. 85).

Branch *b*.—*SIPHONOPODA.*

Cephalopoda in which the two primarily divergent right and left lobes of the mid-region of the foot have their free borders recurved towards the middle line, where they are either held in apposition (Tetrabranchiata), or fused with one another to form a complete cylinder open at each end (Dibranchiata). This fissured or completely closed tube is the siphon (fig. 75, (6), *mf*) characteristic of the Siphonopoda, and is used to guide the stream of water expelled by the contractions of the walls of the branchial chamber. The pallial skirt is accordingly well developed and muscular, subserving by its contractions not only respiration but locomotion. The visceral hump is never twisted, and accordingly the main development of the pallial skirt and chamber is posterior, the excretory apertures, anus, and gills having a posterior position, as in the archi-Mollusc. At the same time the visceral hump is usually much elongated in a direction corresponding to an oblique line between the vertical dorso-ventral and the horizontal antero-posterior axes (see fig. 75, (6)).

The fore-part of the foot which surrounds the mouth, as in all Cephalopoda, is drawn out into four or five pairs of lobes, sometimes short, but usually elongated and even fili-

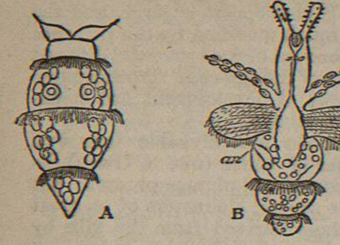

Fig. 84

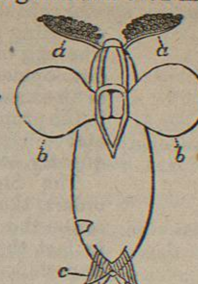

Fig. 85.

FIG. 84.—Larvæ of Pneumodermon (from Balfour, after Gegenbaur). The præ-oral ciliated band of the trochosphere stage (velum) has atrophied. In A three post-oral circlets of cilia are present. The otocysts are seen, and the rudiments of a pair of processes growing from the head. In B the foremost ciliated ring has disappeared; the cephalic region is greatly developed, and, as compared with the adult (fig. 85), is large and free; the pair of hook-bearing processes on each side of the mouth are retractile, probably part of the fore-foot. At the base of the cephalic snout are seen the pair of arm-like processes (fore-foot) provided with suckers, and behind these the broad pteropodial lobes or wing-like fins of the mid-foot.

FIG. 85.—*Pneumodermon violaceum*, d'Orb.; magnified five diameters. *a*, the sucker-bearing arms; *b*, the fins of the mid-foot (in the middle line, between these, is seen the sucker-like median portion of the foot, by means of which the animal can crawl as a Gastropod); *c*, the four branchial processes. (After Keferstein.)

form. These lobes either carry peculiar sheathed tentacles (Nautilus), or, on the other hand, acetabuliform suckers, which may be associated with claw-like hooks (Dibranchiata). The hind-foot is probably represented by the valve which depends from the inner wall of the siphon in many cases.

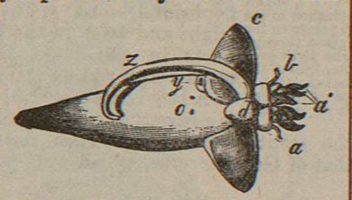

FIG. 86.—*Clione borealis*, L.; magnified two diameters,—postero-ventral aspect. *a*, the cephalic region carrying *a′*—three pairs of cephalic cones provided each with very numerous minute sucker-like processes, and surrounded by a hood-like upgrowth,—and *b*, the more elongated tentacles (the retractile eye-tentacles are not seen, being placed dorsally); *c*, the pteropodial fins; *d*, the median portion of the foot; *a*, the anus; *y*, the vagina; *z*, the penis. (From Owen, after Eschricht.)

A shell (figs. 89, 100) is very generally present, affording protection to the visceral mass and attachment for muscles. It may be external or enclosed in dorsal upgrowing folds of the mantle, which (except in Spirula) close up at an early period of development, so as to form a shut sac in which the shell is secreted. The ctenidia are well developed as paired gill-plumes, serving as the efficient branchial organs (figs. 101, 103, and fig. 2, B).

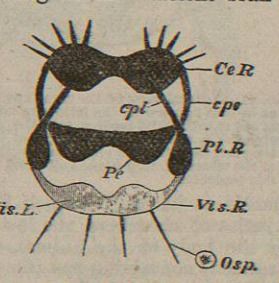

FIG. 87.—Enlarged diagram of the nerve-centres of Pneumodermon (from Spengel, after Souleyet). *CeR*, right cerebral ganglion; *Pl.R*, right pleural ganglion; *Pe*, right pedal ganglion; *Vis.R.*, right visceral ganglion; *Vis.L.*, left visceral ganglion; *cpe*, right cerebro-pedal connective; *cpl*, right cerebro-pleural connective; *Osp.*, osphradium connected by a nerve with the right visceral ganglion.

The vascular system is very highly developed; the heart consists of a pair of auricles and a ventricle (figs. 104, 105) Branchial hearts are formed on the advehent vessels of the branchiæ. It is not known to what extent the minute subdivision of the arteries extends, or whether there is a true capillary system.

The pericardium is extended so as to form a very large sac passing among the viscera dorsal wards and sometimes containing the ovary or testis—the viscero-pericardial sac—which opens to the exterior either directly or through the nephridia. It has no connexion with the vascular system. The nephridia are always paired sacs, the walls of which invest the branchial advehent vessels (figs. 104, 108). They open each by a pore into the viscero-

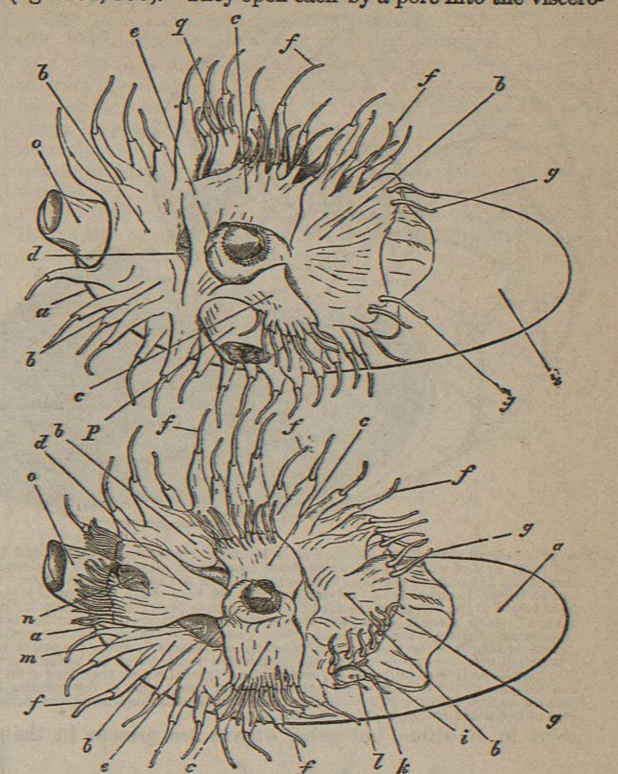

FIG. 88.—Male (upper) and female (lower) specimens of *Nautilus pompilius* as seen in the expanded condition, the observer looking down on to the buccal cone *e*; one-third the natural size linear. The drawings have been made from actual specimens by A. G. Bourne, B.Sc., and serve to show the natural disposition of the tentaculiferous lobes and tentacles of the circum-oral portion of the foot in the living state, as well as the great differences between the two sexes. *a*, the shell; *b*, the *outer* ring-like expansion (annular lobe) of the circum-oral muscular mass of the fore-foot, carrying nineteen tentacles on each side—posteriorly this is enlarged to form the "hood" (marked *v* in fig. 89 and *m*. in figs. 90 and 91), giving off the pair of tentacles marked *g* in the present figure; *c*, the right and left inner lobes of the fore-foot, each carrying twelve tentacles in the female, in the male subdivided into *p*, the "spadix" or hectocotylus on the left side, and *q*, the "anti-spadix," a group of four tentacles on the right side,—it is thus seen that the subdivided right and left inner lobes of the male correspond to the undivided right and left inner lobes of the female; *d*, the inner inferior lobe of the fore-foot, a bilateral structure in the female carrying two groups, each of fourteen tentacles, separated from one another by a lamellated organ *n*, supposed to be olfactory in function—in the male the inner inferior lobe of the fore-foot is very much reduced, and has the form of a paired group of lamellæ (*d* in the upper figure); *e*, the buccal cone, rising from the centre of the three inner lobes, and fringing the protruded calcareous beaks or jaws with a series of minute papillæ; *f*, the tentacles of the outer circum-oral lobe or annular lobe of the fore-foot projecting from their sheaths; *g*, the two most posterior tentacles of this series belonging to that part of the annular lobe which forms the hood (*m*. in figs. 90 and 91); *i*, superior ophthalmic tentacle; *k*, inferior ophthalmic tentacle; *l*, eye; *m*, paired laminated organ on each side of the base of the inner inferior lobe (*d*) of the female, probably olfactory in function; *n*, olfactory lamellæ upon the inner inferior lobe (in the female); *o*, the siphon (mid-foot); *p*, the spadix (in the male), the hectocotylized portion of the left inner lobe of the fore-foot representing four modified tentacles, eight being left unmodified; *q*, the anti-spadix (in the male), being four of the twelve tentacles of the right inner lobe of the fore-foot isolated from the remaining eight, and representing on the right side the differentiated spadix of the left side. The four tentacles of the anti-spadix are set, three on one base and one on a separate base.

There are thus in the female, where they are most numerous, ninety-four tentacles, thirty-eight on the outer annular lobe, four ophthalmic (a pair to each eye), twelve on each of the right and left inner lobes, and twenty-eight on the inner inferior lobe.

pericardial sac except in Nautilus. The anal aperture is median and raised on a papilla. Jaws (fig. 88, *e*) and a lingual ribbon (fig. 107) are well developed. The jaws have the form of a pair of powerful beaks, either horny or calcified (Nautilus), and are capable of inflicting severe wounds