

Possibly the sense of taste resides in certain processes within the mouth of Nautilus and other Siphonopoda.

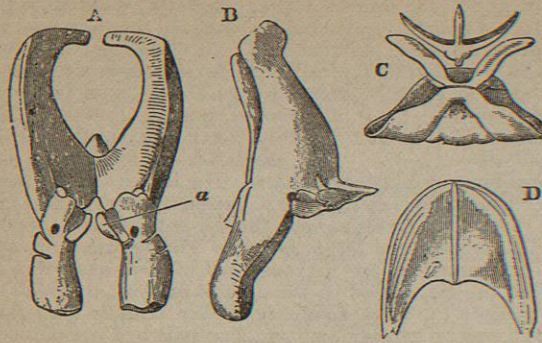


FIG. 116.—Cartilaginous skeleton of Siphonopoda (after Keferstein). A. Capito-pedal cartilage of *Nautilus pompilius*; a points to the ridge which supports the pedal portion of the nerve-centre. B. Lateral view of the same, - the large anterior processes are sunk in the muscular substance of the siphon. C. Cephalic cartilages of *Sepia officinalis*. D. Nuchal cartilage of *Sepia officinalis*.

The otocysts of Nautilus were discovered by Macdonald (40). Each lies at the side of the head, ventral of the eye, resting on the capito-pedal cartilage, and supported by the large auditory nerve which arises from the pedal ganglion. It has the form of a small sac, 1 to 2 mm. in diameter, and contains whetstone-shaped crystals, such as are known to form the otoliths of other Mollusca. The otocysts of Dibranchiata are larger and deeply sunk in the cephalic cartilage. It has been shown by Lankester that they develop as open pits (fig. 121, (5), (6), o), which gradually close up, the communication with the exterior becoming narrowed into a fine canal, which is reflected over one end of the sac, and finally has its external opening obliterated. A single otolith only is found in all Dibranchiata.

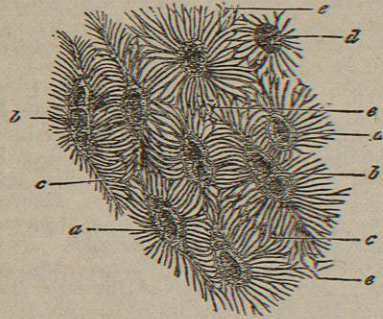


FIG. 117.—Minute structure of the cartilage of *Loligo* (from Gegenbaur, after Furringer). a, simple, b, dividing, cells; c, canaliculi; d, an empty cartilage capsule with its pores; e, canaliculi in section.

The eye of Nautilus is among the most interesting structures of that remarkable animal. No other animal which has the same bulk and general elaboration of organization has so simple an eye as that of Nautilus. When looked at from the surface no metallic lustre, no transparent coverings, are presented by it. It is simply a slightly projecting hemispherical box like a kettle-drum, half an inch in diameter, its surface looking like that of the surrounding integument, whilst in the middle of the drum-membrane is a minute hole (fig. 91, u). Owen very naturally thought that some membrane had covered this hole in life, and had been ruptured in the specimen studied by him. It, however, appears from the researches of Hensen (41) that the hole is a normal aperture leading into the globe of the eye, which is accordingly filled by sea-water during life. There is no dioptric apparatus in Nautilus, and in place of refracting lens and cornea we have actually here an arrangement for forming an image on the principle of "the pin-hole camera." There is no other eye known in the whole animal kingdom which is so constructed. The wall of the eye-

globe is tough, and the cavity is lined solely by the naked retina, which is bathed by sea-water on one surface and receives the fibres of the optic nerve on the other (see fig. 118, A). As in other Siphonopods (e.g., fig. 120, *Ri*, *Re*, *p*), the retina consists of two layers of cells separated by a layer of dark pigment. The most interesting consideration connected with this eye of Nautilus is found when the further facts are noted—(1) that the elaborate lens-bearing eyes of Dibranchiata pass through a stage of development in which they have the same structure as the eye of Nautilus—namely, are open sacs (fig. 119); and (2), that amongst other Mollusca examples of cephalic eyes can be found which in the adult condition are, like the eye of Nautilus and the developing eye of Dibranchs, simple pits of the integument, the cells of which are surrounded by pigment and connected with the filaments of an optic nerve. Such is the structure

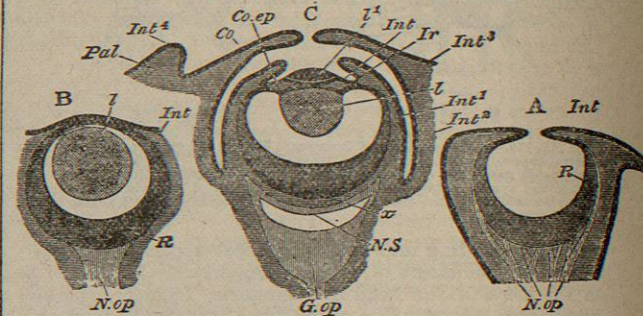


FIG. 118.—Diagrams of sections of the eyes of Mollusca. A. Nautilus (and Patella). B. Gastropod (*Limax* or *Helix*). C. Dibranchiate Siphonopod (Oigopsid). Pal, eyelid (outermost fold); Co, cornea (second fold); Ir, iris (third fold); Int<sup>1</sup>, 2, 3, 4, different parts of the integument; l, deep portion of the lens; u, outer portion of the lens; Co.op, ciliary body; R, retina; N.op, optic nerve; G.op, optic ganglion; z, inner layer of the retina; N.S, nervous stratum of the retina. (From Balfour, after Grenacher.)

of the eye of the Limpet (Patella); and in such a simple eye we obtain the clearest demonstration of the fact that the retina of the Molluscan cephalic eye, like that of the Arthropod cephalic eye and unlike that of the Vertebrate myelonic eye, is essentially a modified area of the general epiderm, and that the sensitiveness of its cells to the action of light and their relation to nerve-filaments is only a specialization and intensifying of a property common to the whole epiderm of the surface of the body. What, however, strikes us as especially remarkable is that the simple form of a pit, which in Patella serves to accumulate a secretion which acts as a refractive body, should in Nautilus be glorified and raised to the dignity of an efficient optical apparatus. Natural selection has had an altogether exceptional opportunity in the ancestors of Nautilus. In all other Mollusca, starting as we may suppose from the follicular or pit-like condition, the eye has proceeded to acquire the form of a closed sac, the cavity of the closed vesicle being then filled partially or completely by a refractive body (lens) secreted by its walls (fig. 118, B). This is the condition attained in most Gastropoda. It presents a striking contrast to the simple Arthropod eye, where, in consequence of the existence of a dense exterior cuticle, the eye does not form a vesicle, and the lens is always part of that cuticle.

In the Dibranchiate division of the Siphonopoda the greatest elaboration of the dioptric apparatus of the eye is attained, so that we have in one sub-class the extremes of the two lines of development of the Molluscan eye, those two lines being the punctigerous and the lentigerous. The structure of the Dibranchiate's eye is shown in section in fig. 118, C, and in fig. 120, and its development in fig. 119 and fig. 123. The open sac which forms the retina of the young Dibranchiate closes up, and constitutes the posterior chamber of the eye, or primitive optic vesicle (fig. 123, A, *poc*). The

lens forms as a structureless growth, projecting inwards from the front wall of this vesicle (fig. 123, B, l). The integument around the primitive optic vesicle which has sunk below

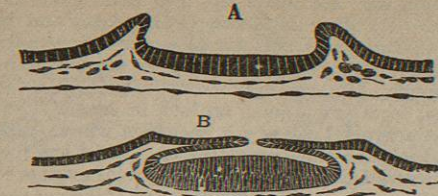


FIG. 119.—Diagrams of sections showing the early stage of development of the eye of *Loligo* when it is, like the permanent eye of Nautilus and of Patella, an open sac. A. First appearance of the eye as a ring-like upgrowth. B. Ingrowth of the ring-like wall so as to form a sac, the primitive optic vesicle of *Loligo*. (From Lankester.)

the surface now rises up and forms firstly nearest the axis of the eye the iridian folds (if in B, fig. 123; ik in fig. 120; Ir in fig. 118), and then secondly an outer circular fold grows up like a wall and completely closes over the iridian folds and the axis of the primitive vesicle (fig. 120, C). This covering is transparent, and is the cornea. In the oceanic Decapoda the cornea does not completely close, but leaves a central aperture traversed by the optic axis. These forms are termed Oigopsidae by d'Orbigny (42), whilst the Decapoda with closed cornea are termed Myopsidae. In the Octopoda the cornea is closed, and there is yet another fold thrown over the eye. The skin surrounding the cornea presents a free circular margin, and can be drawn over the surface of the cornea by a sphincter muscle. It thus acts as an adjustable diaphragm, exactly similar in

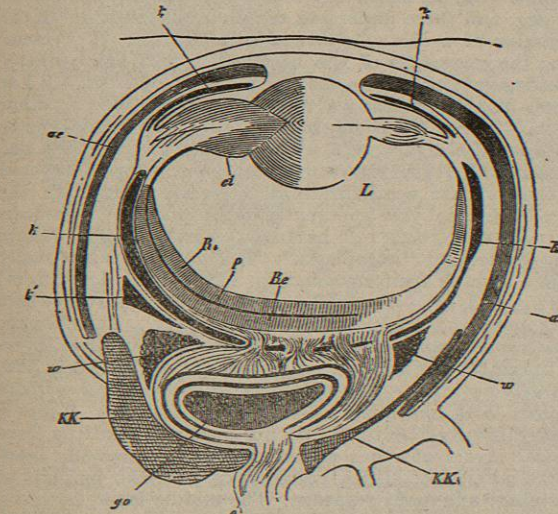


FIG. 120.—Horizontal section of the eye of *Sepia* (Myopsid). KK, cephalic cartilages (see fig. 110); C, cornea (closed); L, lens; c, ciliary body; R, internal layer of the retina; R', external layer of the retina; p, pigment between these; o, optic nerve; go, optic ganglion; k and k', capsular cartilage; ik, cartilage of the iris; w, white body; ae, argentine integument. (From Gegenbaur, after Hensen.)

movement to the iris of Vertebrates. *Sepia* and allied Decapods have a horizontal lower eyelid, that is to say, only one-half of the sphincter-like fold of integument is movable. The exact history of the later growth of the lens in the Dibranchs' eye is not clear. As seen in fig. 120, it appears, after attaining a certain size, to push through the front wall of the primitive optic vesicle at the point corresponding to its centre of closure, and to project a little into the anterior chamber formed by the cornea. The wall of the

primitive optic vesicle adjacent to the embedded lens (L) now becomes modified, forming a so-called "ciliary body," in which muscular tissue is present, serving to regulate the focus of the lens (ci in fig. 120). Bobretzky (43) differs from Lankester, whose view is above given, in assigning a distinct origin to the protruding anterior segment of the lens (l<sup>1</sup> in fig. 118). The optic ganglion, as well as the other large ganglia of the Dibranchiata, originate in the mesoblast of the embryo. The connexion between the cells of the retina and the nerve-fibres proceeding from the optic ganglion must therefore be a secondary one.

**Chromatophores.**—In Nautilus these remarkable structures, which we mention here as being intimately associated with the nervous system, appear to be absent. In Dibranchiata they play an important part in the economy, enabling their possessor, in conjunction with the discharge of the contents of the ink-bag, to elude the observation of either prey or foe. They consist of large vesicular cells (true nucleated cells converted into vesicles), arranged in a layer immediately below the epidermis. Each chromatophore-cell has from six to ten muscular bands attached to its walls, radiating from it star-wise. The contraction of these fibres causes the chromatophore-cell to widen out; it returns to its spherical resting state by its own elasticity. In the spherical resting state such a cell may measure .01 mm., whilst when fully stretched by its radiating muscles it covers an area of .5 mm. The substance of the chromatophore-cells is intensely coloured with one of the following colours—scarlet, yellow, blue, brown—which are usually of the greatest purity and brilliance. The action of the chromatophores may be watched most readily in young *Loligo*, either under the microscope or with the naked eye. The chromatophores are suddenly expanded, and more slowly retracted with rapidly-recurring alternation. All the blue, or all the red, or all the yellow may be expanded and the other colours left quiescent. Thus the animal can assume any particular hue, and change its appearance in a dazzling way with extraordinary rapidity. There is a definite adaptation of the colour assumed in the case of *Sepia* and others to the colour of the surrounding rock and bottom.

**Gonads and Genital Ducts.**—In Nautilus it has recently been shown by Lankester and Bourne (37) that the genital ducts of both sexes are paired right and left, the left duct being rudimentary and forming the "pyriform appendage," described by Owen as adhering by membranous attachment to the ventricle of the heart, and shown by Keferstein to communicate by a pore with the exterior. Thus the Cephalopoda agree with our archi-Mollusc in having bilaterally symmetrical genital ducts in the case of the most archaic member of the class. The ovary (female gonad) or the testis (male gonad) lies in Nautilus as in the Dibranchs in a distinct cavity walled off from the other viscera, near the centro-dorsal region. This chamber is formed by the coelomic or peritoneal wall; the space enclosed is originally part of the coelom, and in *Sepia* and *Loligo* is, in the adult, part of the visceropericardial chamber. In Octopus it is this genital chamber which communicates by a right and a left canal with the nephridium, and is the only representative of pericardium. The ovary or testis is itself a growth from the inner wall of this chamber, which it only partly fills. In Nautilus the right genital duct, which is functional, is a simple continuation to the pore on the postero-dorsal surface of the membranous walls of the capsule in which lies the ovary or the testis, as the case may be. The gonad itself appears to represent a single median or bilateral organ.

The true morphological nature of the genital ducts of the Cephalopoda and of other Mollusca is a subject which invites speculation and inquiry. In all the cases in which such

ducts continuous with the tunic of the gonad itself occur—viz., in Nematoid worms, in Arthropoda, and in Teleostean fishes, besides Mollusca—there is an absence of definite knowledge as to the mode of development of the duct. It seems, however, from such facts as have been ascertained that the gonad lies at first freely in the coelom, and that the duct develops in connexion with the genital pore, and attaches itself to the embryonic gonad, or to the capsule which grows around it. The question then arises as to the nature of the pore. In other groups of animals we find that the pore, and funnel or tube connected with it by which the genital products are conveyed to the exterior, is a modified nephridium (usually a pair, one right and one left). Is it possible that this is also the case where the duct very early becomes united to the gonad, and even gives rise to the appearance of a tubular ovary or testis? Probably this is the case in Teleostean fishes (see Huxley's observations on the oviducts of the smelt, 44); but it seems to be a tenable position that in other cases, including the Mollusca, the genital pore is a simple opening in the body-wall leading into the body-cavity or coelom, such as we find on the dorsal surface of the earth-worm, which has become specialized for the extrusion of the genital products. Possibly, as in Nemertine and Chætopod worms, the condition preceding the development of these definite genital pores was one in which a temporary rupture of the body-wall occurred at the breeding season, and this temporary aperture has gradually become permanent. The absence of genital pores in Patella, and some Lamellibranchs which make use of the nephridia for the extrusion of their genital products, suggests that the very earliest Mollusca or their forefathers were devoid of genital ducts and pores. In no Mollusca, however, is the nephridium used in the same way as a genital duct as it is in the Chætopoda, the Gephyrea, and the Vertebrata; for the open mouth of the nephridium in Mollusca leads into the pericardial space, and it is not through this space and this mouth that the genital products of any Mollusca enter the nephridium (except perhaps in Neomenia), although it is by this mouth that the genital products enter the nephridium in the former classes above named. Hence the arrangement in Patella, &c., is to be looked upon as a special development from the simpler condition when the Mollusca brought forth by rupture (= schizodinic, from *σχιζο*, travail, and not as derived from the common arrangement of adaptation of a nephridium to the genital efferent function (= nephrodinic).<sup>1</sup>

The functional oviduct of Nautilus forms an albuminiparous gland as a diverticulum, which appears to correspond to a dilatation in the male duct, which succeeds the testis itself, and is called the "accessory gland." The male duct has a second dilatation (Needham's sac), and then is produced in the form of a large papilla. In Dibranchs the genital ducts are but little more elaborated. They are ciliated internally. In female Octopoda, in Ommastrephes, and in one male Octopod (*Eledone moschata*) the genital ducts are paired, opening right and left of the anus. But in all other Dibranchs a single genital duct only is developed, viz., that of the left side, and leads from the genital capsule or chamber of the gonad to an asymmetrically-placed pore. In the male Dibranchs the genital duct is coiled and provided with a series of glandular dilatations and

<sup>1</sup> Coelomate animals are, according to this nomenclature, either Schizodinic or Porodinic. The Porodinic group is divisible into Nephrodinic and Idiodinic, in the former the nephridium serving as a pore, in the latter a special (*Blies*) pore being developed. In each of these latter-groups the pore may be—(1) devoid of a duct, (2) provided with a duct which is unattached to the gonad and opens into the body-cavity, (3) provided with a duct which fuses with the gonad. The genital ducts of Idiodinic forms may be called Idiogonaducts, as distinguished from the Nephrogonaducts of nephrodinic forms.

receptacles. These are connected with the formation of the spermatophores. In the Siphonopoda the spermatic fluid does not flow as a liquid from the genital pore, but the spermatozoa are made up into little packets before extrusion. In other Mollusca (Pulmonata) and in other animals (Chætopoda) this formation of "sperm-ropes" is known, but in the Siphonopoda it attains its highest development. Exceedingly complicated structures of a cylindrical form (sometimes an inch in length) are formed in the male genital duct by a secretion which embeds and cements together the spermatozoa. They are formed in Nautilus as well as in Dibranchs, the actual manner in which their complicated structure is produced being not easily conjectured. Accessory glands not forming part of the oviduct, but furnishing the material for enclosing the eggs in an elastic envelope, are found as paired structures, opening some way behind the anus in Nautilus (101, *g.n.*) and in the Dibranchs. They are known as the nidamental glands. In the female Sepia they are particularly large and prominent, and are accompanied by a second smaller pair.

**Reproduction and Development.**—The details of sexual congress and of the actual fertilization of the egg are quite unknown in Nautilus, and imperfectly in the Dibranchs and the Pteropoda. Allusion has already been made to the subject in connexion with the hectocotylized arm. The mature eggs of Nautilus are unknown, as well as the appearance which they present when deposited. In the Dibranchs the eggs are always very large; in some cases the amount of food-yolk infused into the original egg-cell is so great as to give it the size of a large pea. This results in that mode of development which is only known outside this class among the Vertebrata; it is discoblastic. The protoplasm of the fertilized egg-cell segregates to one pole of the egg, and there undergoes cell-division, resulting in the formation of a disc of cleavage cells (fig. 121, (1)) resembling the cicatricle of the hen's egg, which subsequently spreads over and invests the whole egg (fig. 121, (2)). For details of this process we must refer the reader to other works (45, 46); but it may here be noted that in addition to the layer of cleavage cells, which consists of more than one stratum of cells in the future embryonic area as opposed to the yolk-sac area, additional cells are formed in the mass of residual yolk apparently by an independent process of segregation, each cell having a separate origin, whence they are termed "autoplasts." The autoplasts eventually form a layer of fusiform cells (fig. 121, (7), *h*; fig. 122, *m*; and fig. 123, *ps*),—the "yolk-membrane" which everywhere rests upon and encloses the residual yolk. The cleavage cells form a single layer on the yolk-sac area and two layers on the embryonic area, an outer layer one cell deep (fig. 122, *ep*), and an inner—the middle layer of the three—which is often thick and many cells deep (fig. 122, *m*). There is great difficulty here in identifying the layers with the three typical layers of other animal embryos, except in regard to the outermost, which corresponds with the epiblast of Vertebrates in many respects. The middle layer, however, gives rise to the nerve-ganglia as well as to the muscles, coelom, and skeleto-trophic tissues, and to the mid-portion of the alimentary canal with its hepatic diverticula, the liver (see fig. 121, (7) and explanation, where the origin of the mid-gut as a vesicle *r* is seen). It is clearly, therefore, something more than the mesoblast of the Vertebrate, giving rise, as it does, to important organs formed both by epiblast and hypoblast in other animals. Lastly, the yolk-membrane, though corresponding to the Vertebrate hypoblast in position and structure, furnishes no part of the alimentary tract, but disappears when the yolk is completely absorbed. In fact, the developmental phenomena in Sepia, Loligo, and Octopus are profoundly perturbed by the excessive proportion of food-yolk. Balfour has shown

that in the chick the orifice of closure of the overspreading blastoderm does not represent the whole of the blastopore,

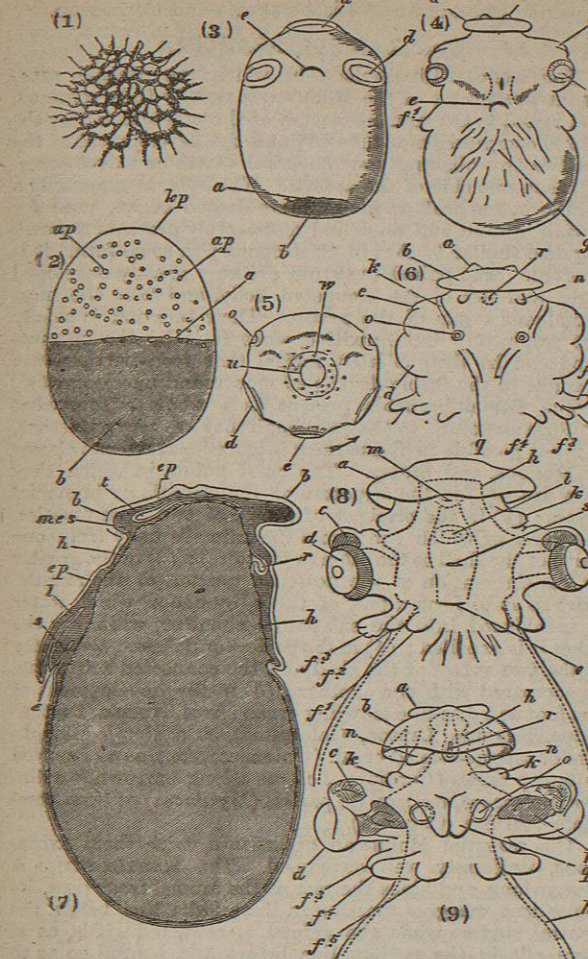


FIG. 121.—Development of Loligo. (1) View of the cleavage of the egg during the first formation of embryonic cells. (2) Lateral view of the egg at a later stage. *a*, limit to which the layer of cleavage-cells has spread over the egg; *b*, portion of the egg (shaded) as yet uncovered by cleavage-cells; *ap*, the autoplasts; *cp*, cleavage-pole where first cells were formed. (3) Later stage, the limit *a* now extended so as to leave but little of the egg-surface (*b*) unenclosed. The eyes (*d*), mouth (*e*), and mantle-sac (*u*) have appeared. (4) Later stage, anterior surface, the embryo is becoming nipped off from the yolk sac (*g*). (5) View of an embryo similar to (3) from the cleavage-pole or centro-dorsal area. (6) Later stage, posterior surface. (7) Section in a median dorso-ventral and anterior-posterior plane of an embryo of the same age as (4). (8) View of the anterior face of an older embryo. (9) View of the posterior face of an embryo of the same age as (8). Letters in (3) to (9)—*a*, lateral fins of the mantle; *b*, mantle-skirt; *c*, supra-ocular invagination to form the "white body"; *d*, the eye; *e*, the mouth; *f*, 1, 2, 3, 4, 5, the five paired processes of the fore-foot; *g*, rhythmically contractile area of the yolk-sac, which is itself a hernia-like protrusion of the median portion of the fore-foot (see fig. 72\*\*); *h*, dotted line showing internal area occupied by yolk (food-material of the egg); *i*, first rudiment of the mid-foot (paired ridges which unite to form the siphon or funnel); *j*, sac of the radula or lingual ribbon; *k*, stomach; *l*, rudiments of the gills (paired ctenidia); *m*, the otocysts,—a pair of invaginations of the surface of the mid-foot; *n*, the optic ganglion; *o*, the distal portion of the ridges which form the siphon or mid-foot, *p* being the basal portion of the same structure; *q*, the vesicle-like rudiment of the intestine formed independently of the parts connected with the mouth, *s*, *k*, *m*, and without invagination; *r*, rudiment of the salivary glands; *t* in (7), the shell-sac at an earlier stage open (see fig. 123), now closed up; *u*, the open shell-sac formed by an uprising ring-like growth of the centro-dorsal area; *w* in (5), the mantle-skirt commencing to be raised up around the area of the shell-sac. In (7) *mes* points to the middle cell-layer of the embryo, *ep* to the outer layer, and *h* to the deep layer of fusiform cells which separates everywhere the embryo from the yolk or food-material lying within it. (Original.)

but that this is in part to be sought in the widely-separated primitive streak. The present writer has little doubt that

a structure corresponding to the primitive streak of the chick, and lying near the klastic pole, will be found in Sepia and Loligo, and the strange vesicular origin of the mid-gut will be traced to and explained by it.

Leaving this difficult question of the cell-layers of the embryo, we would draw the reader's attention to the series of sketches representing the semi-transparent embryo of Loligo, drawn in fig. 121. When the cleavage cells have nearly enclosed the yolk, the upper or embryonic area shows the rudiments of the centro-dorsal mantle-sac or pen-sac, the mouth, the paired optic pits, and the paired

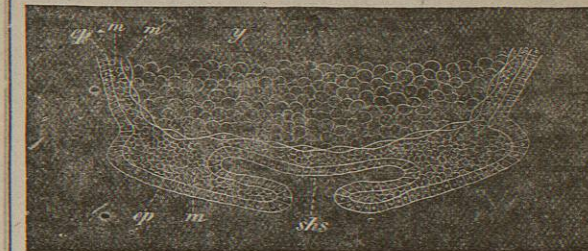


FIG. 122.—Section through the still open shell-sac occupying the centro-dorsal area of an embryo of Loligo; the position is inverted as compared with fig. 121 (3) and (7). *ep*, outer cell-layer; *m*, middle cell-layer; *u*, deep cell-layer of fusiform cells; *y*, the granular yolk or food-material of the egg; *shs*, the still open shell-sac. (From Lankester.)

otic pits (fig. 121, (3), (5)). The eye-pits close up (fig. 119), the orifice of the mantle-sac narrows, and its margin becomes raised and freely produced as mantle-skirt; at the same time an hour-glass-like pinching in of the whole embryo commences, separating the embryo proper from the so-called yolk-sac (fig. 121, (4)). Around the "waist" of constriction, pair by pair, ten lobes arise (fig. 121, (8)),—the arms of the fore-foot. It now becomes obvious that the yolk-sac is but the median surface of the fore-foot bulged out inordinately by food-yolk, just as the hind region of the foot is in the embryo slug (see fig. 72\*\*, and explanation). Just as in the slug, this dilated yolk-holding foot is rhythmically contractile, and pulsates steadily over the area *g* in fig. 121, (4). At this stage, and long subsequently, the mouth of the young Cephalopod is in no way surrounded by the fore-foot, but lies well above its nascent lobes (*e* in fig. 121). Subsequently it sinks, as it were, between the right and left most anterior pair of the series, which grow towards one another and fuse above it, and leave no trace of their original position and relations. Fig. 121, (6) gives a view of the postero-dorsal surface of an embryo, in which the important fact is seen of the formation of the funnel or siphon by the union of two pieces (*g*), which grow up each independently, one right and one left, like the sides of the siphon of Nautilus or the swimming lobes of a Pteropod, and subsequently come together, as shown in (9), where the same letter *g* indicates the same part. The explanations of figs. 121 and 123 are given very full, and here, therefore, we shall only allude to two additional points. A curious mass of tissue of unknown significance occurs in the orbit of Dibranchs, known as the white body (*w* in fig. 120). A strongly-marked invagination just above the orbit is a very prominent feature in the embryo of Loligo, Sepia, and Octopus, and appears to give rise to this so-called white body. This invaginated portion of the outer cell-layer is seen in fig. 121, (8) and (9), lettered *c*; in fig. 123, A and B, it is lettered *wb*.

Lastly, in fig. 123, A, the origin of the optic nerve-ganglion *ng* from the cells of the middle layer should be especially noticed. In some other Molluscs the nerve-ganglia have been definitely traced to the outer cell-layer,

whilst in some Gastropods, according to Bobretzky, they originate, as here shown, for Loligo.

The egg-coverings of the Dibranchiate are very complete. Argonauta and Octopus deposit each egg in a firm oval case, thin and transparent, which has a long stalk by which (in Octopus) the egg is fixed in company with two or three hundred others to some foreign object. Sepia encloses each egg in a thick envelope of many layers resembling india-rubber. Loligo encloses many rows of eggs in a copious tough jelly, and affixes a dozen or twenty such egg-strings to one spot. Sepia and Loligo desert their eggs when laid. The female Octopus most jealously

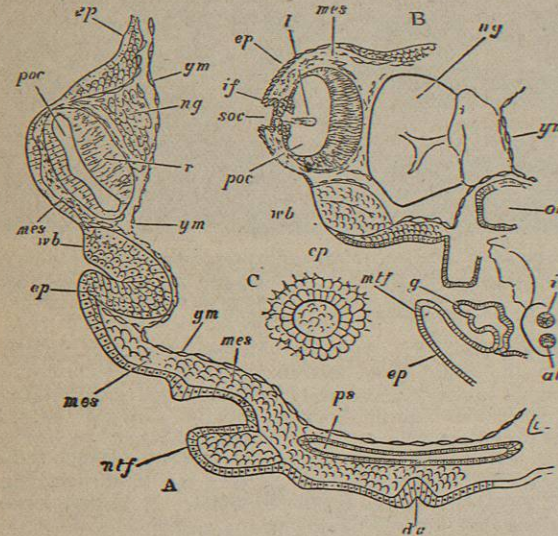


FIG. 123.—Right and left sections through embryos of Loligo. A. Same stage as fig. 121 (4). B. Same stage as fig. 121 (8); only the left side of the sections is drawn, and the food-material which occupies the space internal to the membrane *ym* is omitted. *al*, rectum; *is*, ink-sac; *ep*, outer cell-layer; *mes*, meso-cell-layer; *ym*, deep cell-layer of fusiform cells (yolk-membrane); *ng*, optic nerve-ganglion; *ot*, otcyst; *wb*, the "white body" of the adult ocular capsule forming as an invagination of the outer cell-layer; *mf*, mantle-skirt; *g*, gill; *ps*, pen-sac or shell-sac, now closed; *dg*, dorsal groove; *pos*, primitive optic vesicle, now closed (see fig. 119); *l*, lens; *r*, retina; *soc*, second or anterior optic chamber still open; *if*, iridean folds. C. The primitive invagination to form one of the otcysts, as seen in fig. 121 (5) and (6). (After Lankester.)

guards them, building a nest of stones and incubating. Argonauta carries hers with her in a special brood-holding shell.

The development of the Pteropoda, so far as is known, presents no points of contact with that of the Siphonopoda rather than with that of the Gastropoda, owing to the fact that in them the egg has not an excess of food-yolk. Consequently, we find typical trochosphere and veliger larvæ among the Thecosomata (fig. 8, C, and fig. 81), whilst the isolated observation of Gegenbaur has made known very remarkable larvæ referable to the Gymnosomata, and with little doubt to Pneumodermon (fig. 84). The former set of larvæ are sufficient to demolish once for all the view which has been entertained by some zoologists, viz., that the velar disc of the veliger larva is the same thing as the pteropodial lobes of the mid-foot of Pteropoda. The latter larvæ are of importance in showing that, as in embryo Siphonopods so in embryo Pteropods, the sucker-bearing lobes of the fore-foot are truly podial structures, and only embrace the head and surround the mouth as the result of late embryonic growth.

#### BRANCH B.—LIPOCEPHALA.

**Characters.**—Mollusca with the head region undeveloped. No cephalic eyes are present; the buccal cavity is devoid

of biting, rasping, or prehensile organs. The animal is sessile, or endowed with very feeble locomotive powers. The Lipocephala comprise but one class, the Lamellibranchia, also known as Elatobranchia and Conchifera.

#### Class LAMELLIBRANCHIA

**Characters.**—Lipocephala in which the archaic BILATERAL SYMMETRY of the Mollusca is usually fully retained, and raised to a dominant feature of the organization by the lateral compression of the body and the development of the shell as two bilaterally symmetrical plates or valves covering each one side of the animal. The foot is commonly a simple cylindrical or ploughshare-shaped organ, used for boring in sand and mud, and more rarely presents a crawling disc similar to that of Gastropoda; in some forms it is aborted. The paired CTENIDIA are very greatly developed right and left of the elongated body, and form the most prominent organ of the group. Their function is chiefly not respiratory but nutritive, since it is by the currents produced by their ciliated surface that food-particles are brought to the feebly-developed mouth and buccal cavity.

The Lamellibranchia present as a whole a somewhat uniform structure, so that, although they are very numerous, it is not possible to divide them into well-marked sub-classes or sections, and orders. The chief points in which they vary are—(1) in the structure of the ctenidia or branchial plates; (2) in the presence of one or of two chief muscles, the fibres of which run across the animal's body from one valve of the shell to the other (adductors); (3) in the greater or less elaboration of the posterior portion of the mantle-skirt so as to form a pair of tubes, by one of which water is introduced into the sub-pallial chamber, whilst by the other it is expelled; (4) in the perfect or deficient symmetry of the two valves of the shell and the connected soft parts, as compared with one another; (5) in the development of the foot as a disc-like crawling organ (Arca, Nucula, Pectunculus, Trigonia, Lepton, Galeomma), as a simple plough-like or tongue-shaped organ (Unionacea, &c.), as a re-curved saltatory organ (Cardium, &c.), as a long burrowing cylinder (Solenacea, &c.), or its partial (Mytilacea) or even complete abortion (Ostracea).

The essential Molluscan organs are, with these exceptions, uniformly well developed. The MANTLE-SKIRT is always long, and hides the rest of the animal from view, its dependent margins meeting in the middle line below the ventral surface when the animal is retracted; it is, as it were, slit in the median line before and behind so as to form two flaps, a right and a left; on these the right and the left calcareous valves of the shell are borne respectively, connected by an uncalcified part of the shell called the ligament. In many embryo Lamellibranchs a centro-dorsal PRIMITIVE SHELL-GLAND or follicle has been detected (figs. 8 and 151). The MOUTH lies in the median line anteriorly, the ANUS in the median line posteriorly.

Both CTENIDIA right and left are invariably present, the axis of each taking origin from the side of the body as in the schematic archi-Mollusc (see fig. 1 and fig. 131). A pair of NEPHRIDIA opening right and left, rather far forward on the sides of the body, are always present. Each opens by its internal extremity into the pericardium. A pair of GENITAL APERTURES, connected by genital ducts with the paired gonads, are found right and left near the nephridial pores, except in a few cases where the genital duct joins that of the nephridium (Spondylus). The sexes are often, but not always, distinct. No accessory glands or copulatory organs are ever present in Lamellibranchs. The ctenidia often act as brood-pouches.

A dorsal contractile HEART, with symmetrical right and left auricles (fig. 143, A) receiving aerated blood from the ctenidia and mantle-skirt, is present, being unequally de-

veloped only in those few forms which are inequivalve. The typical PERICARDIUM is well developed. It appears, as in other Mollusca, not to be a blood-space although developed from the coelom, and it communicates with the exterior by the pair of nephridia. As in Cephalopoda (and possibly other Mollusca) water can be introduced through the nephridia into this space. The ALIMENTARY CANAL keeps very nearly to the median vertical plane whilst exhibiting a number of flexures and loopings in this plane. A pair of large glandular outgrowths, the so-called "liver" or great digestive gland, exists as in other Mollusca. A pair of pedal OTOCYSTS, and a pair of OSFRADIA at the base of the gills, appear to be always present. A typical NERVOUS SYSTEM is present (fig. 144), consisting of a cerebro-pleuro-visceral ganglion-pair, united by connectives to a pedal ganglion-pair and an osphradial ganglion-pair (parieto-splanchnic).

A special cæcum connected with the pharynx is sometimes found, containing a tough flexible cylinder of transparent cartilaginous appearance and unknown significance, called the "crystalline style" (Mactra), which possibly represents the radular sac of Glossophora. In many Lamellibranchs a gland is found on the hinder surface of the foot in the mid line, which secretes a substance which sets into the form of threads—the so-called "byssus"—by means of which the animal can fix itself. Sometimes this gland is found in the young and not in the adult (Anodon, Unio, Cyclas). In some Lamellibranchs (Pecten, Spondylus, Pholas, Mactra, Tellina, Pectunculus, Galeomma, &c.), although cephalic eyes are always absent, special eyes are developed on the free margin of the mantle-skirt, apparently by the modification of tentacles which are commonly found there (fig. 145). The existence of pores in the foot and elsewhere in Lamellibranchia by which liquid can pass into and out of the vascular system, although asserted as in the case of other Mollusca, appears to be improbable. It has yet to be shown by satisfactory microscopic sections that the supposed pores are anything but epidermal glands.

The Lamellibranchia live chiefly in the sea, some in fresh waters. A very few have the power of swimming by opening and shutting the valves of the shell (Pecten, Lima); most can slowly crawl or rapidly burrow, others are, when adult, permanently fixed to stones or rocks—either by the shell or the byssus. In development some Lamellibranchia pass through a free-swimming trochosphere stage with pre-oral ciliated band; other fresh-water forms which carry the young in brood-pouches formed by the ctenidia have suppressed this larval phase.

The following classification and enumeration of genera are based primarily upon the characters of the adductor muscles. The Heteromya and Monomya must be conceived of as derived from forms resembling such Gastropodous Isomya as Nucula and Trigonia, which undoubtedly are the nearest living representatives of the ancestral Lipocephala, and bring us nearest to the other branch of the Mollusca, the Glossophora.

#### Order 1.—Isomya.

**Character.**—Anterior and posterior adductor muscles of approximately equal size.

##### Sub-order 1.—Integripallia.

**Characters.**—Marginal attachment of the mantle to the shell not inflected to form a sinus; siphons not developed in some, present in most.

##### Family 1.—Arcaacea.

Genera: *Arca*, L. (fig. 139); *Cucullaea*, Lam.; *Pectunculus*, Lam.; *Limopsis*, Sassi; *Nucula*, Lam. (fig. 134); *Isoarca*, Münster; *Leda*, Schu.; *Yoldia*, Möll.; *Solenella*, Sowerby, &c.

##### Family 2.—Trigoniacea.

Genera: *Trigonia*, Brug.; *Azinius*, Sow.; *Lyrodosma*, Conrad.

##### Family 3.—Unionacea.

Genera: *Unio*, Retz.; *Castalia*, Lam.; *Anodon*, Cuv. (figs. 124 &c.); *Iridina*, Lam.; *Mycetopus*, d'Orb., &c.

##### Family 4.—Lucinacea.

Genera: *Lucina*, Brug.; *Corbis*, Cuv.; *Diplodonta*, Brown; *Kellia*, Turton; *Montacuta*, Turton; *Lepton*, Turton; *Galeomma*, Turton; *Astarte*, Sow.; *Crassatella*, Lam.; *Cardinia*, Ag.; *Cardita*, Brug., &c.

##### Family 5.—Cyprinaea.

Genera: *Tridacna*, Da C.; *Chama*, L.; *Dimya*, Ron.; *Diceras*, Lk.; *Isocardia*, Lam.; *Hippopodium*, Sow.; *Cardium*, L.; *Corbicula*, Meg.; *Cyrena*, Lk.; *Cyclas*, Brug. (fig. 146); *Pistidium*, Pir. (figs. 148-153); *Cyprina*, Lam., &c.

##### Sub-order 2.—Sinupallia.

**Characters.**—Marginal attachment of the mantle to the shell inflected so as to form a sinus into which the pallial siphons can be withdrawn: siphons always present, and large.

##### Family 6.—Veneracea.

Genera: *Cypricardia*, Lam.; *Tapes*, Megl.; *Cyclina*, Desn.; *Cytherea*, Lam. (figs. 125, &c.); *Chione*, Megl.; *Venus*, L.; *Lucinopsis*, F. H.; *Sanguinolaria*, Lam.; *Psammobia*, Lam. (fig. 130); *Tellina*, L.; *Donax*, L.; *Scrobicularia*, Schu.; *Cumingia*, Sow.; *Rangia*, Dsmk.; *Mactra*, L. (fig. 140); *Trigonia*, Da C.; *Vaganella*, Gr.; *Lutraria*, Lam.

##### Family 7.—Myacea.

Genera: *Myochamus*, Stb.; *Chamostrea*, Rois; *Pandora*, Sol.; *Thracia*, Leach; *Thetis*, Sow.; *Pholadomya*, Sow.; *Corbula*, Brug.; *Mya*, Lam.; *Saxicava*, Fleur.; *Panopaea*, Ad.; *Glycymeris*, Lam.; *Siliqua*, Mhlf., &c.; *Solen*, L.

##### Family 8.—Pholadacea.

Genera: *Clavagella*, Lam.; *Aspergillum*, Lam. (figs. 128, 129); *Humphreysia*, Gr.; *Pholas*, L.; *Pholadidea*, Turton; *Teredo*, L.; *Teredina*, Lam.; *Furcella*, Oken, &c.

##### Order 2.—Heteromya.

**Characters.**—Anterior adductor (pallial adductor) much smaller than the posterior adductor (pedal adductor); siphons rarely present.

##### Family 1.—Mytilacea.

Genera: *Mytilus*, L. (fig. 133); *Modiola*, Lam.; *Crenella*, Brown; *Lithodomus*, Cuv.; *Dreissena*, Ben. (fig. 136); *Modiolarca*, Gr., &c.

##### Family 2.—Mulleriacea.

Genera: *Aetheria*, Lam.; *Mulleria*, Fér.

##### Order 3.—Monomya.

**Characters.**—Anterior adductor absent in the adult; siphons never developed.

##### Family 1.—Aviculacea.

Genera: *Cardiola*, Brdp.; *Avicula*, Kl.; *Malleus*, Lam.; *Inoceramus*, Sow.; *Crenatula*, Lam.; *Perna*, Brug., &c.

##### Family 2.—Ostracea.

Genera: *Ostrea*, L. (fig. 6); *Anomia*, L.; *Spondylus*, L.; *Plicatula*, Lam.; *Vulsella*, Lam.; *Lima*, Brug.; *Pecten*, L.; *Huimites*, Dfr., &c.

**Further Remarks on the Lamellibranchia.**—The Lamellibranchia are the only members of the Lipocephalous branch of Mollusca existing at the present day; and we must suppose that, whilst on the one hand the earliest Glossophorous forms were developing from the archi-Mollusca by the elaboration of the buccal apparatus, the bivalved sessile Lamellibranchs were developing in another direction from univalve cephalophorous ancestors. The large bilobed mantle-flap with its pair of shells covering in the whole animal, the current-producing largely-expanded ctenidia, and the reduced cephalic region are characters which go hand in hand, and were simultaneously acquired, each being related to the development of the other. Unless the "crystalline style" of Lamellibranchs is to be considered as the rudiment of the "radular sac" of Glossophora, as suggested by Balfour, there is no indication whatever that the ancestors of the Lamellibranchia had acquired a representative of the buccal apparatus—so highly developed in Glossophora—before diverging from the archi-Mollusca; that is to say, the common ancestors of the two great branches of Mollusca presented the distinctive character of neither branch—they had not an aborted cephalic region, and they had not a lingual ribbon.

As an example of the organization of a Lamellibranch, we shall review the structure of the Common Pond-Mussel (*Anodonta cygnea*), comparing its structure with those of