mately the following history. By division of the egg-cell (fig. 3, A, B; fig. 4, A, B; and fig. 5) a mulberry-mass of embryonic-cells is formed (Morula), which dilates, forming a one-cell-layered sac (Blastula). By invagination one

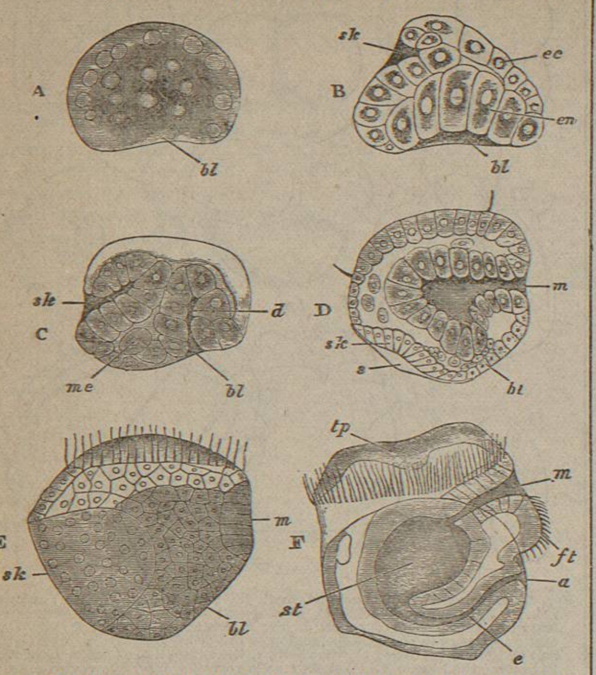

FIG. 6.—Development of the Oyster, *Ostrea edulis* (modified from Horst, 16). A. Blastula stage (one-cell-layered sac), with commencing invagination of the wall of the sac at *bl*, the blastopore. B. Optical section of a somewhat later stage, in which a second invagination has commenced—namely, that of the shell-gland *sk*; *bl*, blastopore; *en*, invaginated endoderm (wall of the future arch-enteron); *ec*, ectoderm. C. Similar optical section at a little later stage. The invagination connected with the blastopore is now more contracted, *d*; and cells, *me*, forming the mesoblast from which the cœlom and muscular and skeleto-trophic tissues develop, are separated. D. Similar section of a later stage. The blastopore, *bl*, has closed; the anus will subsequently perforate the corresponding area. A new aperture, *m*, the mouth, has eaten its way into the invaginated endodermal sac, and the cells pushed in with it constitute the stomodæum. The shell-gland, *sk*, is flattened out, and a delicate shell, *s*, appears on its surface. The ciliated velar ring is cut in the section, as shown by the two projecting cilia on the upper part of the figure. The embryo is now a Trochosphere. E. Surface view of an embryo at a period almost identical with that of D. F. Later embryo seen as a transparent object. *m*, mouth; *ft*, foot; *a*, anus; *e*, intestine; *st*, stomach; *tp*, velar area of the prostomium. The extent of the shell and commencing upgrowth of the mantle-skirt is indicated by a line forming a curve from *a* to F.

N.B.—In this development, as in that of Pisidium (figs. 150, 151), no part of the blastopore persists either as mouth or as anus, but the aperture closes,—the pedicle of invagination, or narrow neck of the invaginated arch-enteron, becoming the intestine. The mouth and the anus are formed as independent in-pushings, the mouth with stomodæum first, and the short anal proctodæum much later. This interpretation of the appearances is contrary to that of Horst (16), from whom our drawings of the oyster's development are taken. The account given by the American naturalist Brooks (19) differs greatly as to matter of fact from that of Horst, and appears to be erroneous in some respects.

portion of this sphere becomes tucked into the other—as in the preparation of a woven night-cap for the head (fig. 6, B; fig. 7, A). The orifice of invagination (blastopore) narrows, and we now have a two-cell-layered sac,—the Diblastula. The invaginated layer is the enteric cell-layer or endoderm; the outer cell-layer is the deric cell-layer or ectoderm. The cavity communicating with the blastopore and lined by the endoderm is the arch-enteron. The blastopore, together with the whole embryo, now elongates. The blastopore then closes along the middle portion of its extent, which corresponds with the later developed foot. At the same time the stomodæum or oral invagination forms around the anterior remnant of the blastopore, and the proctodæum or anal invagination forms around the posterior remnant of the blastopore There are, however, variations in regard to the relation of the blastopore to the mouth and to the anus which are probably modifications of the original process described above. An examination of figs. 3, 4, 5, 6, 7, and of others illustrative of the embryology of particular forms which occur later in this article, is now recommended to the reader. The explanation of the figures has been made very full so as to avoid the

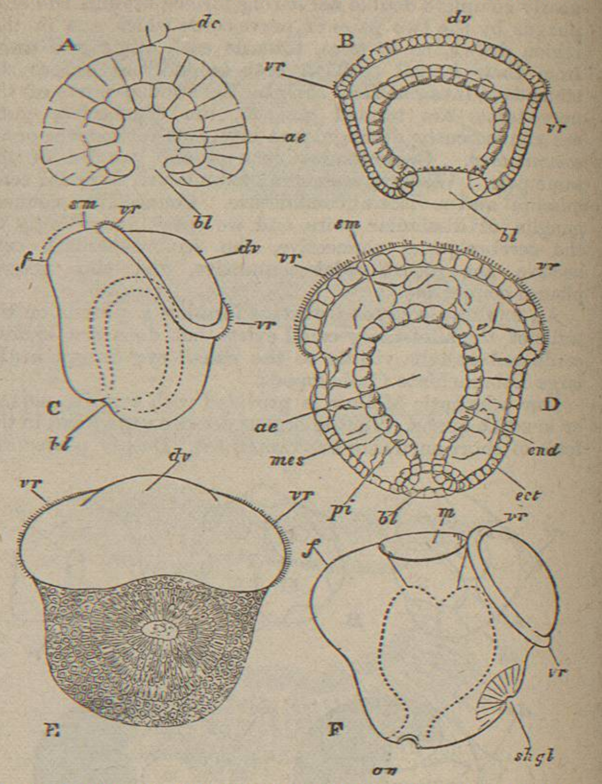

FIG. 7.—Development of the River-Snail, *Paludina vivipara* (after Lankester, 17). *dc*, directive corpuscle (outcast cell); *ae*, arch-enteron or cavity lined by the enteric cell-layer or endoderm; *bl*, blastopore; *vr*, velum or circlet of ciliated cells; *dv*, velar area or cephalic dome; *sm*, site of the as yet unformed mouth; *f*, foot; *mes*, rudiments of the skeleto-trophic tissues; *pi*, the pedicle of invagination, the future rectum; *shgl*, the primitive shell-sac or shell-gland; *m*, mouth; *an*, anus. A. Diblastula phase (optical section). B. The Diblastula has become a Trochosphere by the development of the ciliated ring *vr* (optical section). C. Side view of the Trochosphere with commencing formation of the foot. D. Further advanced Trochosphere (optical section). E. The Trochosphere passing to the Veliger stage, dorsal view showing the formation of the primitive shell-sac. F. Side view of the same, showing foot, shell-sac (*shgl*), velum (*vr*), mouth, and anus.

N.B.—In this development the blastopore is not elongated; it persists as the anus. The mouth and stomodæum form independently of the blastopore.

necessity of special descriptions in the text. Internally, by the nipping off of a pair of lateral outgrowths (forming part of the indefinable "mesoblast") from the enteric cell-layer the foundations of the cœlomic cavity are laid. In some Cœlomata these outgrowths are hollow and of large size. In Mollusca they are not hollow and large, which is probably the archaic condition, but they consist at first of a few cells only, adherent to one another; these cells then diverge, applying themselves to the body-wall and to the gut-wall so as to form the lining layer of the cœlomic cavity. Muscular tissue develops from deep-lying cells, and the rudiments of the paired nerve-tracts from thickenings of the deric-cell layer or ectoderm.

The external form meanwhile passes through highly characteristic changes, which are on the whole fairly constant throughout the Mollusca. A circlet of cilia forms when the embryo is still nearly spherical (fig. 4, F; fig. 6, E; fig. 7,

B), in an equatorial position. As growth proceeds, one hemisphere remains relatively small, the other elongates and enlarges. Both mouth and anus are placed in the larger area; the smaller area is the prostomium simply; the ciliated band is therefore in front of the mouth. The larval form thus produced is known as the Trochosphere. It exactly agrees with the larval form of many Chætopod worms and other Cœlomata. Most remarkable is its agreement with the adult form of the Wheel animalcules or Rotifera, which retain the præ-oral ciliated band as their chief organ of locomotion and prehension throughout life. So far the young Mollusc has not reached a definitely Molluscan stage of development, being only in a condition common to it and other Cœlomata. It now passes to the veliger phase, a definitely Molluscan form, in which the disproportion between the area in front of the ciliated circlet and that behind it is very greatly increased, so that the former is now simply an emarginated region of the head fringed with cilia (fig. 8; fig. 6, F; fig. 7, F; and fig. 60, A). It is termed the "velum," and is frequently drawn out into lobes and processes. As in the Rotifera, it serves the veliger larva as an organ of loco-

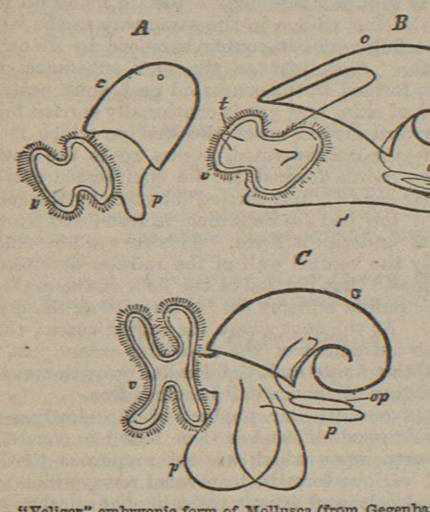

FIG. 8.—"Veliger" embryonic form of Mollusca (from Gegenbaur). *v*, velum; *c*, visceral dome with dependent mantle-skirt; *p*, foot; *t*, cephalic tentacles; *op*, operculum. A. Earlier, and B, later, Veliger of a Gastropod. C. Veliger of a Pteropod showing lobe-like processes of the velum and the great paired outgrowths of the foot.

motion. In a very few Molluscs, but notably in the Common Pond-Snail, the emarginated bilobed velum is retained in full proportions in adult life (fig. 70), having lost its marginal fringe of specially long cilia and its locomotor function. The body of the Veliger is characterized by the development of the visceral hump on one surface, and by that of the foot on the other. Growth is greater in the vertical dorso-ventral axis than in the longitudinal oro-anal axis; consequently the foot is relatively small and projects as a blunt process between mouth and anus, which are not widely distant from one another, whilst the antipedal area projects in the form of a great hump or dome. In the centre of this antipedal area there has appeared (often at a very early period) a gland-like depression or follicle of the integument (fig. 6, C, *sk*; fig. 7, E, F, *shgl*; fig. 60, B; fig. 68, *shs*; fig. 72***, *ss*). This is the primitive shell-sac discovered by Lankester (18) in 1871, and shown by him to precede the development of the permanent shell in a variety of Molluscan types. The cavity of this small sac becomes filled by a horny substance, and then it very usually disappears, whilst a delicate shell, commencing from this spot as a centre, forms and spreads upon the surface of the visceral dome.

The embryonic shell-sac or shell-gland represents in a transient form, in the individual development of most Mollusca, that condition of the shell-forming area which we have sketched above in the schematic Mollusc. In very few instances (in Chiton, and probably in Limax), as we shall see below, the *primitive shell-sac* is retained and enlarged as the permanent shell-forming area. It is supplanted in other Molluscs by a *secondary shell-forming area*, namely, that afforded by the free surface of the visceral hump, the shell-forming activity of which extends even to the surface of the depending mantle-skirt. Accordingly, in most Mollusca the *primitive shell* is represented only by the horny plug of the primitive shell-sac. The permanent shell is a new formation on a new area, and should be distinguished as a *secondary shell*.

The ctenidia, it will be observed, have not yet been mentioned, and they are indeed the last of the characteristic Molluscan organs to make their appearance. Their possible relation to the præ-oral and post-oral ciliated bands of embryos similar to the Trochosphere will be discussed in the final section of this article dealing with the Polyzoa and Brachiopoda. The Veliger, as soon as its shell begins to assume definite shape, is no longer of a form common to various classes of Mollusca, but acquires characters peculiar to its class. At this point, therefore, we shall for the present leave it.

SYSTEMATIC REVIEW OF THE CLASSES AND ORDERS OF MOLLUSCA.

We are now in a position to pass systematically in review the various groups of Mollusca, showing in what way they conform to the organization of our schematic Mollusc, and in what special ways they have modified or even suppressed parts present in it, or phases in the representative embryonic history which has just been sketched. It will be found that the foot, the shell, the mantle-skirt, and the ctenidia, undergo the most remarkable changes of form and proportionate development in the various classes —changes which are correlated with extreme changes and elaboration in the respective functions of those parts.

Division of the Phylum into two Branches.—The Mollusca are sharply divided into two great lines of descent or branches, according as the prostomial region is atrophied on the one hand, or largely developed on the other.

The probabilities are in favour of any ancestral form—the hypothetical archi-Mollusc which connected the Mollusca with their non-Molluscan forefathers—having possessed, as do all the more primitive forms of Cœlomata, a well-marked prostomium, and consequently a head. The one series of Mollusca descended from the primitive head-bearing Molluscs have acquired an organization in which the Molluscan characteristics have become modified in definite relation to a sessile inactive life. As the most prominent result of the adaptation to such sessile life they exhibit an atrophy of the cephalic region. They form the branch LIPOCEPHALA—the mussels, oysters, cockles, and clams. The other series have retained an active, in many cases a highly aggressive, mode of life; they have, correspondingly, not only retained a well-developed head, but have developed a special aggressive organ in connexion with the mouth, which, on account of its remarkable nature and the peculiarities of the details of its mechanism, serves to indicate a very close genetic connexion between all such animals as possess it. This remarkable organ is the odontophore, consisting of a lingual ribbon, rasp, or radula, with its cushion and muscles. On account of the possession of this organ this great branch of the Molluscan phylum may be best designated GLOSSOPHORA. Any term which merely points to the possession of a head is objectenable, since this is common to them and the hypothetical archi-Mollusca from which they descend. The term Odontophora, which has been applied to them, is also unsuitable, since the organ which characterizes them is not a tooth, but a tongue.

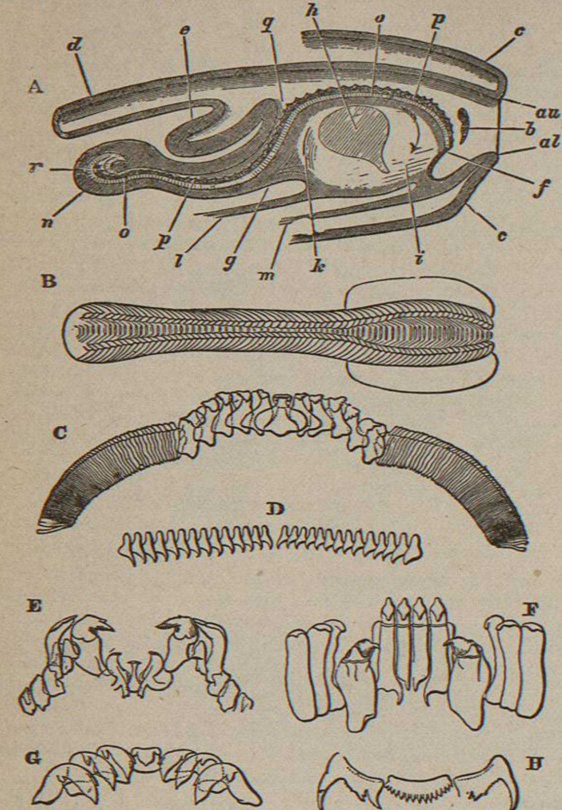

FIG. 9.—Odontophore of Glossophorous Mollusca.

A. Diagram showing mouth, œsophagus, and lingual apparatus of a Gastropod in section. *au*, upper lip; *al*, lower lip; *b*, calcareo-corneous jaw of left side; *c*, outer surface of the snout; *d*, œsophagus; *e*, fold in the wall of the œsophagus behind the radular sac (*n*); *f*, anterior termination of the radula and its bed, the point at which it wears away; *g*, base of the radular sac or recess of the pharynx; *h*, cartilaginous piece developed in the floor of the pharynx beneath the radula, and serving for the attachment of numerous muscles, and for the support of the radula; *i*, anterior muscles; *k*, posterior muscles attached to the cartilage; *l*, muscle acting as a retractor of the buccal mass; *m*, muscle attached to the lower lip; *n*, posterior extremity of the radular sac; *o*, the bed of the radula or layer of cells by which its lower surface is formed; *p*, the horny radula or lingual ribbon; *q*, opening of the radular sac into the pharynx or buccal cavity; *r*, cells at the extreme end of the inner surface of the radular sac which produce as a "cuticular secretion" the rows of teeth of the upper surface of the radula.
B. Radula or lingual ribbon of *Paludina vivipara*, stripped from its bed,—a horny, cuticular product.
C. A single row of teeth from the radula of *Trochus cinerarius*. Rhipidoglossate; formula, x.5.1.5.x.
D. A single row of teeth from the radula of *Faultima fragilis*. Ptenoglossate; formula, x.0.x.
E. A single row of teeth from the radula of *Chiton cinereus*. Too elaborate for formulation.
F. A single row of teeth from the radula of *Patlla vulgata*. Formula, 3.1.4.1.3.
G. A single row of teeth from the radula of *Cypræa helvola*. Tænioglossate, formula, 3.1.3.
H. A single row of teeth from the radula of *Nassa annulata*. Rachiglossate; formula, 1.1.1. The Common Whelk is similar to this.

The general structure of the odontophore (=tooth-bearer, in allusion to the rasp-like ribbon) of the glossophorous Mollusca may be conveniently described at once. Essentially it is a tube-like outgrowth—the *radular sac* (fig. 9, A, *g*, *n*)—in the median line of the ventral floor of the stomodæum, upon the inner surface of which is formed a chitinous band (the radula) beset with minute teeth like a rasp (*p*). Anteriorly the ventral wall of the diverticulum is converted into cartilage (*h*), to which protractor and retractor muscles are attached (*k*, *i*), so that by the action of the former the cartilage, with the anterior end of the ribbon resting firmly upon it, may be brought forward into the space between the lips of the oral aperture (*au*, *al*), and made to exert there a backward and forward rasping action by the alternate contraction of retractor and protractor muscles attached to the cartilage. But in many Glossophora (*e.g.*, the Whelk) the apparatus is complicated by the fact that the diverticulum itself, with its contained radula, rests but loosely on the cartilage, and has special muscles attached to each end of it, arising from the body wall; these muscles pull the whole diverticulum or radular sac alternately backwards and forwards over the surface of the cartilage. This action, which is quite distinct from the movement of the cartilage itself, may be witnessed in a Whelk if the pharynx be opened whilst it is alive. It has also been seen in living transparent Gastropods. The chitinous ribbon is continuously growing forward from the tube-like diverticulum as a finger-nail does on its bed, and thus the wearing away of the part which rests on the cartilage and is brought into active use, is made up for by the advance of the ribbon in the same way as the wearing down of the finger-nail is counterbalanced by its own forward growth. And, just as the new substance of the finger-nail is formed in the concealed part, sunk posteriorly below a fold of skin, and yet is continually carried forward with the forward movement of the bed on which it rests, and which forms its undermost layers, so is the new substance of the radula formed in the compressed extremity of the radular sac (*n*), and carried forward by the forward movement of the bed (*o*) on which it rests, and by which is formed its undermost layer. This forward-moving bed is not merely the ventral wall of the radular diverticulum, but includes also that portion of the floor of the oral cavity to which the radula adheres (as far forward as the point *f* in fig. 9, A). At the spot where the radula ceases, the forward growth-movement of the floor also ceases, just as in the case of the finger-nail the similar growth-movement ceases at the line where the nail becomes free.

The radula or cuticular product of the slowly-moving bed can be stripped off, and is then found to consist of a ribbon-like area, upon which are set numerous tooth-like processes of various form in transverse rows, which follow one another closely, and exactly resemble one another in the form of their teeth (fig. 9, B). The tooth-like processes in a single transverse row are of very different shape and number in different members of the Glossophora, and it is possible to use a formula for their description. Thus, when in each row there is a single median tooth with three teeth on each side of it more or less closely resembling one another, as in fig. 9, G, we write the formula 3.1.3. When there are additional lateral pieces of a different shape to those immediately adjoining the central tooth, we indicate them by the figure 0, repeated to represent their number, thus 0000.1.1.1.0000 is the formula for the lingual teeth of *Chiton Stelleri*. A single median tooth, an admedian series, and a lateral series may be thus distinguished. In some Glossophora only median teeth are present, or large median teeth with a single small admedian tooth on each side of it (fig. 9, H); these are termed Rachiglossa (formula, —.1.— or 1.1.1). In a large number of Glossophora we have three admedian on each side and one median, no lateral pieces (fig. 9, G); these are termed Tænioglossa (formula, 3.1.3). Those with numerous lateral pieces, four to six or more admedian pieces, and a median piece or tooth (fig. 9, C) are termed Rhipidoglossa (formula, x.6.1.6.x, where x stands for an indefinite number of lateral pieces). The Toxoglossa have

1.0.1, the central tooth being absent and the lateral teeth peculiarly long and connected with muscles. The term Ptenoglossa (fig. 9, D) is applied to those Glossophora in which the radula presents no median tooth, but an indefinite and large number of admedian teeth, giving the formula x.0.x. When the admedian teeth are indefinite (forty to fifty), and a median tooth is present, the term Myriaglossa is applied (formula, x.1.x). It must be understood that the pieces or teeth thus formulated may themselves vary much in form, being either flat plates, or denticulated, hooked, or spine-like bodies. We shall revert to the terms thus explained in the systematic descriptions of the groups of Glossophora.

The muscular development in connexion with the whole buccal mass, and with each part of the radular apparatus, is exceedingly complicated,—as many as twenty distinct muscles having been enumerated in connexion with this organ. In addition to the radula, and correlated with its development, we find almost universally present in the Glossophora a pair of horny jaws (usually calcified) developed as cuticular productions upon the epidermis of the lips (fig. 9, A, *b*). The radula and the shelly jaws of the Glossophora enable their possessors not only to voraciously attack vegetable food, but the radula is used in some instances for boring the shells of other Mollusca, and the jaws for crushing the shells of Crustacea, and for wounding even Vertebrata.

PHYLUM MOLLUSCA.

BRANCH A.—*GLOSSOPHORA.*

Characters.—Mollusca with head-region more or less prominently developed; always provided with a peculiar rasping-tongue—the odontophore—rising from the floor of the buccal cavity.

The Glossophora comprise three classes, chiefly distinguished from one another by the modifications of the foot.

Class I.—**GASTROPODA.**

Characters.—Glossophora in which (with special exception of swimming forms) the FOOT is simple, median in position, and flattened so as to form a broad sole-like surface, by the contractions of which the animal crawls, often divided into three successive regions—the pro-, meso-, and meta-podium—by lateral constrictions.

The Gastropoda exhibit two divergent lines of descent indicated by the term sub-class (see p. 649).

Sub-class 1.—GASTROPODA ISOPLEURA.

Characters.—Gastropoda in which not only the head and foot but also the visceral dome with its contents and the mantle retain the primitive BILATERAL SYMMETRY of the archi-Mollusc. The anus retains its position in the median line at the posterior end of the body. The whole visceral mass together with the foot is elongated, so that the axis joining mouth and anus is relatively long, whilst the dorso-pedal axis at right angles to it is short. The CTENIDIA, the NEPHRIDIA, GENITAL DUCTS, and CIRCULATORY ORGANS are paired and bilaterally symmetrical. The pedal and visceral NERVE-CORDS are straight, parallel with one another, and all extend the whole length of the body; the ganglionic enlargements are feebly or not at all developed. The Isopleura comprise three orders.

Order 1.—**Polyplacophora (the Chitons).**

Characters.—Gastropoda Isopleura with a metameric repetition of the shell to the number of eight. The shells of the primitive type are partially or wholly concealed in shell-sacs comparable to the single embryonic shell-sac of other Mollusca. On the surface of the mantle-flap numerous calcified spines and knobs are frequently developed. The ctenidia are of the typical form, small in size and metamerically repeated along the sides of the body to the

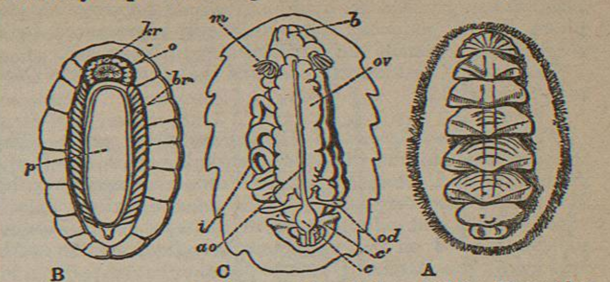

FIG. 10.—Three views of Chiton. A. Dorsal view of *Chiton Wosnessenksii*, Midd., showing the eight shells (After Middendorf.) B. View from the pedal surface of a species of Chiton from the Indian Ocean. *p*, foot; *o*, mouth (at the other end of the foot is seen the anus raised on a papilla); *kr*, oral fringe; *br*, the numerous ctenidia (branchial plumes); spreading beyond these, and all round the animal, is the mantle-skirt. (After Cuvier.) C. The same species of Chiton, with the shells removed and the dorsal integument reflected. *b*, buccal mass; *m*, retractor muscles of the buccal mass; *ov*, ovary; *od*, oviduct; *i*, coils of intestines; *ao*, aorta; *c'*, left auricle; *c*, ventricle.

number of sixteen or more; an osphradium or area of "olfactory epithelium" (Spengel) is found at the base of each ctenidium. The other organs are not subject to metameric repetition. The odontophore is highly developed; the teeth of the lingual ribbon are varied in form,—several in each transverse row (fig. 9, E). Paired genital ducts distinct from the paired nephridia are present.

The order Polyplacophora contains but one family, the *Chitonidæ*, with the genera: *Chiton*, Lin. (figs. 10, 15, &c.); *Cryptochiton*, Midd., 1847; and *Cryptoplax* (=*Chitonellus*), Blainv., 1818.

Order 2.—**Neomeniæ.**

Characters.—Gastropoda Isopleura devoid of a shell, which is replaced by innumerable microscopic calcified plates or spicules set in the dorsal epidermis; mantle-flap not lateral, but reduced to a small collar surrounding the

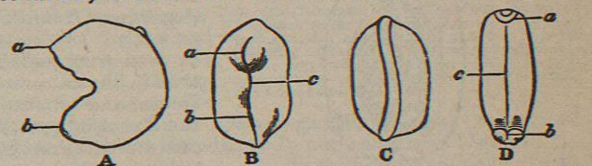

FIG. 11.—*Neomenia carinata*, Tullberg (after Tullberg). A. Lateral view. B. Ventral view. C. Dorsal view. D. Ventral view of a more extended specimen. *a*, anterior; *b*, posterior extremity; *c*, furrow, in which the narrow foot is concealed.

anus; ctenidia represented by a symmetrical group of branchial filaments on either side of the anus; foot very narrow, sunk in a groove; odontophore feebly developed, but the radula many-toothed: gonads placed in the pericardium discharging by the nephridia; no special generative ducts.

The order Neomeniæ contains the two genera *Neomenia*, Tullberg (*Solenopus*, *Sars*) (fig. 11); and *Proneomenia*, Hubrecht.

Order 3.—**Chætoderma.**

Characters.—Gastropoda Isopleura devoid of a shell, which is replaced by numerous minute calcareous spines

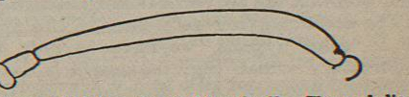

FIG. 12.—*Chætoderma nitidulum*, Loven (after Graff). The cephalic enlargement is to the left, the anal chamber (reduced pallial chamber, containing the concealed pair of ctenidia) to the right.

standing up like hairs on the surface of the body; body much elongated so as to be vermiform; mantle-flap as in Neomeniæ; ctenidia in the form of a pair of branchial plumes, one on each side of the anus; foot aborted, its position being indicated by a longitudinal furrow; odontophore greatly reduced, the radula only represented by a single tooth; gonads and nephridia as in Neomenia.

The order Chætoderma contains the single genus *Chætoderma* (fig. 12).

Further remarks on the Isopleurous Gastropods.—The union of the Chitons with the remarkable worm-like forms Neomenia and Chætoderma was rendered necessary by Hubrecht's discovery (25) in 1881 of a definitely constituted radula and odontophore in his new genus Proneomenia, founded on two specimens brought from the arctic regions by the Barents Dutch expedition.

By some writers—*e.g.*, Keferstein—the Chitons have been too intimately associated with the other Gastropoda, whilst, on the other hand, Gegenbaur seems to have gone a great deal too far in separating them altogether from the other Mollusca as a primary subdivision of that phylum, inasmuch as they are intimately bound to the other Glossophora by the possession of a thoroughly typical and well-developed odontophore. They undoubtedly stand nearer to the archi-Mollusca than any other Glossophora in having retained a complete bilateral symmetry and the primitive shell-sac, though the metameric repetition of this organ and of the ctenidia is a complication of, and departure from, the primitive character. It is not improbable that in the calcareous spines and plates of the dorsal integument of Neomenia and Chætoderma, which occur also on the part of the dorsum uncovered by shell in Chiton, we have the retention of a condition preceding the development of the solid Molluscan shell, or a reversion to it. The minute calcareous bodies may have the same relation to a compact shell which the shagreen denticles of the sharks have to a continuous dermal bone.

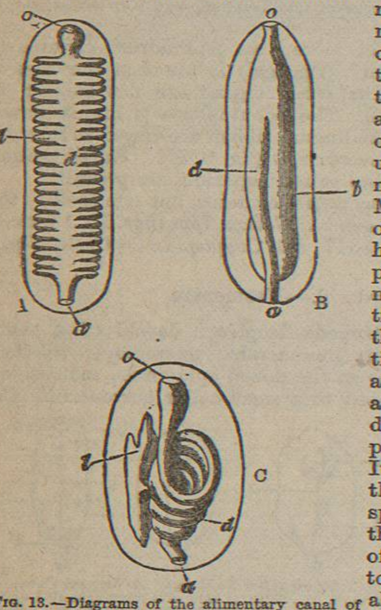

FIG. 13.—Diagrams of the alimentary canal of Isopleura (from Hubrecht). *o*, mouth; *a*, anus; *d*, alimentary canal; *l*, liver (digestive gland). A. Neomenia and Proneomenia. B. Chætoderma. C. Chiton.

The anatomy of the Gastropoda Isopleura has been largely elucidated within the past year by the researches of Hubrecht and of Sedgwick, who have been the first to apply the method of sections to the study of this group.

The leading points in the modifications of mantle-flap, foot, and ctenidia are set forth in the preceding summaries, and in the accompanying references to the figures. With regard to other organs, we have to note the form of the alimentary canal (fig. 13), which is simplest in Chætoderma, symmetrically sacculated in Neomenia, and wound upon itself, forming a few coils, in Chiton. The latter has a compact liver with arborescent duct, which is represented by the sacculi in Neomenia and by a single cæcum in Chætoderma. Salivary glands are present in Chiton and in Proneomenia. The radula is highly developed in Chiton, and, though present in Proneomenia, has not been described in Neomenia. A single tooth in Chætoderma appears to represent the radula in a reduced state. The circulatory organs of Chiton alone are known with any degree of detail (fig. 10, C). There is a median dorsal blood-vessel—the aorta—which is enlarged to form a ventricle in the posterior region of the body. On either side the ventricle is connected to a well-developed auricle, which pours into it the aerated blood from the gills (ctenidia). The extent to which vascular trunks are developed has not been determined, but vessels to and from the ctenidia, and in the mid-line of the foot, are known. As in other Mollusca, the vessels do not extend far, but lead into lacunæ between the organs and tissues. Dorsal and ventral vessels have been detected in Neomenia and Chætoderma, but no specialized heart.

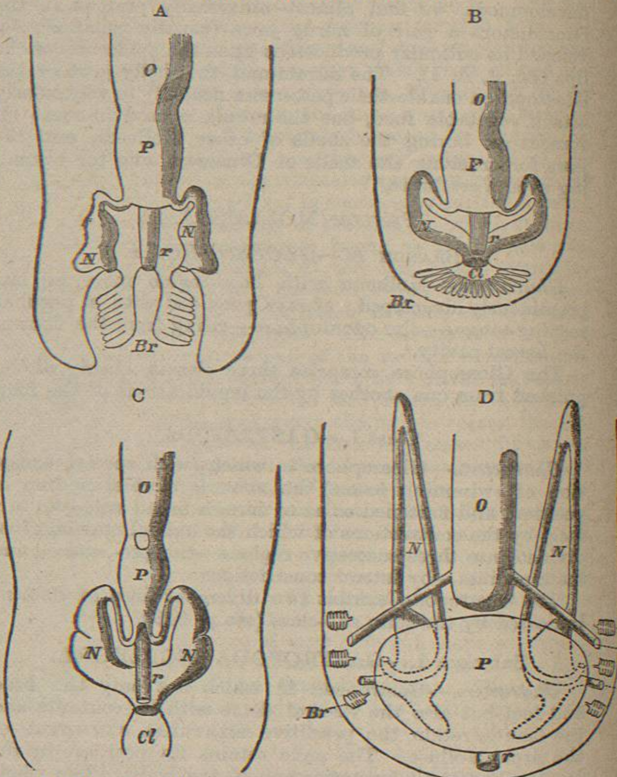

FIG. 14.—Diagrams of the excretory and reproductive organs of Isopleura (after Hubrecht). *O*, ovary; *P*, pericardium; *N*, nephridium; *u*, external aperture of nephridium; *g*, external aperture of the genital duct of Chiton; *r*, rectum; *Cl*, cloacal or pallial chamber of Neomeniæ and Chætoderma; *Br*, ctenidia (branchial plumes). A. Chætoderma. B. Neomenia. C. Proneomenia. D. Chiton.

The heart of Chiton lies in a space which is to be regarded as a specialized part of the cœlom, and, as in other Molluscs, is termed the pericardium. In front of this space in Chiton lies the ovary (fig. 14, D). In the other Isopleura the genital bodies (gonads) lie in the pericardium, which has a longer form and extends dorsally above the intestine. Opening into the pericardium equally in all the Isopleura (fig. 14) is a pair of bent tubes which lead to the exterior. These are the nephridia, which in Chiton are essentially renal in function. Their disposition has been determined by Sedgwick (26), who has shown that each nephridium is much bent on itself, so that, as in the

nephridia of Conchifera (organ of Bojanus), the internal aperture lies near the external. From the folded stem of the nephridium very numerous secreting cæca are given off,—omitted in the diagram (fig. 14, D), but accurately drawn in fig. 15. The sexes in Chiton are distinct, and the ovary or testis, as the case may be, though lying in and filling a chamber of the original cœlom, does not discharge into the pericardium, but has its own ducts, which pass to the exterior just in front of those of the nephridia (fig. 14, D, *g*, and fig. 16). In this respect Chiton is less primitive than the other Isopleura, and even than some other Gastropods (the Zygobranchia), and some Conchifera (Spondylus, &c.), which have no special genital apertures, but make use of the nephridia for this purpose. In *Chiton discrepans*, in which there are sixteen pairs of ctenidia, the orifices of the nephridia are coincident with the sixteenth pair of ctenidia, those of the genital ducts with a point between the thirteenth and fourteenth ctenidia.

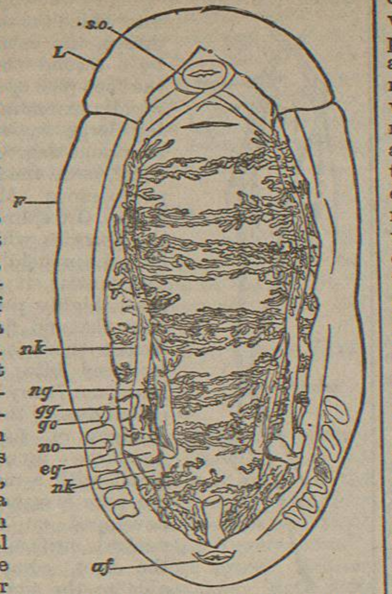

FIG. 15.—Dissection of the renal organs (nephridia) of *Chiton siculus*, after Haller (*Arbeiten, Zool. Instit.*, Vienna, 1882). *F*, foot; *L*, edge of the mantle not removed in the front part of the specimen; *s.o.*, œsophagus; *af*, anus; *gg*, genital duct; *go*, external opening of the same; *eg*, stem of the nephridium leading to *no*, its external aperture; *nk*, reflected portion of the nephridial stem; *ng*, fine cæca of the nephridium, which are seen ramifying transversely over the whole inner surface of the pedal muscular mass.

In the Neomeniæ and Chætoderma the nephridia are short and wide (*N* in fig. 14, A, B, C), and function as excretory ducts for the genital products, the gonads being lodged in the long pericardium. Their separate or united apertures open near the anus into the small chamber formed by the restriction of the mantle-skirt to the immediate neighbourhood of the anus.

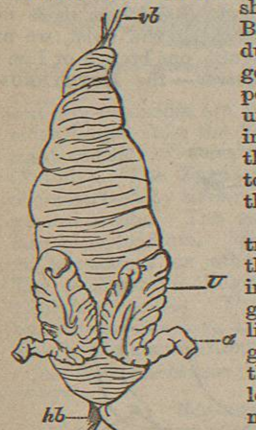

FIG. 16.—Ovary and oviducts of *Chiton siculus* (after Haller, *loc. cit.*). *vb*, *hb*; anterior and posterior suspensor of the ovary; *U*, uterus (enlarged part of oviduct); *a*, oviduct.

The nervous system of the Gastropoda Isopleura is represented in the diagram fig. 17. In all it is important to observe that nerve-ganglion cells are by no means limited to special swellings—the ganglia—but are abundant along the whole course of the four great longitudinal trunks. This is a primitive character comparable to that presented by the nerve-cords of Nemertine worms, and of the Arthropod Peripatus. Higher differentiation in other Mollusca leads to predominance if not an exclusive presence of nerve-*fibres* in the cords, and of nerve-*ganglion cells* in the specialized ganglia. The numerous transverse connexions of the pedal nerve-cords in Chiton and Neomenia (seen also in Fissurella (fig. 36) and some other Gastropods) are comparable to the transverse connexions of the ventral nerve-cords of Chætopod worms and Arthropods. In the abundance of the nervous network connected with its longitudinal nerve-tracts, Chiton appears to retain something of the early condition of the Cœlomate nervous system when it had the form of a sub-epidermic network or nerve-tunic (seen more clearly in Planarians and some Nemertines), and when the concentration into definitely compacted cords had not set in.

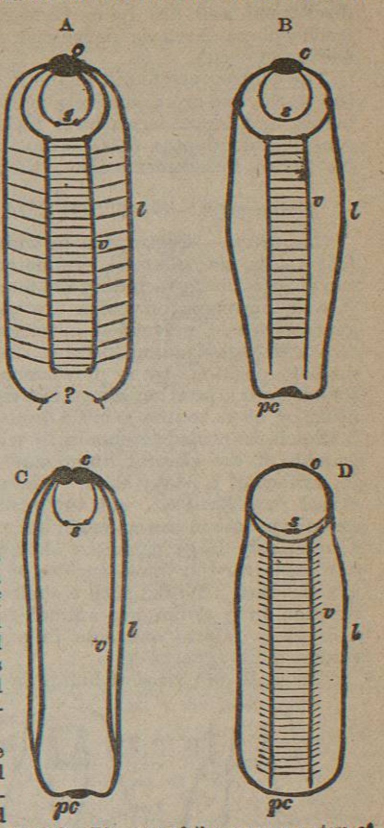

FIG. 17.—Diagrams of the nervous system of Isopleura (after Hubrecht, *loc. cit.*). *c*, cerebral ganglia; *s*, sublingual ganglia; *v*, pedal (ventral) nerve-cord; *l*, visceral (lateral) nerve-cord; *pc*, post-anal junction of the visceral nerve-cords. A. Proneomenia. B. Neomenia. C. Chætoderma. D. Chiton.

Ganglia are, however, distinguishable upon the nervous cords of Chiton (fig. 18). The cerebral ganglia are not distinguishable as such, but a pair of buccal ganglia (B in fig. 18) are developed on two connectives which pass forward from the cerebral region to the great muscular mass of the mouth. These buccal ganglia are special developments connected with the special muscularity of the lips and odontophore, and are found in all Glossophora, but not in the Lipocephala. Such special ganglia related to special organs (and not introduced in our schematic Mollusc, fig. 1) we find in connexion with the siphons of the Lipocephala, and in various positions upon the visceral nerve-cords of other Mollusca, both Glossophora and Lipocephala. A pair of pedal ganglia but little developed (*p* in fig. 18), and a special group of sublingual ganglia are present in Chiton. On the whole, the nervous system of the Isopleura is exceedingly simple and archaic, whilst it does not well serve as a type with which to compare that of other Mollusca on account of the small amount of concentration of its nerve-ganglion cells into ganglia, such as we find well developed in other forms.

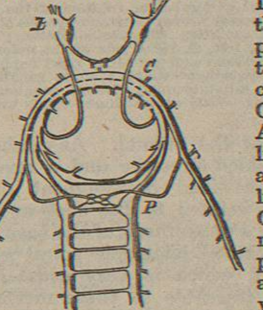

FIG. 18.—Anterior part of the nervous system of *Chiton cinereus*, in more detail (from Gegenbaur, *Elements of Comp. Anatomy*). *B*, buccal ganglia (concerned with the odontophore); *C*, cerebral nerve-mass; *P*, pedal ganglion and commencement of pedal nerve-cord; *pl*, visceral nerve-cord. The sublingual ganglia are not lettered.

The development of Neomenia and Chætoderma from