to the interior by fine closed tubuli or *dermal branchiæ* between the plates of the perisome. In *Solaster* water can enter the body-cavity by the interbrachial cribriform plates through which the genital ducts pass.

Among the Asteridea several modes of development have been observed. In some species reproduction appears at times to be effected by division of the rays. The species *Pteraster militaris* hatches its young in a special pouch on the dorsal surface. The larva on leaving its egg is oval, but subsequently assumes a pentagonal form, and the provisional mouth comes to be placed at one of the body angles. The central mouth and stomach afterwards developed open into each other at the time that the young star-fish leaves the maternal pouch. In other cases the breeding-chamber may be formed by the bringing together of the bases of the rays, and the ciliated embryo develops at its anterior end club-shaped tubercles, by which it can attach itself to the breeding-chamber or to submarine objects. Until these processes appear the breeding-chamber remains closed. In general, the larva of the Asteridea begins life as a lobed and ciliated pseud-embryo, a common form of which is the *Bipinnaria*. Another form, the *Brachiolaria*, is distinguished principally by three tuberculated processes at the anterior end of the body. The ambulacral vessels of the adult are developed in the pseud-embryo from a portion of one of the diverticula of the stomach in which originate the peritoneal cavity and the whole or great portion of the mesodermic structures.

The Asteridea are classed by M. Edmond Perrier as follows :—

Division I. Pedicellariæ pedunculated; pedicels (except in *Labidiaster* and *Pedicellaster*) quadriserial.
- Asteridæ. Ex. *Asterias* (*Asteracanthion*), *Heliaster*, *Calvasterias*, *Anasterias*, *Labidiaster*, *Pedicellaster*.

Division II.—Pedicellariæ sessile; pedicels ordinarily biserial.
- i. Dorsal skeleton reticulate.
  - Echinasteridæ. Ex. *Acanthaster*, *Solaster*, *Echinaster*, *Cribrella*.
- ii. Dorsal skeleton of longitudinal series of rounded or quadrangular ossicles; integument generally granulated.
  - Linckiadæ. Ex. *Ophidiaster*, *Linckia*, *Scytaster*.
- iii. Skeleton, at least of lower surface, of tesselated ossicles; dorsal and ventral marginal plates very distinct.
  - Goniasteridæ. Ex. *Pentagonaster*, *Goniodiscus*, *Goniaster*, *Culcita*, *Asterodiscus*, *Choriaster*.
- iv. Skeletal ossicles imbricated; with spines on the free border, or rounded and completely covered with small spines.
  - Asterinidæ. Ex. *Palmipes*, *Asterina*, *Nepanthia*.
- v. Skeleton of paxillæ.
  - Astropectinidæ. Ex. *Chætaster*, *Luidia*, *Astropecten*, *Archaster*, *Ctenodiscus*.
- vi. Dermal investment supported by spines radiating from the prominent skeletal ossicles.
  - Pterasteridæ. Ex. *Pteraster*.
- vii. Arms long, straight, distinct from disk, with minute spines on dorsal surface.
  - Brisingidæ. Ex. *Brisinga*.

Distribution in time of Asteridea (fig. 17).—The Asteridea are represented in the Lower Silurian series of strata by the genera *Edriaster*, *Palæaster* (ranging to Carboniferous), *Stenaster*, *Tœniaster*, and *Urasterella*; in the Upper Silurian by *Glyptaster*, *Palæasterina*, *Palæocoma*, *Petraster*, *Palnipes*, *Lepidaster*, and *Trochitaster*; in the Devonian by *Aspidosoma*, *Ptilonaster*, *Asterias* (also in Carboniferous), and *Helianthaster*; in the Carboniferous by *Schœnaster* and *Cribellites*; by *Pleuraster* in the Trias; by *Tropidaster* in the Lias; and by *Astropecten* with other still living genera in the Lias and Oolites. The Cretaceous strata are more especially characterized by species of the recent genera *Oreaster*, *Astrogonium*, *Goniodiscus*, and *Stellaster*.

Fig. 17.—Fossil Asteridea.
1. Lepidaster Grayi, Forbes; *U. Silurian*, Dudley.
2. Protaster Miltoni, Salter; *L. Ludlow rock*, Salop.

Order III.—Ophiuridea. The Brittle-stars (fig. 18) have a general external resemblance to the Asteridea. The body consists of a central disk with five or more simple or less usually ramifying rays, which are sharply distinguished from the disk, are without ambulacral grooves, and contain no prolongations of the stomach. Spines and plates, also hooks (considered to be the representatives of the pedicellariæ of the Asteridea), are developed in the perisome. The dermal skeleton of the arms is constituted usually of a ventral or superambulacral row of plates, a

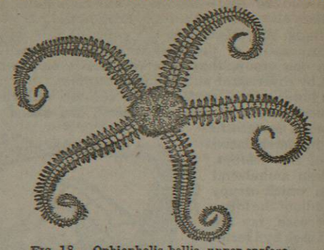

Fig. 18.—Ophiopholis bellis, upper surface.

dorsal median or antambulacral row, and two side rows of spinous imbricated plates. More rarely the perisome of the arms is leathery in consistence, and bears small plates, of which the ventral are the largest, and perforated with a double line of pores. The internal axial skeleton is formed by the *vertebral* or *axial* ossicles (fig. 19), the right and left halves of which are united by a longitudinal suture. The axial ossicles are articulated to one another by means of peg-and-socket joints. On the lower surface of each, corresponding to a depression on its dorsal surface, there is a groove for the passage of a radial ambulacral vessel and a nerve. The innermost of the axial ossicles is in two articulated halves, and the neighbouring halves of every two arms are connected with a couple of interambulacral pieces, with the inner edges of which is articulated a single ossicle, the *torus angularis*. The last-mentioned bears the *papillæ angulares*, and beneath these the *palæ angulares*, which are short flat processes, moved by muscles, and serving as teeth (see fig. 20). Right and left of the origin of each arm, within the body disk, on the ventral side, is an elongated ossicle, which in the *Euryalidæ* unites at the margin of the disk with an arched piece running towards the centre of the dorsal surface. The mouth is in the centre of the ventral face, and at each of its angles is a pair of tentacles. It leads into a simple sac-like alimentary canal, which is without anus. The madreporic canal, the walls of which are strengthened with calcifications, leads from the surface of one of the interradially situated *scuta buccalia* on the ventral side of the disk into a circular ambulacral canal, upon which rest minute plates, the homologues of the Holothuridean calcareous ring. Opening into the circular ambulacral canal, and corresponding in position to the madreporic canal, there

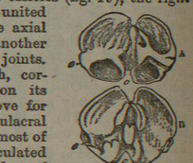

Fig. 19.—Axial ossicle of *Ophiolepis*. (After Müller.)
A, adoral surface; B, aboral surface; c, ventral groove; c, facet for tentacle.

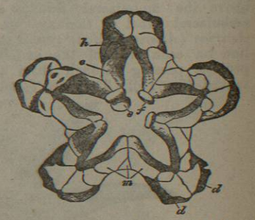

Fig. 20.—Mouth skeleton of *Ophioderma longicauda*. (After Müller.)
d, *d*, first vertebral ossicles; *c*, interambulacral piece of oral angle; *h*, torus angularis; *h*, groove for nerve-ring; *m*, peristomial plates; *o*, palæ angulares.

are usually four interradially placed Polian vesicles. The necks of the Polian vesicles and the ambulacral ring give off the diverticula termed by Simrock *vasa ambulacralia cavi*. From the ambulacral ring proceed the five radial canals between the superambulacral plates and the axial ossicles. In front of each ossicle they give off right and left branches to the pedicels. These are tentacle-like, devoid of basal vesicles, and, except in the *Euryalidæ*, pass out through openings between the superambulacral and lateral plates. The nervous system consists of an oral ring, which supplies a branch to each arm, running superficial to its radial ambulacral canal. Between the nerve and the latter is a neural canal. The genital organs are pairs of racemose glands attached to the inner dorsal surface of the disk; their products are shed into the perivisceral cavity, whence they make their way through the genital clefts between the origins of the arms.

Hermaphrodism has been observed in the species *Ophiolepis squamata*; and in some genera, as *Ophiocoma* and *Ophiactis*, scissiparous reproduction occurs. According to Lütken, this at an early age is more especially exhibited by the six-rayed forms. In certain cases development takes place within the egg, without any free pseud-embryonic stage; but most generally metamorphosis from a pluteiform larva takes place. The bilaterally symmetrical skeleton of the pluteus consists of eight radially diverging calcareous rods. The development of the embryo commences with the production of two cylindrical solid bodies, one on each side of the gullet, which form cellular blastemic masses, one behind and another in front of the stomach, and a third to the left of the pseudostome. The ambulacral system of the adult is developed from the last of these, which unites with the mass in front of the stomach to form the ventral portion of the body, whilst the posterior mass furnishes the dorsal portion.

The Ophiuridea may be classified as follows :—

Sub-order I.—Ophiuridæ. Arms unbranched; ambulacral furrows covered with plates; genital clefts ordinarily five; habit creeping.
- A. Oral clefts armed.
  - (i.) No *papillæ angulares*.
    - Ophiodermatidæ. Buccal scutes trigonal; disk granulated. Ex. *Ophiura* (*Ophioderma*), *Ophiochæta*, *Ophiopsammus*.
    - Ophiolepidæ. Buccal scutes pentagonal; disk scales naked. Ex. *Ophiolepis*, *Ophioceramis*, *Ophiopus*.
    - Amphiuridæ. Disk rugged and scaly; ray-plates spinous. Ex. *Amphiura*, *Ophiacantha*, *Ophiopholis*, *Ophiostigma*, *Ophiactis*.
    - Ophiomyxidæ. Disk naked; rays clothed with soft integument. Ex. *Ophiomyxa*, *Ophioscolex*.
  - (ii.) *Papillæ angulares* present.
    - Ophiocomidæ. Disk covered with solid plates. Ex. *Ophiocoma*, *Ophiomastix*, *Ophiarthrum*.
- B. Oral clefts unarmed.
  - Ophiothricidæ. Radial plates very large. Ex. *Ophiothrix*, *Ophiocnemis*, *Ophiogymna*.

Sub-order II.—Euryalidæ. Arms simple or ramified, and capable of being rolled up towards the mouth; ambulacral furrows covered by soft integument. Spines are not present, but there are tufts of papillæ on the ventral surface of the arms; genital clefts ten.
- Astrophytidæ. *Astrophyton*, *Trichaster*, *Asteromyxa*, *Asteromorpha*, *Asteroporpa*.

Distribution in time of Ophiuridea.—The following Palæozoic genera are commonly referred to the Ophiuridea :—*Protaster* (Lower Silurian); *Palæodiscus*, *Acroura*, and *Eucladia* (Upper Silurian); *Eugaster* (Devonian of New York). Ophiura (?) occurs in the Carboniferous Limestone of Russia. In the Muschelkalk occur *Aspidura* and *Aplocoma*, and in higher Secondary strata *Ophioderma*, *Ophiocoma*, *Amphiura*, and other genera.

The Ophiuridea and Asteridea possess, in a marked degree, the power exhibited by the whole of the Echinodermata of reproducing lost portions of the body. The former have received the name of "Brittle-stars" on account of the remarkable facility with which species of the genus *Ophiocoma* not merely cast away their arms entire, but, at will, rapidly break them into little pieces. The same property has been noticed in the genus *Luidia* among the star-fishes, in the Crinoidean genus *Comatula*, and the *Synaptidæ* among the Holothuridea. Writing of a species of *Luidia*, Prof. E. Forbes remarks: "The first time I ever took one of these creatures I succeeded in getting it into the boat entire. Never having seen one before, and quite unconscious of its suicidal powers, I spread it out on a rowing bench, the better to admire its form and colours. On attempting to remove it for preservation, to my horror and disappointment, I found only an assemblage of rejected members. My conservative endeavours were all neutralized by its destructive exertions, and it is now badly represented in my cabinet by a diskless arm and an armless disk." Major Fred. H. Lang relates (*Nature*, Oct. 12, 1876), that during a dredging expedition in Torbay, presuming on the fact that as a rule he could take up the specimens of *Comatula rosacea* and *Ophiocoma rosula* he had captured without occasioning their dismemberment, he "put about a hundred of the two sorts into a sponge-bag; but this was asking too much of them;" for on reaching home he found "that both Feather-stars and Brittle-stars had converted themselves into a mass of mince-meat! It would have been difficult to find a single portion of an arm a quarter of an inch long."

Order IV.—Crinoidea.—The body in the Crinoidea is cup-shaped or bursiform, and its base always in the young state and usually in the adult is attached by the apical pole either directly or, as more commonly, by means of a calcareous stem to submarine objects. The inferior or dorsal wall of the body or *calyx* is formed of polygonal plates articulated by their edges, and the superior or ventral face or disk, which may be either flat or arched, is formed either by a perisomal membrane, occasionally strengthened with scattered calcifications, or, as in the *Tesselata*, by regularly arranged plates, *tegminalia*, resembling those of the inferior wall. At the border of the calyx are 2–18, usually 5, arms or *brachia*, which are movable, and can be closed together over the oral disk (fig. 22). Between them, commonly in the centre of the disk, is the mouth, and near it, in one of the interradial spaces, is the anus.

Fig. 21.—Pentacrinus caput-Medusæ. (After Guttard.)

It has been shown by Sir Wyville Thomson, (*Phil. Trans.* vol. clv. pt. 2), that the skeleton of *Antedon rosaceus* may be divided into two systems of plates, the *radial* and the *perisomatic*, the former including the articuli of the stem, the centro-dorsal plate, the radial plate, and the joints of the arms and pinnules, and the latter the basal, oral, and anal plates, and the interradial and other plates or spiculæ developed in the disk-membrane. "The body of

the pentacrinoid is at first, while yet included within the pseud-embryo, and during its earliest fixed stage, surrounded and inclosed by plates of the perisomatic system alone." The predominance of the perisomatic system in the calyx of the older Crinoids and forms allied to them is hence a fact of considerable interest to the embryologist.

The stem is made up of numerous ossicles articulated and interpenetrated by elastic fibres and soft connective tissue. It is attached at its distal end by a root-like expansion, or by numerous, filamentous, branched cirri, having joints similar to those of the stem. Other and unbranched cirri are attached in whorls to many of the ossicles of the stem. Through the centre of the stem runs a canal containing a soft solid substance. In the adult *Antedon*, as has been pointed out by Dr Carpenter (*Proc. Roy. Soc.*, 1876), the medullary portion of the Crinoidal axis passes up through a pentangular five-chambered dilatation of its cortical portion within the centro-dorsal plate, and, reaching the cavity of the calyx, forms the pedicle by which chiefly the basal or dorsal surface of the visceral mass is attached to the calyx. The pedicle enters into the axial canal and passes through out its entire length, more or less imbedded in its walls, to the commencement of the subtentacular canals, where it apparently becomes continuous with the generative plexus of the disk. The stem varies in length, being short in *Apiocrinus*, long in *Pentacrinus*; it is round and sometimes moniliform in most Palæozoic Crinoids, but in *Platycrinus* compressed as it nears the calyx, in *Woodocrinus* it tapers from the calyx downwards. In the Palæozoic Crinoids the articulations of the ossicles radiate from the central canal, which is larger than in the more modern forms. In the Mesozoic genera the articular facets are commonly united by crescentic or stellate ridges. In the Silurian genus *Periechocrinus* the ossicles of the stem are alternately thicker and thinner. The calyx, which may be regarded as formed of the uppermost ossicles of the stem, is composed of several series of plates. The lowest of these is commonly formed by 2–6 pieces, the *basalia*, which in *Rhizocrinus* appear to be represented by a single central plate. The basalia in the *Tesselata* are succeeded by the *parabasalia* or *sub-radialia*; after the basalia or these come one or more rows of plates (in *Rhizocrinus* three), the *radialia* (see fig. 23). In *Pentacrinus* the radialia seem to form the commencement of the calyx. Supported by the radialia are series of arm plates, or *brachialia*, from the uppermost of which, as in *Pentacrinus*, may bifurcate the *palmaria*. The ossicles of the arms are sometimes single, sometimes united by *syzygies*, or immovable sutures. In the Silurian genera *Anthocrinus* and *Crotalocrinus* the subdivisions of the arms are very numerous, and by their lateral articulation form web-like expansions. The arms of *Poteriocrinus plicatus* bifurcate 4 times, giving 80 rays; the total number of plates in that species has been estimated at 1300 (see J. G. Grenfell, *Rep. Brit. Assoc.*, 1875, p. 65). In the calyx of the *Tesselata* there are plates, *interradialia*, present between the radialia. In *Antedon* the central portion of the viscera is contained in a basin formed by the 1st, 2d, and 3d radialia, and by the 1st and 2d pairs of brachialia, and the basal segments of the pinnules borne by the second; and the calycine cavity is completed by the perisome uniting the basal segments of the arms. Where, as in the *Articulata*, represented by the modern Crinoids, the disk is more or less membranous, four or five deep furrows radiate upon its surface from the mouth, which pass on to the oral surface of the arms and extend to the extremity of their pinnules. They carry the hollow ambulacral tentacles, which pass out through pores in the perisome. In 1865 Mr J. Rofe demonstrated (*Geol. Mag.*, ii. 245) in the case of several genera of Tesselate Crinoids from the Mountain Limestone (*Actinocrinus*, *Amphoracrinus*, *Cyathocrinus*, and *Platycrinus*) that the groove on the upper surface of the arms divides at their base into two channels—(1) a superior channel passing up beneath (in some cases partly within) the plates of the dome or disk to its apex, and there uniting with an internal circular aperture, probably the mouth; and (2) an inferior channel which goes direct into the visceral cavity. These channels, since their discovery by Mr Rofe, have been shown to be generally present in the Tesselate Crinoids. The superior channels, on the supposition that the central opening is a mouth, doubtless served for the supply of food and of water for respiration; whilst the inferior channels probably gave passage to the motor muscles of the arms, and placed the visceral cavity in connection with the ovaries, if the latter, as in modern Crinoids, were situated in the arms. In the Palæozoic genus *Rhodocrinus* the arm is cylindrical, and without a groove on the upper surface, but immediately below its base is situated the orifice of a passage which turns upwards under the dome. What in the Palæozoic Crinoids is commonly regarded as the anal opening, is situated at the extremity of a proboscidiform tube (fig. 24) interradially placed, and often of great length—as much as 4¼ inches in *Poteriocrinus plicatus*. In existing Crinoids there are two apertures in the disk—the mouth, usually central, as in *Rhizocrinus*, and the interradially situated anus. The mouth is closed by lobes of the perisome, the *oral valves*, which may contain calcareous plates. Between these run the oral or ambulacral grooves from the mouth to the arms. In *Antedon* (*Comatula*) the alimentary canal passes obliquely downwards from the mouth, then horizontally, and after more than a complete turn bends upwards again, and ends in a rectal chamber terminating in a spout-like prominence. Between the exterior of the mucous wall of the alimentary canal and its peritoneal covering is the intramural space. The double wall of the canal is strengthened by calcareous disks; and it is by the folding of the inner side of the wall, and the resultant piling together of layers of these plates that the vertical *columella* is produced. The body cavity is lined by a smooth peritoneal membrane. The ambulacral furrows are bordered by plates, the *ambulacral* or *marginal lamellæ*, as in *Rhizocrinus* and *Pentacrinus*, or, as in *Antedon*, by elevated ridges of the perisome, produced at the edge into a series of small lobes or valvules, and having grouped on their inner side the pedicels. The epithelial floor of the grooves, there is good reason to believe, is lined with cilia, which, like those of the gullet, serve to create currents in the water and thus to bring into the mouth Diatomaceæ, spores of Algæ, minute Entomostraca, and other nutritive material.

In *Antedon*, as has been shown by Dr Carpenter

Fig. 22.—Cyathocrinus tuberculatus. (After Goldfuss.)

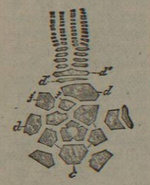

Fig. 23.—Dissection of calyx of *Eucalocrinus macropetalus* (after Hall). *c*, subradialia succeeding the central basalia; *d*, *d'*, *d²*, radialia; *f*, *f'*, interradialia.

Fig. 24.—Dendrocrinus longidactylus. A, calyx; B, proboscis.

(fig. 25), the tentacles communicate at their bases with a common trunk, the *tentacular canal*. Beneath this, but having no communication with it, lies the *subtentacular canal*, which is usually divided by a more or less incomplete septum. Each of the subtentacular canals is continuous with a branch of the *axial canal*, which communicates with the deeper portion of the perivisceral cavity by means of a minute pore situated nearly at the centre of the lower surface of the visceral mass, and partly occupied by the pedicel before referred to. As the axial canal extends downward through the visceral mass it comes into contiguity with the alimentary canal, and opens into it by irregular passages. There is in the arms a third canal, the *cœliac*, which is a continuation of the body-cavity or cœlom, and is separated from the subtentacular canal by a transverse partition. At the junction of this partition with the septum of the subtentacular canal there is a passage, the *genital canal*, in which lies the cellular cord known as the *generative rachis*, in connection with the visceral genital tissue. Enlargements of the rachis in the pinnules constitute the genital glands of the Crinoidea, the products of which may or may not be discharged by special orifices. Towards the extremity of the pinnules, in *Antedon*, the partition between the cœliac and subtentacular canals thins away, and becomes finally obsolete, thus possibly affording a means for the circulation of the nutritive fluid of the body, the subtentacular canals constituting an arterial or distributive and the cœliac a venous or collective system of vessels.

Fig. 25.—Section of arm of *Antedon rosaceus*. (After Carpenter.) *tc*, tentacular canal, giving off lateral branches to the saccular (sensory?) organs, *s*, *s*; *stc*, the two subtentacular canals, *gr*, genital rachis; *cc*, cœliac canal; *m*, muscles; *a*, organic basis of calcareous segment; *b*, solid cord from quinquelocular organ.

From the arms the tentacular canals proceed inwards to unite with a circular canal situated around the gullet, and having connected with it numerous short processes similar to the *vasa ambulacralia cavi* of the Ophiuridea (see page 635). There is no madreporic tubercle, and the madreporic canal is apparently unrepresented in the Crinoidea. Respiration seems to be effected by the tentacles, and in *Comatula* also by the access of water through pores in the oral perisome, communicating with a series of sinuses below its under surface by means of funnel-shaped canals. The central organ of the nervous system in *Antedon*, according to Carpenter, is the dilated cortical portion of the axis of the stem within the centro-dorsal plate, which supplies branches to the cirri and the arms, and corresponds probably with the axial sheath which, in *Pentacrinus*, sends off cords at the nodes of the stem into the whorls of cirri (see fig. 21). A fibrillar band underlying the epithelial floor of the brachial furrows is regarded by Ludwig as a nerve —"an afferent rather than a motor nerve" (Carpenter).

The development commences with the formation from the egg of an oval morula, which acquires four hoop-like ciliated bands, and a posterior terminal tuft of cilia. An endodermal sac or archenteron results from an invagination of the blastoderm between the third and fourth ciliated bands; and from this three diverticula, two lateral and one ventral, take their rise, the remainder of the archenteron becoming an alimentary cavity communicating with an anterior œsophagus. The lateral diverticula are transformed into peritoneal sacs, one on the dorsal the other on the ventral side of the alimentary cavity, and their walls coming in contact produce a circular mesentery. In the ventral diverticulum the ambulacral vessels have their origin. Around the alimentary cavity, when the pseud-embryo is scarcely a line in length, there are formed two circles, each of five calcareous plates, which eventually become the oral and basal ossicles of the calyx. From the centre of the posterior circle extends a row of eight calcareous rings, the future stem of the Crinoid, surrounding a backward prolongation of the dorsal peritoneal sac. At the posterior extremity of the row is a cribriform disk, by which the young Crinoid subsequently attaches itself. The sarcodic body of the pseud-embryo begins to shrink, the pseudostome and the two lower bands of cilia disappear, and afterwards the two upper bands, and the embryo then becomes fixed to a stone, seaweed, or some other object. A new mouth is formed in the centre of the disk by the separation of the oral plates, and the intestine by the production of a diverticulum of the alimentary cavity. In the early Pentacrinoid stage of *Comatula* the basals rest upon the centro-dorsal segment, but become at length metamorphosed into a single piece, the *rosette*, and the centro-dorsal segment by degrees increasing in size, the first radials come to rest upon its enfolded lip. During the same period, after the formation of an anus, the oral and basal plates disappear. The development of the dorsal cirri takes place as the proximal joint of the column enlarges to form the centro-dorsal piece. At the end of five or six months, when about ¼ an inch in diameter, the young *Comatula* detaches itself from its stalk, and is then able to swim by means of its arms. The Pentacrinoid larval form of *Comatula* (fig. 26), previous to his discovery of the ultimate stages of its growth, had been termed by Vaughan Thompson *Pentacrinus europæus*.

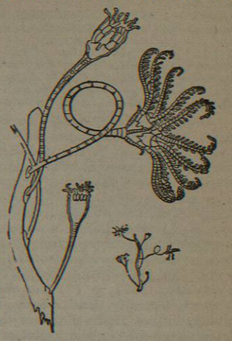

Fig. 26.—Pentacrinoid larval forms of *Comatula*, natural size and magnified.

The Crinoidea are classified as follows:—

Order I. Tesselata. Calyx completely formed of calcareous plates, oral face without ambulacral furrows.

Family. *Tesselata*. Ex. *Cyathocrinus*, *Actinocrinus*.

Order II. Articulata. Oral face of calyx usually membranous or sub-membranous, with ambulacral furrows.

Family 1. *Pentacrinidæ*. Always attached. Ex. *Pentacrinus*, *Rhizocrinus*.

Family 2. *Comatulidæ*. Attached only in the young state. Ex. *Antedon*, *Phanogenia*. The Cretaceous genus *Marsupites* appears to have been unattached.

The Crinoidea are represented by *Glyptocrinus*, *Eucalyptocrinus*, *Marsupiocrinus*, *Taxocrinus*, *Ichthyocrinus*, *Periechocrinus*, *Cupressocrinus*, *Poteriocrinus*, *Woodocrinus*, *Cyathocrinus*, *Rhodocrinus*,

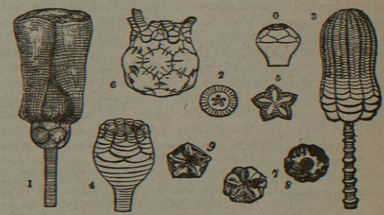

Fig. 27.—Fossil *Crinoidea*.

1. Crotalocrinus rugosus, Mill.; *U. Silurian*, Dudley.
2. Poteriocrinus (joint of column); *Carboniferous*, Yorkshire.
3. Encrinus entrocha; *L. Muschelkalk*, Germany.
4. Apiocrinus Parkinsoni, Mill.; *Bradford Clay*.
5. Pentacrinus basaltiformis, Mill.; *Lias*, Lyme.
6. Marsupites ornatus, Mill.; *Chalk*, Sussex.
7. Comatula Glenotremites (upper surface of body).
8. Comatula (lower surface); *Chalk*, Sussex.
9. Eugeniacrinus quinquedactylus, Schl.; *Oxfordian*, Würtemberg.
10. Bourgueticrinus ellipticus, Mill.; *Chalk*, Kent.

and numerous other genera in Palæozoic strata, where their remains, especially in the Carboniferous series, are often the chief constituents of vast masses of compact limestone.[1] From their form the insulated articuli of the stem have come to be known as *entrochi*, *screw-stones*, or *wheel-stones*, and in the north of England, as "St Cuth-

[1] On Crinoidal Limestone, see J. Rofe, F.G.S., *Geol. Mag.*, x. p. 262.

bert's beads." Among the various forms by which the Crinoidea were represented during the Mesozoic period, towards the close of which they diminished materially in number, are *Encrinus* (Muschelkalk); *Extracrinus*, *Pentacrinus* (Lias); *Conaturidæ* (Rhætic); *Apiocrinus*, *Millericrinus*, *Eugeniacrinus*, and such forms as *Saccocoma* and *Pterocoma*, related to *Comatula* (Jurassic); and *Bourgueticrinus*, *Marsupites*, and (?) *Comatulidæ* (Chalk). The Tertiary genera are but few. They include *Bourgueticrinus* and *Caincrinus* (London Clay), and *Comatula* (Coralline Crag.). *Pentacrinus*, *Rhizocrinus* (allied to *Apiocrinus* and *Bourgueticrinus*) and the related forms *Bathycrinus* and *Hyocrinus*, the sessile genus *Holopus*, *Actinometra*, and *Comatula* are living forms.

Order V.—Cystidea.—The body in the Cystidea is in most cases rounded, and is covered with polygonal plates; it is attached by a stem, and may be provided with arms or pinnules developed from the upper or oral surface. The stem is short, usually similar to that of the Crinoidea in construction, but without cirri; the joints are rounded, and sometimes moniliform, and usually become broader but thinner towards the base of the body. In *Ateleocystites* (see H. Woodward, *Geol. Mag.* 1871, p. 71) the calyx is compressed laterally, and shows sculpturing similar to that of the plates of the pedunculated *Cirripedia*. The plates of the calyx are pentagonal, hexagonal, or imperfectly triangular, and are closely united together; they vary in number, and in *Sphæronites* (1 in fig. 28) are very numerous. In *Cryptocrinus* the calyx is composed of three rows of plates, which may be regarded as basalia, parabasalia, and radialia. According to Professor E. Forbes (*Mem. of the Geolog. Survey of Great Britain*, 1848, vol. ii. part 2), the following series of plates may be generally distinguished:—a *basal* series; *subovarian*, *centro-lateral*, and *supra-ovarian* series on a plane below, on the same plane with, and on a plane above the ovarian pyramid respectively; *circa-ovarian* plates or ossicles, encircling that structure; and *oral* plates, immediately surrounding the mouth, which vary considerably in number (fig. 29). The plates are frequently ornamented with grooves and tubercles. Arms and pinnules are not universal. In *Comarocystites punctatus*, Billings, the arms are free; sometimes they are wanting, and the pinnules are attached to the upper portion of the calyx. Commonly the arms resemble ambulacra, and are reflected towards the base of the calyx, and closely applied to its surface. Pores on the antambulacral surface may be absent (*Cryptocrinus*), irregularly scattered (*Caryocrinus*), in pairs (*Sphæronites*), or, as in *Pseudocrinus* (2 in fig. 28), *Echinoencrinus*, and other genera, slit-like, and arranged to form "pectinated rhombs," or "hydrospires," the two halves of each rhomb being on separate plates.

Fig. 28. Cystidea.
1. Sphæronites aurantium, Wahl.; *L. Silurian*, Sweden.
2. Pseudocrinus bifasciatus, Pearce; *U. Silurian*, Dudley.

Fig. 29. — *Echinoencrinus armatus*; dissection and projection of plates. (After Forbes.)
1–4, basal; 5–9, subovarian; 10–14, centro-lateral; 15–19, supra-ovarian; 1, genital pyramid and plates. Plates 1, 6, 14, and 15 bear semi-rhombs.

In *Caryocrinus ornatus* there are thirty pectinated rhombs, consisting each of a number of parallel internal flat tubes communicating at both ends with pores opening internally. The rhombs in *Pleurocystites* are not tubular as in *Caryocrinus*, but are made up of numerous parallel inward folds of an exceedingly thin part of the test. Again in *Palæocystites tenuiradiatus* the whole surface bears rhombs, which, when uninjured, have a complete though very thin calcareous covering, and communicate by a small pore at their base with the body-cavity. (See Billings, *Ann. and Mag. of Nat. Hist.* 1870, p. 259–61.)

What is usually regarded as the mouth is situated in the centre of the ventral surface of the calyx, opposite the point of attachment of the stem, and from it radiate the furrows for the arms, when those appendages are present. It is apparently small and circular in *Sphæronites*; in *Caryocystites* it is transversely elongated and lobed; in *Hemicosmites* elevated on a proboscis; in *Echinoencrinus* usually longitudinal and bordered by peculiar plates. A small perforation alongside the mouth, considered to be the anus, is generally present. It has sometimes, as in *Echinoencrinus* (fig. 30) and *Apiocystites*, the form of "an

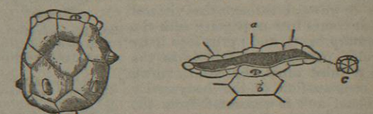

Fig. 30.—Echinoencrinus armatus. (After Forbes.)
a, mouth; *b*, anal aperture; and *c*, ovarian pyramid of the same, enlarged.

arched or crescentic groove terminating apparently at each end with a pore, and having united with it, or placed a little below it, an orifice in the middle line of a suture, as if in the junction of two oral plates" (Forbes). Almost invariably, on the oral portion of the body, interradially placed, is a round or oval aperture covered by a pyramid of 5 or 6 triangular valves. This in the opinion of most authorities is probably the ovarial orifice; but according to Mr Billings it is an oro-anal aperture, the central opening or mouth above mentioned being an "ambulacral orifice." *Cystidea* first occur in strata of Cambrian age. They especially characterize the Lower and Upper Silurian series of rocks, and apparently died out in the Carboniferous epoch.

Order VI.—Edrioasterida.—Under this head are grouped such forms as *Edrioaster*, *Agelacrinites*, and *Hemicystites*. The shape is that of a rounded star-fish or flattened echinus with a concave base. There is an ovarian pyramid, but stem and arms are wanting, and the ambulacra communicate by perforations with the calycine cavity. The Edrioasterida are exclusively Palæozoic. Their nearest living ally is the Australian species *Hyponome Sarsii*, Lov., which approaches *Agelacrinites* in form.

Order VII.—Blastoidea.—In this group of fossil Echinoderms the bud-shaped or prismatic, armless, and closely plated calyx is supported on a short, jointed stem. Of the three basal plates in *Pentremites* two are double; succeeding the basals is a row of five pieces, and into the deep clefts of the upper portion of these fit the lower ends or apices of the ambulacra; a third series of five small, deltoid, interradial plates occupy the spaces between the oral portions of the ambulacra. The ambulacra, or "pseudambulacral areas," present a superior surface formed by a double series of ossicles running from a median line to the border, where they support pinnules; beneath the ossicles is usually a lanceolate plate formed in many if not all species of *Pentremites* of two contiguous plates, and edged by a simple row of transverse pieces, which are pierced with marginal pores.

Fig. 31. Pentremites florealis.

Each row of pores opens below into one or more flat canals, or, according to the definition of Billings (*Ann. and Mag. of Nat. Hist.*, vol. v. 4th ser. p. 263), into a "hydrospire" consisting of "an elongated internal sac, one side of which is attached to the inside of the shell [or

test], while the side opposite, or towards the central axis of the visceral cavity, is more or less deeply folded longitudinally" (see fig. 32). These internal canals, as suggested by Rofe, may possibly represent the tubes under the dome of the Crinoidea. In *Codonaster* the ambulacra are confined to the upper portion only of the calyx. Pores and attached tubes are wanting; but there are striated structures between the arms, similar in appearance and probably also in function to the pectinated rhombs of the *Cystidea*, their ridges, as first shown by Rofe (*Geol. Mag.*, 1865, ii. p. 251), being the tops of a series of folds of a thin test or membrane, which were perhaps "respiratory sacs, lined with cilia, and constructed of a porous test, through which air from the water could pass by diffusion." The expanded ends of the neighbouring tubes of each two ambulacra form at the summit of the test four double and two single apertures commonly termed "ovarian orifices;" between the two latter there is usually a third, apparently anal, opening. In *Eleutherocrinus* there are three paired, and two single pores only. The Blastoidea, which are (?) represented by *Pentremites* in Upper Silurian strata, attained their principal development during the Carboniferous epoch, at the close of which they seem to have become extinct.

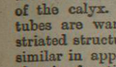

Fig. 32.—Transverse section of ambulacrum of *Pentremites Godoni*, × 3. (After Billings.)
l, lancet plate; *g*, ambulacral groove; *p*, *p*, pores leading into the canals, *c*, *c*.

Order VIII.—Holothuridea.—The Holothuridea, Sea-slugs, Trepangs, or Sea-cucumbers (figs. 33 and 34) have a long, cylindroid, sometimes flattened body, which is without shell, and is brown to purplish-red in colour. The perisome, which is unciliated, is composed of three layers,—a structureless epidermis, a cellular dermis, and an internal elastic layer. The two interior layers contain calcareous spiculæ, which vary much according to the species, and may take the shape of perforated disks, wheels, anchors, and hooks (fig. 35). Rarely the dorsal integument may develop an armature of overlapping plates (*Psolus*), which may bear spines (*Echinocucumis*). Underlying the perisome is a layer of circular muscular fibres, some of which pass into the mesenteries; a second internal set of five simple or paired bands of longitudinal muscular fibres are attached at one end to the radial pieces of the calcareous oral ring, and supply branches to the oral tentacles, and at the other are inserted into the sphincter of the anus. It is by means of the longitudinal muscles that the Holothurid, when irritated, effects the discharge of its viscera at the hinder extremity of its body. In the midst of a circle of tentacles, five or multiples of five in number, is the mouth, which is without dental apparatus. The tentacles vary considerably in shape, and may be cylindrical, shield-shaped, pinnate, or ramified. They serve as organs of touch, of nutrition, and occasionally also of locomotion. The alimentary canal is simple, and usually longer than the body, so as to be two or three times folded on itself; it is attached to the interior surface of the body by mesenteries, and may terminate in a cloaca. Its walls are composed of an external layer of circular, and an internal layer of longitudinal muscular fibres, and an innermost cellular lining. In common with the peritoneal surface of the body, it is ciliated. Two, or more rarely four or five, branched processes of the cloaca, the *respiratory trees* or *water-lungs*, are ordinarily present, and are connected to the body-wall by a mesentery or by threads (fig. 36). They appear to be excretory in function, water being continually passed into and out of them through the contractile cloaca. Their ultimate ramifications terminate in minute openings, by means of which they appear to have communication with the peritoneal cavity. In *Echinocucumis* the respiratory trees are only single-branched. In *Synapta*, in which they do not occur, there are funnel-shaped ciliated bodies attached to the mesentery of the alimentary canal. The respiratory tree occupying the ventral left interradial space has been observed in many cases to be surrounded by a plexus of the pseudhæmal system of vessels. What are termed *Cuvierian organs* are appendages of the cloaca, which, according to Semper (*Reisen im Archipel der Philippinen*, i. pp. 139, 140), are muscular, and can be used as a means of defence, being capable of protrusion externally. The main trunks of the pseudhæmal system, which is often exceedingly complex, are two vessels, one on the dorsal, the other on the ventral face of the intestine, which are connected with each other by capillary reticulations. The calcareous ring surrounding the gullet, already referred to,

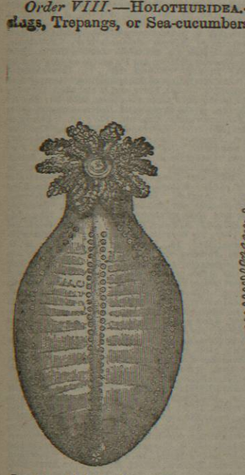

Fig. 33.—Holothuria papillosa.

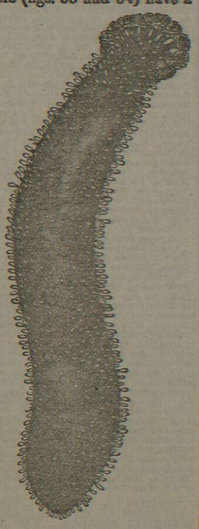

Fig. 34.—Holothuria tubulosa.

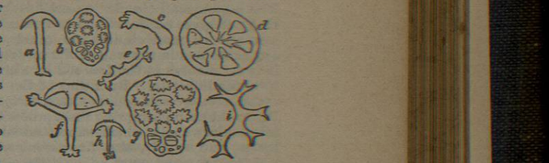

Fig. 35.—Spicules of Holothuridea. (After Semper.)
a and *b*, anchor and anchor-plate of *Synapta inhærens*, Semper; *c*, spicule of *Chirodota rigida*, Semper; *d*, wheel-spicule of *Chirodota stichensis*, Grube; *e*, spicule of *Thyone chilensis*, Semper; *f*, *g*, *h*, anchors and anchor-plate of *Synapta Godeffroyi*, Semper; spicule of *Rhopalodina lageniformis*, Gray.

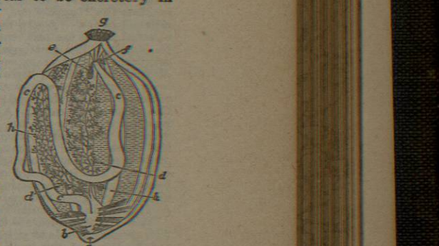

Fig. 36. — Diagrammatic section of a Holothurid. (After Gegenbaur.)
a, anus; *b*, cloaca; *c*, alimentary canal; *d*, *d*, respiratory trees; *e*, Polian vesicle; *f*, ambulacral ring; *g*, tentacles; *h*, longitudinal muscle.