

II. NOTES ON SOME ECHINODERMATA FROM THE MOUNTAIN-LIMESTONE, ETC.

By JOHN ROFE, Esq., F.G.S.

[Plate VIII.]

1. *Actinocrinus*.

SEVERAL years since, when collecting Mountain-limestone fossils on the borders of Lancashire and Yorkshire, I found some specimens of *Actinocrinus* which appeared to have internal channels from the base of the arms towards the summit of the dome. Not having seen such channels noticed by any author, I showed some of the specimens to Mr. Salter, then of the Geological Survey, who suggested that they probably might be analogues of the aquiferous channels found in recent Echinoderms; and he advised me to follow up the subject, and ascertain if such passages were to be found in other *Crinoidea* occurring in these rocks. His advice has been followed, and a large collection of specimens, some in good preservation and others weathered, has been made, which I have had the advantage of collating with a series from the same district collected by Mr. James Parker of the Manchester Museum; and upon examination they give the following results, some of which, though probably of no great importance in themselves, may serve to illustrate some doubtful points in the organization of this confessedly obscure Order of the Animal Kingdom.

It is unnecessary here to give in detail the construction of the arms of the *Crinoidea*, as that has been done so satisfactorily by Messrs. Austin, M. de Koninck, and others; but, as I shall have hereafter to point out an exception, it may be shortly stated that they describe these arms as not being truly cylindrical, but as formed like a cylinder, or branching cylinders, having a deep longitudinal groove along the upper side, with a row of tentacles on each of its margins, forming an open channel throughout the whole length, until the arms join the body; but at this point, it will be seen from what follows, this channel is divided into two passages, an upper and a lower; the former passing up within the dome to the apex, where the passages from the five arms meet, the latter going direct into the visceral cavity.

The species in which these passages were first observed by me is *Amphoracrinus** *rugosus*. In this, and in all the species of this genus hitherto examined, the plates forming the dome are extremely thick; and the upper passages above named are, for at least two-thirds of their length, in the substance of these plates; but in *Actinocrinus* the plates are thinner, and are arched over the passages. In the angle between two of these passages, on the anal side, the proboscis is placed. In *Actinocrinus* this is close to the junction; but in *Amphoracrinus* it is more or less removed from the angle. Plate VIII. fig. 1, is a horizontal section of a specimen of

* To avoid repetition and confusion, the genus *Actinocrinus* is, in this paper, divided into its sub-genera *Actinocrinus* and *Amphoracrinus*.

Amphoracrinus, showing the passages within the thickness of the plates; and fig. 2 is an elevation or side-view of another specimen, exhibiting both the openings into the visceral cavity at *a*, and the passages towards the apex at *b*. Fig. 3 is a view of the cast of a dome of *Actinocrinus tessellatus*, showing the five passages meeting at the apex, with the base of the proboscis in the anal angle. The position of the proboscis may be verified by tracing from the anal plate at the base.

2. *Cyathocrinus*.

Casts of some species of *Platycrinus* have been found showing passages similar to those in *Actinocrinus*; but in the genus *Cyathocrinus* the passages into the viscera and to the apex are better seen than in any other; and from this genus a clue to their nature may probably be gained. The arm-bearing plates, or 'primary radials,' of *Cyathocrinus* are deeply notched, or cut down, at the insertion of the arms; and the upper part of the plate on each side of the arm is in-arched more or less in different species, so as partially to cover the dome.* The 'radial plates' are attached to each other at their sides; and at the junction of their upper ends each pair form a very obtuse angle, into which a tetragonal plate is fitted; but the sides of these last plates are produced across the notch in the 'radial,' so as to meet each other, the projecting part being grooved out so as to form a channel from the base of the arm to the centre of the dome, where the five channels meet in a round aperture, which is described by M. de Koninck as the mouth; the proboscis at the side being considered the anus. This arrangement of the plates in *C. planus* is shown by fig. 4. I have not found any radial plates formed as described by Messrs. Austin; but in such a case the above tetragonal plates would form a continuation of the groove to the mouth. Specimens of *Cyathocrinus* showing the passages from the arms meeting at the central opening are not uncommon; but in the British Museum, and in Professor Tennant's collection, there are specimens which show that these were covered with thin plates like those in *Amphoracrinus*, thus being within the thickness of the dome, as in that genus; and that the mouth, if such was the circular aperture, was internal, as in the Ascidians. With the exception of the mouth, the only apparent difference in the organization of the above Crinoids is that in some the passages are in, and in some under, the plates of the dome; and with respect to the mouth, although we have as yet no specimen showing its existence in some of the genera, it would be too much absolutely to deny it, when in so many other respects they appear to be similarly constituted.

It is probably presumption at present to speculate on the nature

* Messrs. Austin, when describing *Cyathocrinus*, say—'The ray-bearing plates are perforated low down from their upper edges, for the passage of the muscles of the rays. A deep groove runs from each perforation to the summit of each plate, which is prolonged considerably beyond the point of attachment for the rays, and is in-arched, so as to partially cover in the vertex. This is particularly conspicuous in *C. geometricus*, and appears to be very common in Crinoids of this genus.'

or uses of these passages; but they appear to give strength to the idea suggested by Mr. Sowerby (*Zoological Journal*, vol. ii. p. 313), when speaking of the *Blastoidea*, 'that the animal fed on the minute beings that abounded in the sea-water, and that it obtained them in the manner of *Ascidia*, by taking them in with the water;' and to the statement of M. Dujardin, when describing *Comatula*, 'that the ventral surface of the arms and pinnæ is provided with a double range of fleshy tentacula, protected by a double range of fleshy lamellæ, presenting between them a furrow filled with papillæ, furnished with vibratile cilia, by the motion of which animalcula and microscopic vegetables are conducted along the arms to the mouth, in order to serve as food for the animal.' It certainly does appear more probable that an animal, fixed to one spot, and probably in deep water (for, if within the reach of storm-waves, its long branching arms would be caught by them with force sufficient to break the body from the slender column of attachment), would have to depend upon minute organisms abounding in sea-water, rather than upon such Crustaceans or Molluscs as might perchance come near it. If we assume M. Dujardin's statement to be correct, the upper passages, above described, would be for the supply of food, and of water for respiration; whilst the lower served probably for the passage of the muscles which gave motion to the arms and their appendages, as well as for the connection between the visceral cavity and the ovaries, if they were situated in the arms of the *Crinoidea* as in *Comatula*.

3. *Rhodocrinus*.

The genus *Rhodocrinus* (Miller), or *Gilbertocrinus* (Phillips), is not uncommon in this district. Miller appears to have confounded a Silurian specimen with the Mountain-limestone genus, and figures one from Dudley, which, so far as can be determined from the imperfect specimen, was of a different genus. Those, however, which he describes from near Bristol are undoubtedly *Rhodocrini* of the Mountain-limestone. This genus differs from most other *Crinoidea* in the form of the arms and the position of the ovarian apertures; and in these respects it appears to hold the same relative position to them as the *Ophiuridæ* do to the *Asteriadæ*. The arms have no groove on the upper side, but are cylindrical, with a tubular canal through the axis; and the ovarian openings are placed immediately under the base of the arms (figs. 5 and 6).

The arms vary in size in different species; in some being almost equal in diameter to the column or stem; whilst in others they are very small. The rarity of specimens with any portion of the arms attached, and the peculiar shape and position of the ovarian openings, have led to these latter being mistaken for the excavation for a cuneiform plate at the base of the arms, as they are at first sight very similar to those in *Platycrinus* and in some species of *Cyathocrinus*;^{*} but in a well-preserved specimen from Thorneley there

^{*} Phillips, in his 'Geology of Yorkshire' (Part II., Pl. IV. fig. 25), gives a diagram of one set of radial plates in which the ovarian openings, under the base of the arms, are clearly indicated.

appears to be a fillet round the aperture, very like that round the ovarian openings in *Gorgonocephalus*, excepting that in *Rhodocrinus* the fillet is formed by a small plate, as shown in fig. 6, and not by a thickening of the integument.

Mr. Billings, in the 'Third Decade of the Geological Survey of Canada,' in treating of the ambulacral openings of *Rhodocrinus*, says—'In no other species is there more unequivocal evidence of the existence of these openings; but they are accompanied by a structure which seems to indicate two sets of arms placed one above the other. Beneath the orifices there are two articular surfaces, which mark the bases of two arms; and above each pair of the orifices there is a projection, which also much resembles the base of one or two more arms. . . . In some of the specimens this feature is exhibited so prominently that it strongly impresses the observer with the idea of two tiers of brachial appendages. It may be, however, that there were projecting from this part of the vault a set of large spines corresponding in numbers with the arms.' Since, however, Mr. Billings's paper was published, more perfect specimens have been found with portions of the arms attached; and their articulated structure, and the passage through the axis, forbid the idea of their being spines; and an examination of the specimens in the Museum will leave little doubt of the true nature of either the arms or the lower openings. No specimen has yet been found showing distinctly the course of the upper passages, as in the other *Crinoidea*; but they evidently turn upwards under the dome. The anal opening is excentric; and, supposing the passages to exist, as there is reason to suppose they did, as in other genera, this opening would be between them.

4. *Pentremites*.

Having so far examined the *Crinoidea*, it became a matter of interest to see how far the *Blastoidea* corresponded with them. As in the former case, a number of weathered specimens were procured, and sections of more perfect ones were made; and from their examination it appears that the external characteristics of *Pentremites* are correctly described by M. de Koninck. The base, like that of *Platycrinus*,* is composed of three pieces; two, of equal size, being pentagonal, and the other quadrilateral and smaller. Upon this base rest five 'radial plates,' similar in form and size. They are attached to the base-plates as in *Platycrinus*; that is, two of these plates join to the upper sides of two of the pentagonal pieces; whilst the other three alternate or break joint, and are in contact with two adjacent plates of the base. The radial plates are very similar to

* In well-preserved specimens of plates of the *Crinoidea*, and probably of all the *Echinodermata*, the face of the joints of the plates is minutely wrinkled or corrugated, which will at once distinguish true joints from fractures. By this means the doubt as to the construction of the base of the *Platycrinus* has been removed, a divided base having been found showing the wrinkled structure on the face of the joints. As these bases are generally found whole, and very rarely in detached plates, most probably M. de Koninck's view, that in full-grown specimens they are ankylosed into one, is correct.

those of *Platycrinus*; but, instead of the semilunar depression for the attachment of the arms in that genus, there is in *Pentremites* a deep excavation, or sinus, down the middle of each plate, giving it somewhat the appearance of a fork with two broad prongs. The upper sides of the adjoining radial plates are connected by a quadrilateral plate, fitted into the more or less obtuse angle formed at their junction (in this strongly resembling the plates on the dome of *Cyathocrinus* above noticed); whilst the two other sides of this plate form continuations of the sinus nearly to the summit. So far, undoubtedly, *Pentremites* may be considered to be allied to the *Crinoidea*; but beyond this they appear to differ; for, instead of the long branching arms attached to the radial plates of *Crinoidea*, there is only a row of short fimbriated tentacles, ranging along each side of the above sinus, nearly meeting in its centre, and forming the so-called 'pseudambulacral area.' The removal of the tentacles (which, however, are not often found *in situ*) leaves a groove down each side of the sinus; and at the bottom of this a row of minute pores is seen. On making a cross section of a *Pentremite*, it is found that these pores are openings into one or more flat tubes, varying in number in different species, which pass from the base of the sinus to the apex, and are attached nearly at right angles to the plates on each side of the sinus by one edge; whilst the inner edge, which projects into the visceral cavity of the animal, expands so as to form a nearly circular tube as seen at fig. 7, which is a section of *Pentremites ellipticus*. Varieties of this species and of *P. orbicularis* are the most commonly found in this district; and they all have only one tube to each side of the sinus, and appear to have in all respects similar organization. As these flat tubes approach the summit, they become gradually narrower; and at the apex of the quadrilateral plate the expanded parts of the tubes from the adjoining sinus (and not from the same sinus) meet, and form one of the summit-openings characteristic of this genus. These flat tubes may be called the 'pore-tubes;' and the interval between those in each sinus is filled by what M. F. Roemer calls the 'lancet-plate,' which forms a bed for the tentacles, and is slightly indented to receive them; but in many species of *Pentremite*, if not in all, this lancet-plate is in reality a compound plate, formed of two contiguous plates, extending from the bottom of the sinus to the top, and, there turning right and left round the summit-openings, they pass down the adjoining sinus, to form half its lancet-plate, leaving at the apex of the body a pentagonal aperture, supposed to be the mouth. In some weathered specimens, the two parts of the lancet-plate are separate; and in many they appear to meet only at the top and bottom of the cross section, leaving a lozenge-shaped opening between them, as shown at *a*, fig. 7.

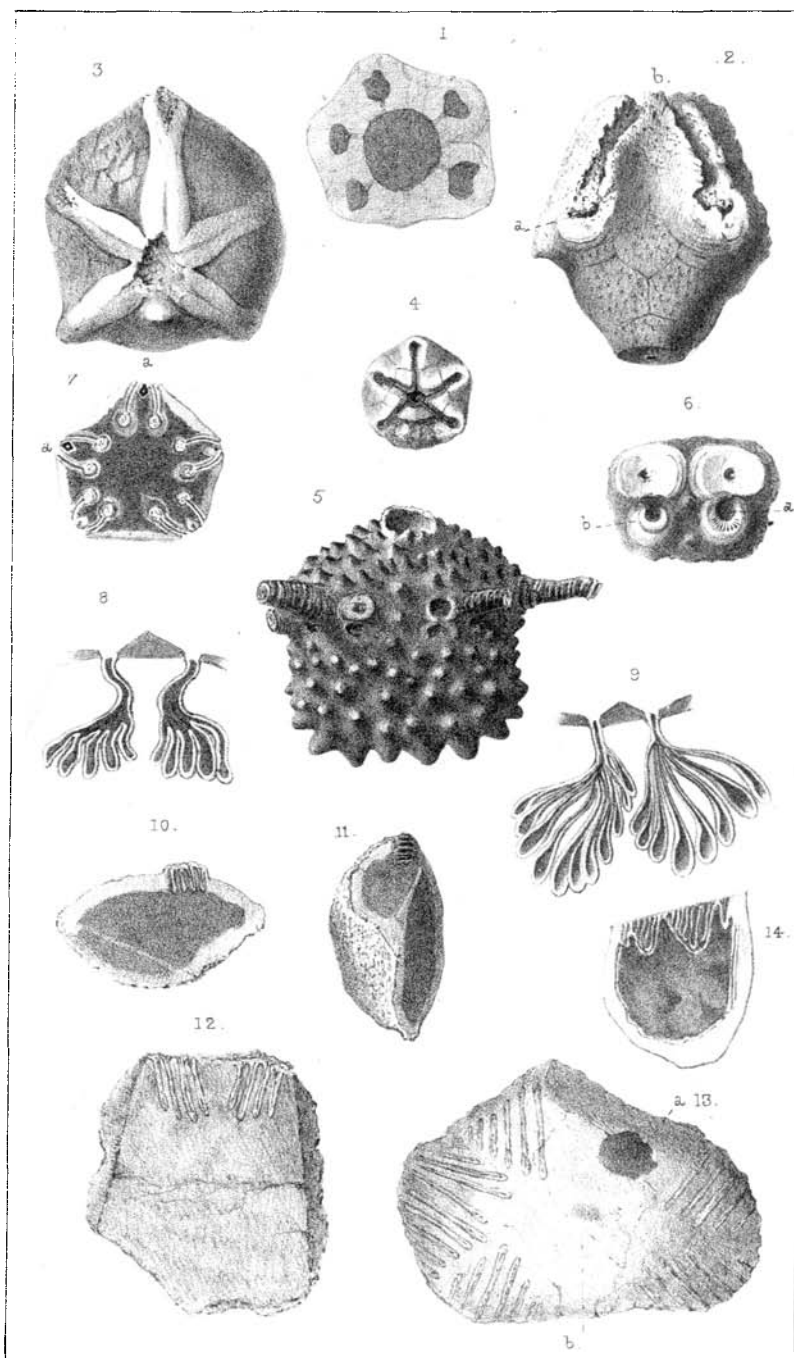
Possibly we should not be very far wrong if we were to suggest that the tentacles of *Pentremites* represent the arms and tentacles of *Crinoidea*, and the internal tubes of the former those under the dome of the latter; and in that case *Pentremites* would be nearly allied to *Crinoidea*.

Specimens of some American *Pentremites* (*P. florealis*), which have been cut for the sake of comparison, show a very similar structure to *P. ellipticus*, with the exception that there are from four to six tubes connected with each row of tentacles, instead of one, as in that species; and those tubes are formed of a thin test folded longitudinally, so as to form a number of flat lobes or tubes, which communicate with one another at the outer edge, whilst at the inner edge they expand into tubes, as seen in fig. 8, which is a section of a pair of these tubes, with the intervening lancet-plate, showing the connection with the pores, and removing the difficulty stated by M. Ferd. Roemer in his 'Monograph on the Blastoidea,' as it will be seen that the compressed longitudinal tubes shown in his Plate IV. fig. 6, are really the lobes of the above-described tube. An examination of the specimens (both vertical and horizontal sections) now in the British Museum will leave no doubt on this point.

Pentremites inflatus (Phillips) and *P. Waterhousei* (de Koninck) differ from all the above, as they do not show the summit-openings, from which this genus derives its name; but they have one large circular opening at the summit of one of the quadrilateral plates, in the place usually occupied by the largest of those openings, and which is shown by Prof. Forbes to be anal. In the comparatively few good specimens I have been able to procure, no trace has been found of the pores at the base of the tentacles; but the tentacles appear to be inserted in a groove which forms the outer edge of the lobed tubes (similar to those in *P. florealis* above described), and which in these species appear to pass to the summit under the shell, and to open within the body, as above seen in *Cyathocrinus*. Neither the grooves nor the tentacles in these species extend quite to the top of the sinus. Fig. 9 is a section of a pair of the tubes of *P. inflatus*, from Bolland, which resembles *P. florealis*, but has more lobes to the tubes.

5. *Codonaster*.

The similarity in the arrangement of the plates forming the 'cup' of this beautiful little fossil to that of some of the *Crinoidea*, and the resemblance of the rows of tentacles to those of *Pentremites*, suggested a similar organization, and led to the anticipation of finding similar pores and tubes attached to them; but on cutting many specimens no trace of such appendages has been found. Sections thus made show, however, a great similarity in the construction of the striations between the arms of *Codonaster* and those of the 'pectinated rhombs' of the *Cystidea*. Professor M'Coy, in the 'Cambridge Pal. Fossils,' notices their external resemblance. Professor E. Forbes, in his 'Memoir on the Cystidea,' when describing the 'pectinated rhombs,' refers to a figure of a specimen of *Echinoencrinus prunum*, from Mr. Capewell's collection, in which the striæ penetrated into the substance of the body; but he was inclined to regard the appearance as dependent rather on some peculiarity in the mineralization of the specimen than on true organic arrangement. Mr. Billings, in his paper on the structure of the *Cystidea*,



DeWitt lith. ad nat.

M. & N. Eschschert imp.

STRUCTURE OF ECHINODERMATA.

in the 'Third Decade of the Canadian Geological Survey,' describes their 'rhombs' as 'pores which penetrated through the plates of the body, and probably served as media of communication between the interior and exterior of the body, although the precise nature of their functions has not yet been ascertained.' Figs. 10 and 11 are vertical and horizontal sections of the 'pectinated rhombs' of *Echino-enerinus armatus*; and figs. 12 and 13 are like sections of the summit of *Codonaster*: and it will be seen that in each case the ridges on the striated surface are the tops of a series of folds of a thin test or membrane; the alternate folds being so united at their ends as to form a series of long, but very narrow, sacs. In some specimens of *Codonaster* there is an appearance of a membrane, or peritoneum, lining the cup, and following round the outline of, and forming bags under, the above folds, as shown in fig. 14.

From the construction of these striations on the face of *Codonaster* and on the 'pectinated rhombs' of the *Cystidea*, may we, without assumption, suggest the possibility of their being respiratory sacs, lined with cilia,* and constructed of a porous test, through which air from the water could pass by diffusion?

Beyond the form and construction of part of the cup, there appears to be little in common between *Codonaster* and *Pentremites*; and it must then be doubtful whether they should be left in the same family (*Blastoidea*), as the latter is apparently more nearly allied to the *Crinoidea*, whilst the construction of the 'rhombs' shows an affinity between the former and the *Cystidea*. *Codonaster* may possibly hereafter be found to be the representative of *Cystidea* in the Carboniferous series, or perhaps a connecting link between *Crinoidea* and *Cystidea*, having the cup of the one with the respiratory apparatus of the other.

EXPLANATION OF PLATE VIII.

Fig. 1. Horizontal section of *Amphoracrinus*, cut below the proboscis, which would be on the lower side of the figure.

2. Side-view of *Amphoracrinus*: *a*, the opening, at the base of the arms, into the visceral cavity; *b*, the passages in the shell from the base of the arms to the apex.

3. Cast of *Actinocrinus tessellatus*, Phillips.

4. Top-view of *Cyathocrinus planus*, Miller. The proboscis, on the lower side of the figure, is broken off.

5. Side-view of *Rhodocrinus*, with portions of the arms attached.

6. A pair of the arms of *Rhodocrinus*; enlarged about $\frac{4}{3}$; showing the openings under them: *a*, opening with striæ round it for the articulation of the fillet *b*, shown under the other arm.

7. Section of *Pentremites ellipticus*, Sowerby; enlarged: *a*, the opening in the 'lancet-plate.'

8. Section of a pair of tubes and the 'lancet-plate' of *Pentremites florealis*, Say; much enlarged.

9. Section of a pair of tubes and the 'lancet-plate' of *Pentremites inflatus*, Sowerby; much enlarged.

* Cyclopædia of Anatomy and Physiology, vol. ii. p. 40, and vol. iv. p. 332.

- 10 & 11. Vertical and horizontal sections of the 'pectinated rhombs' of *Echinoencrinus armatus*, Forbes; enlarged $\frac{1}{2}$.
- 12 & 13. Vertical and horizontal sections of *Codonaster*; enlarged $\frac{1}{2}$: *a*, the position of the anal; *b*, of the central opening.
14. Vertical section of *Codonaster*; enlarged about $\frac{1}{2}$; showing the lining membrane.

III. GEOLOGICAL NOTES ON SCOTLAND.—No. I.

By GEORGE E. ROBERTS, Esq., F.G.S., &c.

ANY Geologist travelling to Nairn, *viâ* Perth, will be interested (in a degree compatible with his sense of the nuisance created) in the wonderful outspread of wind-blown sand between Dalwhinnie and Kingussie. I do not know any more wonderful *drift* of sand than is here displayed; a sand-surface so constantly in motion, that I believe it must really be in connection with the ever-shifting sand-drift of Culbin, near Elgin, which may be rightly termed the British Sahara. The nuisance caused by the constant settlement, even in the calmest weather, of this fine-grained siliceous sand upon everybody and everything passing through the district, was annoying enough, even in the old coaching days, but is increased tenfold to the traveller now that the Central Scottish Railway has superseded the more tedious method of travel; for the more rapid rate of motion raises such legions of blinding sand-atoms, that when Forres Junction was reached, a traveller is scarcely recognizable for the dust, and the vacant cushions are coated two inches deep. Indeed, I would call special attention to the Sands of Culbin, mentioned as probably being in geographical connection with the shifting sands cut through by the railway, as they have afforded the best instance of a real sand-storm known in Britain; hills of blown sand, from 60 to 100 feet in height, and from 200 to 300 feet in circumference, having been formed by wind-action during a single night.

The remarkable isolated mound of gravel and sand which stands in the throat of the Great Glen, about half a mile from Inverness, has always claimed the interest of geologists specially interested in the subject of drift-accumulations. To those who have not seen it, I may explain that it is a mound, about 130 feet high, 600 long, and 250 wide, shaped like a galley turned upside down, from whence its name, Tomnahuirich. It is undoubtedly the remains of an accumulation of water-borne drift derived from the hills which tower over the chain of lakes now utilized as the 'Caledonian Canal.' I allude to it, however, on account of its geological composition having now been placed beyond a doubt; for however much I regretted to find that the well-wooded sides of the mound had been despoiled of some of their trees by the axe, I was rejoiced to see what fine sections were laid bare of well-stratified layers of sand and gravel, showing that the mound was but the remaining portion of a huge sand-bank which must, at a time prior to its denudation, have nearly closed the entrance of the 'Straits of Ness.' The spoliation of Tomnahuirich was a consequence of the hill having been chosen by