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XLVIII.—British fossil crinoids

F.A. Bather M.A. F.G.S.

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in front than behind, very obtusely angular at the sides, more finely sculptured than the head, very delicately but densely rugose, and finely punctured; the punctures are small but distinct, and separated from each other by about three diameters of a puncture, at the sides they are indistinct; the lateral fovea is small and round. There are no basal impressions. The elytra are less shining than the thorax, very finely coriaceous, with very closely-placed, minute, shining dots or granules; the striæ are fine, and in them some very fine punctures may be seen. The metasternum is shining, with an interrupted median impressed line, slightly curved down anteriorly, and then more obliquely declivous, the front part rather dull, rather closely asperate-punctate and pilose, with an indication of a small angular tuberosity in the middle. The anterior femora have a small tooth rather beyond the middle. ♀.

This species is allied to *G. hilaris*, Hope, but the thorax is more narrowed at the base, &c.

XLVIII.—*British Fossil Crinoids*.

By F. A. BATHER, M.A., F.G.S.

II. *The Classification of the Inadunata Fistulata* (continued from p. 334).

[Plate XV.]

DIFFERENTIAL CHARACTERS.

C. *The Arms*.

We have now to consider the value of Arm-characters in classification. Here the main principles are so simple and so generally acknowledged that their discussion need not detain us long. They are as follows:—

The simplest form of arm consists of a series of ossicles continuing the line of the Radial; the joint-faces of the ossicles are parallel to one another, and there are no pinnules. This, it is fairly obvious, must also be the most primitive form of arm: examples are, *Hybocrinus*, *Hoplocrinus*, and *Baerocrinus* (Pl. XV. figs. 1a, b).

Nearly as simple would be an arm splitting in two, on the 2nd or 3rd costal as axillare, and of which each half should resemble the preceding type: such arms are not indeed found in any known *Fistulata*, but they represent a stage through

which that group must have passed. What appears to have been the case is that this dichotomy once started was rapidly continued, so that the next stage presents us with arms dividing equally at fairly regular intervals: *Dendrocrinus*, *Homocrinus*, *Iocrinus*, *Merocrinus*, *Cyathocrinus*, and a few genera closely allied to these have arms of this type (Pl. XV. figs. 2, 3, 4). As every additional bifurcation is an advantage to the animal, it is reasonable to suppose that an arm with a large number of terminal branches is more advanced in development than one with few; some species of *Cyathocrinus* for instance have a far larger number of bifurcations than others.

The next stage shows one limb of each bifurcation after the first becoming smaller than the other; thus, instead of one regularly dichotomous arm, there arise two main arms with bifurcating branches given off alternately on either side. At first these branches attain quite or almost the length of the main arm, e. g. *Heterocrinus*, *Ohioocrinus*, and *Belemnocrinus* (Pl. XV. figs. 5, 6, 7, 20). The advantage of such an arrangement over simple dichotomy is not at once obvious, but it seems to be that the food-grooves are thus more evenly distributed over the area covered by the extended arms; further we may suppose the arms to be more easily wielded when there is a stout median ridge. At any rate further evolution takes place in this direction; the main arm becomes fringed with armlets which again bear small lateral branches, e. g. *Vasocrinus*, *Barycrinus*, and some *Botryocrini* (Pl. XV. figs. 9, 10). When finally the armlets become small, cease to branch, and are regularly placed on alternate sides of successive joints, they are called Pinnules; a species of *Botryocrinus* from the Wenlock Limestone is the earliest form known to have reached this stage, which is again exemplified in *Decadocrinus*, *Scytalecrinus*, *Graphiocrinus*, and other allied genera (Pl. XV. figs. 13, 14, 15).

This, however, is not the only way in which pinnulate arms have arisen; pinnules of course always originate in the same way, but their arrangement on the arm may be different. *Anomalocrinus* (Pl. XV. fig. 11) is enough to show that pinnules may be developed directly on a dichotomous arm, although it is so anomalous a form that it leads no further. But the pinnules of *Scaphiocrinus* and *Poteriocrinus* also appear to have arisen on dichotomous arms without interfering with the dichotomy (Pl. XV. fig. 12); how this may have happened is seen in a very beautiful specimen of *Cyathocrinus* in the British Museum in which the arms are very finely divided at the tips and so closely resemble pinnules that even Mr. Springer was deceived when he examined the

specimen. Similar minute division of the arms is common in *Homocrinus* and may equally well have occurred in *Pariscrinus*; and it is with these genera rather than with *Cyathocrinus* that *Poteriocrinus* is in other respects allied. Pinnulate arms of this type may continue to increase in complexity by dichotomy, and then by giving off lateral branches just in the same way as simple arms; but such complexity does not appear till the Mesozoic Epoch.

The types of arm hitherto considered are uniserial, *i. e.* with the joint surfaces of the ossicles more or less parallel to one another. But in pinnulate arms, since every ossicle of the main arm is really an axillare with its two upper joint surfaces unequal in size, there arises a zigzag arrangement of the joint surfaces. This may be so intensified as to produce a biserial arrangement of arm-ossicles; thus in a given length of arm the number of pinnules is doubled, greatly to the advantage of the animal. This biserial arrangement is chiefly developed in the genera with the two main arms in each ray; the same physiological end is attained in a different manner by the genera with dichotomous arms.

The foregoing statement of facts will probably be accepted by all; from it the following consequences arise:—Neither the branching of the arms by itself, nor the development of pinnules by itself can be taken as characters indicative of divergence, for similar evolution may have taken place along many different lines. As regards arms, for instance, no one would associate *Ohioocrinus* with *Vasocrinus*, *Holocrinus* with *Scytalecrinus*, *Iocrinus* with *Homocrinus* or *Cyathocrinus*, or *Euspirocrinus* with *Oncocrinus* because these genera happen respectively to have very similar arm-structure. The unimportance of pinnules on the other hand is best exemplified by the genus *Botryocrinus*, for while the Swedish species have armlets and not pinnules, the common Dudley species has undoubted pinnules and its arm-arrangement in no way differs from that of *Decadocrinus*. In recent Crinoids pinnules differ from arms only by containing the fertile portions of the genital glands; but it is pretty obvious that in these older Crinoids without pinnules, the genital products must have been borne at the tips of all the arm-branches: hence the physiological difference need not even have been so great as the morphological. There is, however, one character, or rather combination of characters, which seems to be of rather greater importance, and that is the persistence of a simply bifurcate arm bearing first armlets and then pinnules, as opposed to the development of pinnules on a dichotomous arm. Between these two types no connecting-links are evident.

Arm-characters in general may, however, be used as a check on other methods of classification; they enable us to correct possible errors in phylogeny, for instance a pinnulate form cannot be the ancestor of one with simple arms. In this aspect their study proves of great importance.

D. *Modes of Union.*

The different varieties of suture and articulation by which the plates and ossicles of Crinoidea are held together will be found explained in the section on Terminology (p. 314, *antè*) under the words Syzygy, Close Suture, Loose Suture, and Muscular Articulation; repetition is therefore unnecessary.

On the variations of these structures in different genera Messrs. Wachsmuth and Springer have laid some stress (Rev. III. (189) Proc. 1886, p. 113), and have taken the greater differentiation of articulation in their family Poteriocrinidæ as "a good distinction" between them and their family Cyathocrinidæ. These differences are, however, rather of degree than of kind; loose suture and even articulation may take the place of a close suture whenever there is any need for greater movement; while on the other hand a sutural union may become syzygial when greater firmness is required. It would certainly not be philosophical to separate a genus because certain of its articulations were better developed than those of the other genera of its family. Undoubtedly, however, some amount of regular evolution is observable in this point; later forms, as a rule, combine firmness and free motion, while earlier forms are but slightly flexible.

A difference of union, correlated with a difference in arm-branching already pointed out, is worth notice. In dichotomous pinnulate arms the several axillaria are united to the succeeding plates by muscular articulation; in simply bifurcating pinnulate arms there is only one axillare that can be so united. Thus the more cumbrous dichotomous arms have their powers of movement equalized with those of the simply bifurcating arms (*Decadocrinus*, *Scytalecrinus*). But in some later genera of the simply bifurcate type the balance is again brought over by the articulation of several of the proximal arm-plates (*Graphiocrinus*, *Erisocrinus*, *Eupachyrinus*), such as never takes place in dichotomous pinnulate arms.

PRINCIPLES OF CLASSIFICATION.

The chief variations in the structure of the *Fistulata* considered, it only remains to be seen how we can best frame a

classification that shall show the true relationships of the various genera. For it is this which has come to be the object of Systematic Biology. Morphology nowadays devotes itself to tracing the past history and true kinship of the forms of life; most especially is this the province of those divisions of the science known as Embryology and Palæontology. But whereas Embryology deciphers its history in the palimpsest of an individual, Palæontology reads records that are both consecutive and distinct. The first step then is to gather from the successive fossils the actual history of the lines of life. Two forms might be very similar, but if one came from the Cambrian and the other from the Trias, we should hesitate to place them near one another before having worked out the actual descent; indeed we should not be surprised to find them belonging to quite different Families. This, however, might equally be the case with two forms not only similar but contemporaneous. How many a group once thought to be self-centred and clearly circumscribed has been proved to have a polygenetic origin!

But Palæontology, while thus indicating the solution of one problem of classification, puts before us another of no less difficulty. The Zoologist, or—to better name him—the Neontologist, deals with forms co-existing at a single epoch; the Palæontologist has to deal with forms that come and go through many an earth-period. A line of life not only gives off branches, but itself varies, so that the later descendants differ greatly from their earlier ancestors. The problem is to express this latter variation in Classification. A new term is required: a *Series* must be distinguished from a *Division*; the former is a difference in degree, the latter in kind. I have thought it necessary to draw attention to these well-known principles, for any Classification must depend on its methods no less than on the facts to be represented by it, and every one's method does not seem to be the same. It is in fact the fashion with a certain school of naturalists to sneer at phylogeny. But surely to learn the history of the races of living beings, and the laws governing that history, is the object of all our labours. On this alone can a true and final Classification be based, and to express this in convenient form is the Classifier's only purpose.

GEOLOGICAL HISTORY.

Let us then turn to the history of the Fistulate Crinoids. The outline of this history must be sought for in the time-succession of the various genera. This is expressed in the
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accompanying Table (I.) of Geological Distribution. The American rock series has been taken as the most convenient; for the horizons of the various fossils are more distinct and have been more carefully noted by American geologists, and Crinoids appear to be found in America at more horizons than in Europe. The horizons or localities of extra-American genera are noted in brackets: W. L.=Wenlock Limestone and M. L.=Mountain Limestone. To those who have read carefully the earlier part of this paper, a mere inspection of this table will suggest the various lines of descent. So far as positive evidence goes there is nothing here to conflict with the history of evolution in various structures as sketched out in preceding sections. There are of course gaps in the chain of evidence; but these were to be expected. Their slight importance is brought out more clearly by the plan here adopted of printing the name of a genus only opposite those strata in which it has actually been found. *Calceocrinus* for instance, which is known in the Niagara and Wenlock Limestones and which persists with slight modifications to the Keokuk, must have been living in the Waverley, Chemung, and Helderberg eras. Till it has been discovered we need not hope to find forms intermediate between, say, *Botryocrinus* and *Vasocrinus*. Moreover the sudden appearance in the Trenton Limestone of no less than 9 genera, all very distinct from the 3 rare genera found in earlier rocks, is an obvious indication of a series of Cambrian ancestors as yet known only by a few undecipherable fragments: it is as unnecessary, as it would be absurd, to derive all these from *Hybocrinus* and *Hoplocrinus*.

Among the forms known from the Trenton and earlier rocks are both Monocyclic and Dicyclic genera. I have already given reasons to show that Monocyclica may have been derived from Dicyclica (p. 318 *antè*); but the table shows that certain Monocyclic forms are actually the earliest known, viz. *Hybocrinus*, *Hoplocrinus*, and *Baerocrinus*. Now these forms differ so markedly, both in the arm-structure and in the arrangement of the anal plates, from the other early Monocyclica that they must be regarded as quite a separate family. It is impossible to derive any of the other genera immediately from them. This family—the Hybocrinidæ of v. Zittel, as emended by Wachsmuth and Springer—may therefore be set on one side, and the course thus far cleared.

The remaining Monocyclica of the Trenton are *Ectenocrinus*, *Heterocrinus*, *Iocrinus*, and *Castocrinus*. Of these the last is obviously already much modified in the direction of *Proclivocrinus* and *Calceocrinus*; if the line along which the

* Dr. Ringueberg tells me of this in a letter dated 5th March, 1890.

[illegible]

development of these genera has proceeded be prolonged *backwards* instead of forwards, we arrive at an ancestral image not unlike *Ectenocrinus*, *Heterocrinus*, or *Iocrinus*. We therefore conclude that these latter forms approach more nearly to the common ancestor. It remains to be seen which of the three is the most ancestral. In the first place *Iocrinus* has a simpler structure so far as the radials proper are concerned; and that in this case the simplicity is archaic I have already tried to show (p. 327, end of first paragraph). Secondly as regards the anal plates I have argued that *Iocrinus* represents a more primitive condition (top of p. 330). Thirdly the arms are simply dichotomous and not at all specialized into main arm and armlets. These arguments should be enough; but to my mind the existence of an exactly similar and contemporaneous form among the Dicyclica—viz. *Merocrinus*—proves that the two were descended from an ancestor possessing their common characters, and probably with a Dicyclic base. This ancestor then, if its existence be granted, was likewise the progenitor of *Ectenocrinus* and *Heterocrinus*, and, among the Dicyclica, of *Ottawacrinus* and probably *Carabocrinus*, and possibly of *Dendrocrinus* and *Euspirocrinus*.

The Monocyclic base is of course enough to separate *Ectenocrinus*, *Iocrinus*, &c. from the Dicyclic genera, and at their subsequent history we shall now do well to glance. Whether *Heterocrinus* or *Ectenocrinus* be the older is hard to say; *Heterocrinus* probably, as the brachianal is in a slightly more primitive position; the arms also are simpler in that the armlets are not so reduced in size, and the syzygial union of alternate joints characteristic of *Ectenocrinus* is not here developed. Be this as it may, *Ohioocrinus* is, both in time and arm-development, a natural descendant of *Heterocrinus*. *Anomalocrinus* is a peculiar offshoot from the same stock. Further than this it is impossible to trace the history of this family. *Edriocrinus*, *Belemnocrinus*, and *Holocrinus*, though Monocyclic, had certainly a different origin; *Edriocrinus*, however, is so extremely specialized in other respects that one cannot perceive its true affinities.

Mycocrinus and *Catillocrinus* appear to be connected in the structure of the dorsal cup with *Calceocrinus*; but the drooping on the stem, which seems to have been the main factor in inducing the structure of *Calceocrinus*, does not operate here. The resemblance may be merely homoplastic; if anything more, we must suppose that structures originally selected as conducing to one special object, were on a sudden diverted to another quite distinct. The peculiar arm-arrange-

ment may have arisen from the modified lateral arms of *Calceocrinus* along lines similar to those followed in the evolution of *Crotalocrinus*. The whole problem, however, is one that, in the absence of more complete knowledge, admits of much speculation but of no satisfactory solution.

To pass to the Trenton Dicyclica—similar reasons cause me to regard *Merocrinus* as the most ancestral of the 5 genera. From *Merocrinus*, *Ottawacrinus* differs but little, and the two were doubtless derived from a common ancestor of not much earlier date. With this same ancestor *Carabocrinus*, though an anomalous form, may have been closely connected. But *Dendrocrinus* was probably derived more directly from *Ottawacrinus*, which, except in the development of a radianal, it closely resembles. *Euspirocrinus* again shows, so far as the arrangement of the anal area is concerned, a slight advance on *Dendrocrinus*, from an immediate ancestor of which genus it was probably descended. The arms of these genera resemble one another in their simple dichotomy, and afford no evidence either way. One thing is plain—*Merocrinus*, *Ottawacrinus*, *Dendrocrinus*, and *Euspirocrinus* are all closely connected, and are all primitive. Their exact relationships are of less importance.

Proceeding to the Niagara and Wenlock Limestones we find, chiefly in the Old World, a great influx of new forms. *Thenarocrinus* may be connected with *Carabocrinus*, but its exact significance will be more fittingly discussed in a later paper. *Homocrinus* very obviously carries on the line of *Dendrocrinus*. *Euspirocrinus* of Gothland and *Closterocrinus* of the Clinton group are direct descendants of the Trenton *Euspirocrinus obconicus*, while *Ampheristocrinus* is a very close relation.

The four genera *Streptocrinus*, *Arachnocrinus*, *Cyathocrinus*, and *Gissocrinus* resemble one another in the presence of a large brachianal in line with the radials, and in the absence of a radianal. In this latter respect they differ from all their contemporaries; and here a moot point crops up:—has the radianal become atrophied in *Cyathocrinus*, or was it never developed? Messrs. Wachsmuth and Springer adopt the former, I incline to the latter view. If my reading of *Ottawacrinus* (Pl. XIV. fig. 12) be correct, it is very easy to derive *Cyathocrinus* and its allied genera from that genus without supposing such a waste of force as the sudden growth and more sudden disappearance of a radianal. The American authors were evidently driven to their view by their belief that the radianal was a primitive element of the dorsal cup. They will perhaps point out that *Botryocrinus* and *Sicyocrinus*

actually represent the intermediate stages in the atrophy of the radianal; this, however, is disproved by the arms, for while those of *Cyathocrinus* &c. are simply dichotomous, the more specialized armlets are already developed in *Sicyocrinus* and *Botryocrinus*.

Clearly then the Dicyclica of Niagara and Wenlock age must be divided into three groups: one with brachianal, large radianal, and tendency of tube-plates to sink into dorsal cup; a second with large brachianal only; and a third with large brachianal and with small radianal. The first group has rather slender, long, dichotomous arms; the second has short, rather stout, dichotomous arms; the third has stouter arms, as a rule with armlets.

Following the fortunes of the first group, *Homocrinus* leads us through the Lower Devonian to the Eifel-Kalk of Europe and the Hamilton group of America. Here occur *Parisocrinus*, *Poteriocrinus*, and *Scaphiocrinus*, all closely resembling one another in the anal area, and in this point also not far removed from *Homocrinus*. The main difference is observable in the arms; those of *Homocrinus* and *Parisocrinus* are simple and dichotomous, while those of *Poteriocrinus* and *Scaphiocrinus* are already pinnulate. There is here one of those gaps which a better knowledge of American Devonian Crinoids would probably fill. From *Scaphiocrinus* through *Woodocrinus* to *Caeliocrinus* and *Hydreionocrinus* the stages are gradual and easily traced.

It is convenient next to take the third group mentioned above, viz. the *Botryocrinus* group. Here again is a great gap: at the same time there can be little doubt that both *Vasocrinus* and *Barycrinus* are direct descendants of *Botryocrinus*; with them *Atelestocrinus* is closely connected. *Decadocrinus*, which comes in with *Vasocrinus*, appears to me to be also descended from *Botryocrinus*, although it is rather further removed from it than is *Vasocrinus*. With *Decadocrinus* are closely connected the rather later forms *Graphiocrinus* and *Scytalecrinus*. *Graphiocrinus*, however, presents that modification in the anal area (Pl. XIV. fig. 36) which through *Bursacrinus*, *Phialocrinus*, and *Synnyphocrinus* leads on to *Erisocrinus*, *Ceriocrinus*, and *Stemmatocrinus*, and culminates in the Triassic *Dadocrinus* and *Encrinus*. A different modification of the *Decadocrinus* type is seen in *Eupachyocrinus*, with which *Tribrachiocrinus* is probably to be connected. *Cromyocrinus* is a direct offshoot from *Eupachyocrinus* and to it in turn *Agassizocrinus* is closely allied.

These relationships are so obvious, and in fact so generally

acknowledged, that I have not judged it necessary to enter into details. But there is one point in which I differ very materially from previous writers; that is the separation of these forms which I have just described as descended from *Botryocrinus*. Other authors place them close beside *Poteriocrinus* (s. str.) and *Scaphiocrinus*. But the dichotomous many-branched arms of these two genera and their allies could hardly have sprung from the bifurcate, heavily pinnulate arms of *Decadocrinus*, *Graphiocrinus*, and *Scytalecrinus*, without leaving some traces of the process; these latter closely resemble the arms of *Vasocrinus* and of some species of *Botryocrinus*. This seems a sufficient reason for separating the two groups; I have already alluded to differences of articulation connected therewith; besides this there is a general similarity of what is called "habit" in the members of each group, and there is certainly nothing to oppose their alliance in this manner.

To return to the *Cyathocrinus* group; that genus itself persists unchanged to the Coal-measures. In *Codiocrinus* the brachial seems to have been again raised above the level of the radials, and has not yet been observed. *Achradocrinus* shows an atrophy of the brachial, and a diminution of the arms, characters which are still more pronounced in *Hypocrinus*. *Lecythocrinus* is probably a descendant of *Gissocrinus*, and *Lecythiocrinus* of *Codiocrinus*.

The Dorsal Cup of *Belemnocrinus*, except for its monocyclic base, resembles that of *Cyathocrinus*; the arms show a tendency to the development of armlets, but are not a great advance on those of *Cyathocrinus*: on the whole I incline to the belief that this genus is descended from *Cyathocrinus*, but that intermediate stages have not yet been found. *Holocrinus* is an advance on *Belemnocrinus* both as regards atrophy of the brachial and the conversion of armlets into stout pinnules.

In each of these lines there is a gradual development of articulation; this, however, can merely serve to confirm the general evolution, and it varies so much according to the needs of individual genera that under no circumstances could any great argument be based on it.

CLASSIFICATION.

The Genealogy of the *Fistulata* may be summed up in the accompanying table (Table II.). It is of course needless in the present year of grace to point out the differences between a scheme such as this, which shows general relationships, and

Table II.—GENEALOGICAL TREE OF FISTULATE CRINOIDS.

a tree that follows out the descent of individuals. To represent this in convenient classificatory form is the final problem.

First there is a group which one feels almost inclined to remove entirely from the *Fistulata*, viz. the *HYBOCRINIDÆ*; the ventral sac of *Hybocrinus* and *Hybocystis*, in which genera alone it has been observed, is very small, and its truly fistulate nature doubtful*.

There are next two main groups, one of which includes the families *HETEROCRINIDÆ* (to which I add *Anomalocrinus*), *CALCEOCRINIDÆ*, and *CATILLOCRINIDÆ*. So far the families are very nearly the same as those maintained by Messrs. Wachsmuth and Springer.

The second group, which comprises all the *Dicyclic* and two *Monocyclic* forms, must be again split up, and here a rather different arrangement from that of previous writers seems inevitable.

First comes a Division characterized by brachianal, large radianal, and usually some other anal plates in the dorsal cup, and by dichotomous arms. This can again be divided into three; on one side a Family including *Carabocrinus* and *Thenarocrinus*, but of this I am doubtful; on the other a Family of *Euspiocrinus* and its descendants, and in the middle a Family continuing the main line through *Dendrocrinus*; this is conveniently split into two Series marking the development of pinnules; Series 1. may be called **Dendrocrinites**, Series 2. **Scaphiocrinites**. The Family itself, which will include *Merocrinus* and *Ottawacrinus*, may be called *DENDROCRINIDÆ*.

The next great Family starts from *Botryocrinus*, and this again must be split into series; the **Botryocrinites** will include all in which the radianal is rudimentary, and pinnules as a rule not yet evolved from armlets; the **Scytalecrinites** will include *Decadocrinus* and *Scytalecrinus*, both of which are elongate (*σκυτάλη*), have three anal plates in dorsal cup, and have pinnules; the **Graphiocrinites** will include genera in which the radianal is lost but in which the brachianal remains in the limits of the dorsal cup; the **Erisocrinites** of Wachsmuth and Springer may remain, or may be included with the **Encrinites**, as comprising genera in which no anal plate remains in the dorsal cup of the adult; the **Cromyocrinites** will include the rounded forms in which the three anal plates are retained in the cup. In allusion to the ten arms borne by all genera of the Family, the name *DECAOCRINIDÆ* may be fitly applied to it.

* W. & S. Rev. III. (199, 200) Proc. 1886, p. 123.

The last great family consists of descendants of *Cyathocrinus*, and for it may be best retained the name CYATHOCRINIDÆ, though at the risk of some confusion with the previous applications of the term; but these applications have been so numerous that one more can hardly make the confusion worse confounded than it already is. It will be advisable to separate this family into *Cyathocrinites*, *Codiocrinites*, *Achradocrinites*, and *Belemnocrinites*.

Possibly, however, the Family BELEMNOCRINIDÆ, as its origin is so uncertain, may be allowed to stand as Wachsmuth and Springer defined it (Rev. III. (193) Proc. 1886, p. 117).

The Classification then may be tabulated as follows:—

FISTULATA.

? Fam. HYBOCRINIDÆ. *Hybocrinus*, *Hoplocrinus*, *Baerocrinus*.

GROUP A.

Fam. 1. HETEROCRINIDÆ. *Iocrinus*, *Heterocrinus*, *Ectenocrinus*, *Ohiocrinus*, *Anomalocrinus*.

Fam. 2. CALCEOCRINIDÆ. *Castocrinus*, *Proclivocrinus*, *Calceocrinus*.

Fam. 3. CATILLOCRINIDÆ. *Mycocrinus*, *Catillocrinus*.

GROUP B.

Fam. 1. DENDROCRINIDÆ.

Series 1. **Dendrocrinites**. *Merocrinus*, *Ottawacrinus*, *Dendrocrinus*, *Herpetocrinus* (?), *Homocrinus*, *Parisocrinus*.

Series 2. **Scaphiocrinites**. *Poteriocrinus*, *Scaphiocrinus*, *Woodocrinus*, *Zeacrinus*, *Cœliocrinus*, *Hydreionocrinus*.

Fam. 2. ? CARABOCRINIDÆ. *Carabocrinus*, *Thenarocrinus*.

Fam. 3. EUSPIROCRINIDÆ. *Euspirocrinus*, *Closterocrinus*, *Ampheristocrinus*.

Fam. 4. DECAOCRINIDÆ.

Series 1. **Botryocrinites**. *Botryocrinus*, *Sicyocrinus*, *Oncocrinus*, *Vasocrinus*, *Barycrinus*, *Atelestocrinus*.

Series 2. **Scytalecrinites**. *Decadocrinus*, *Scytalecrinus*.

Series 3. **Graphiocrinites**. *Graphiocrinus*, *Phialocrinus*, *Ceriocrinus* (*Bursacrinus*, *Synsphyocrinus*)?

Series 4.—(a). **Erisocrinites**. *Erisocrinus*, *Stemmatocrinus*.

(b). **Encrinites**. *Dadocrinus*, *Encrinus*.

Series 5. **Cromyocrinites**. *Eupachycrinus*, *Tribrachioocrinus*, *Cromyocrinus*, *Agassizocrinus*.

Fam. 5. CYATHOCRINIDÆ.

Series 1. **Cyathocrinites**. *Cyathocrinus*, *Streptocrinus*, *Arachnocrinus*, *Gissocrinus*, *Lecythocrinus*.

Series 2. **Codiacrinites**. *Codiocrinus*, *Lecythiocrinus*.

Series 3. **Achradocrinites**. *Achradocrinus*, *Hypocrinus*.

Fam. 6. BELEMNOCRINIDÆ. *Belemnocrinus*, *Holocrinus*.

Incertæ sedis—*Edriocrinus*.

It seems unnecessary to indicate the diagnostic characters of these families and series more clearly than has been already done. The more *natural* a classification is, the more difficult must be any attempt at definition: as knowledge grows, delimitations vanish. Not that this classification is either natural or complete; of its imperfections in those directions no one can be more sensible than myself. The facts, indeed, on which the argument has been based have been verified as far as possible; the labour of collecting them, which would otherwise have been too great, has been lightened by the previous work of Messrs. Wachsmuth and Springer, to whom all students of palæozoic crinoids owe a debt of gratitude. That I differ from these authors is due partly to difference in the interpretation of the facts, partly to a difference of principle. The principles that govern the above classification, though not yet universally accepted, are steadily gaining ground among biologists. It is in the interpretation of the facts that the real difficulty lies, and here I am as likely as not to be wrong. Increased knowledge alone can solve our problems. The proposed classification should be regarded as

a scaffolding necessary for the erection of that more solid structure to which it must one day give place.

EXPLANATION OF PLATE XV.

(Illustrating chief types of Arm-structure in Fistulate Crinoids.)

While the figures of this Plate are necessarily diagrammatic, they have been constructed either from actual specimens or from the best published drawings obtainable. Their order is merely intended to facilitate comparison and follows no scheme of classification. It is not possible to indicate in such a Plate the various degrees of articulation, but in figures 7 & 20 syzygies are represented by dotted lines. In each figure the radial is drawn in whole or in part. In the following notes the specific name is inserted when that particular species has served as copy for the diagram; other species of the genus have of course the same general structure. In the case of a genus not actually figured, the number indicates the type to which it approximates in arm-structure.

Achradoerinus—arms unknown.

Agassioerinus—15; long, stoutish; ossicles short, cuneate; pinnules strong.

Ampheristocrinus—one brachial only known, quadrangular and very small.

Anomalocrinus—11; figure based on description by W. & S. Rev. III. (212) Proc. 1886, p. 136.

Arachnoerinus—3; heavy, scarcely diminishing towards tips; ossicles short, quadrangular, but axillaries longer.

Atelestocrinus—10; armlets from every 2nd ossicle, on alternate sides, extend to tips of arms.

Baerocrinus Ungeri—1 a; after Grewingk, from P. H. Carpenter, Quart. Journ. Geol. Soc. xxxviii. pl. xi. fig. 1.

Baryerinus—10; arms sometimes branch again on 3rd or 4th distichal, but never in anterior ray, and only in one arm to a ray; in *B. tumidus* (?) the antero-lateral rays have only one main arm apiece.

Belemnoerinus typus—20; see W. & S. Rev. III. 1885, pl. v. fig. 10.

Botryocrinus ramosissimus—9; after Angelin, *op. cit.* pl. xx. fig. 8.

Botryocrinus sp. nondescr.—13; from specimens from Dudley.

Bursacrinus—arms branch, and are in contact laterally; distichals wide, flat, slightly cuneate; palmars less than half the width. W. & S. consider this so close to *Graphioerinus* that they have made it a subgenus thereof; otherwise its place would seem to be with the Scaphioerinites, near *Woodoerinus*, from which it differs in the more advanced condition of the anal area. Without seeing specimens I do not like to venture on the alteration.

Calceocrinus—pinnules not developed; lateral arms dichotomize in a peculiar manner, out of the ordinary line of evolution.

Carabocrinus—3; arms short compared with size of calyx.

Castocrinus—arms irregularly dichotomous, non-pinnulate.

Catilloerinus—arms simple, not branched, many rise from a single radial as shown in Pl. XIV. fig. 29.

Cerioerinus—15.

Closterocrinus—arms obscure, see Hall, Pal. N. Y. vol. ii. p. 179, pl. xli A. figs. 2 a-f.

Codiocrinus—3; see Follmann, "Unterdevonische Crinoiden," Verh. d. nat. Ver. preuss. Rheinh. xlv. pl. iii. fig. 1, 1887.

- Cælicrinus*—"in its arm-structure leans decidedly towards *Woodocrinus*," W. & S. Rev. III. (245) Proc. 1886, p. 169.
- Cromyocrinus*—15; brachials short, at first quadrangular, then cuneate and in some species interlocking.
- Cyathocrinus*—3.
- Dadocrinus Kunischi*—17; after Kunisch, Zeitschr. d. deutsch. geol. Ges. xxxv. pl. viii. 1883. In the separation of *Dadocrinus* and *Holocrinus* from *Encrinus*, I have followed W. & S.; for a conspectus of the literature see H. Eck, "Bemerkungen über einige Encrinus-Arten," Zeitschr. d. deutsch. geol. Ges. xxxix. 540, 1887.
- Decadocrinus*—14.
- Dendrocrinus*—4.
- Ectenocrinus*—7.
- Edriocrinus*—arms broad at base; in *E. sacculus* costals 10 or more, dischials 3 or 4, palmars 3 or 4, all very short and wide; nothing known of pinnules; Hall, Palæont. N.Y. iii. pl. lxxxvii. fig. 10.
- Encrinus*—18.
- Erisocrinus*—15; costals abut laterally; brachials uniserial, transversely oblong.
- Eupachyocrinus*—as in *Cromyocrinus*; arms from 1 to 3 in a ray.
- Euspirocrinus*—3; ossicles stout and wide.
- Gissocrinus*—3.
- Graphiocrinus*—15.
- Herpetocrinus*—4.
- Heterocrinus exilis*—5 a; *H. juvenis*—5 b; both after Hall, Rep. Geol. Surv. Ohio, Palæont. i. pl. i. figs. 12 and 3 a.
- Holocrinus Beyrichi*—19; after Picard, Zeitschr. d. deutsch. geol. Ges. xxxv. pl. ix. figs. 4 and 1.
- Homocrinus*—4.
- Hoplocrinus*—1 b.
- Hybocrinus conicus*—1 b; after E. Billings; in Canadian Org. Rem. decade iv. pl. ii. fig. 2 b, the long arms are all shown.
- Hydreionocrinus*—16; throw off branches towards inner side of ray, meet laterally; earlier ossicles cuneate and tend to interlock; pinnules short.
- Hypocrinus*—arms unknown, evidently very small.
- Iocrinus*—2.
- Leeythiocrinus*—arms unknown.
- Lecythiocrinus*—3; see Schultze, "Echinod. Eifer Kalkes," Denkschr. k. Akad. Wiss. xxvi. pl. iv. fig. 1, Wien, 1867.
- Merocrinus*—2; see Walcott, State Mus. 35th Regent's Rep. pl. xvii. figs. 5 and 6, 1883.
- Mycocrinus*—arms unknown, probably as in *Catilloocrinus*.
- Ohiocrinus oehanus*—6; after Ulrich, Journ. Cincinn. Soc. Nat. Hist. v. pl. v. fig. 9.
- Oncocrinus*—simple, dichotomous, with broad ossicles. *Cyathocrinites scrobiculatus*, Hisinger (Leth. Suec. Suppl. Secund. p. 6, tab. xxxix. fig. 4, a, b, c: Stockholm, 1840), appears to be of the same genus as the specimens I was about to describe as *Oncocrinus bucephalus*. *C. scrobiculatus*, however, has been referred by Angelin (Icon. Crinoid. pp. 13 and 14) to his genus *Pycnosaccus*. This genus has been placed by W. & S. in the Ichthyocrinidæ as a subgenus of *Lecanocrinus* (Rev. I. (41) Proc. 1879, p. 264), and, so far as *P. nodulosus*, Ang., is concerned, they are no doubt right. *P. costatus*, Ang., was by both Angelin and W. & S. regarded as belonging more probably to the Cyathocrinidæ (*auctorum*); this also seems correct. But *P. costatus* was in

Angelin's opinion allied to *C. scrobiculatus*, and I believe that the latter also should be removed from *Pycnosaccus*; only the evidence of Angelin's pl. xv. fig. 11 could lead one to retain it in that genus, and this figure has a most artificial appearance. Until, therefore, an examination of the type specimens is possible, I shall, for convenience' sake, continue to speak of *Oncocrinus*.

Ottawacrinus—(4?) ; beyond the 6 quadrangular costals nothing is yet known.

Parisocrinus radiatus—8 ; after de Koninck and Le Hon, Recherches sur les Crin. carb. Belgique, pl. i. fig. 12 *b*.

Phialocrinus—15.

Philocrinus—16.

Poteriocrinus—12.

Proclivocrinus—as *Calceocrinus*, *q. v.*

Scaphiocrinus Swallowi—12 ; in this sp. the ossicles interlock towards tips of arms ; after Whitfield, Amer. Mus. Nat. Hist. N. Y. Bull. i. December 1881, sub *Poteriocr. Jesupi*. For clearness' sake the pinnules are only shown along one set of branches.

Scytalecrinus—15.

Sicyocrinus—9.

Sphaerocrinus—3.

Stemmatocrinus—18. See Trautschold, "Mon. Kalkbr. Mjatschkowa," Mém. Soc. Imp. Nat. Moscou, xiv. pl. xiv. fig. 12 (1879).

Streptocrinus—3, but not much known of arms.

Synophocrinus—vide sub *Bursacrinus*.

Tribrachiocrinus—arms unknown except so far as shown in Pl. XIV. fig. 35.

Vasocrinus—10 ; 3 costals ; arms and armlets less robust.

Woodocrinus macrodactylus—16 ; after de Koninck, Mém. Acad. Roy. Belgique, xxviii. pl. viii. fig. 1 *c* (1854). For clearness' sake the pinnules are only shown along one branch.

Zeacrinus—16 ; dichotomize towards inner side of ray ; ossicles short, their width diminishes by $\frac{1}{2}$ in successive orders ; arms meet laterally, cf. *Bursacrinus*.

XLIX.—On some new and imperfectly-defined Species of Jurassic, Cretaceous, and Tertiary Nautili contained in the British Museum (Natural History). By ARTHUR H. FOORD, F.G.S., and G. C. CRICK, Assoc.R.S.M., F.G.S., Assistant in the Geological Department, British Museum.

In the last number of this Magazine we described and re-defined some species of Jurassic Nautili in the British Museum. In this article we complete for the present our work upon the Jurassic and take up the Cretaceous and Tertiary species. Since the former paper was published some Jurassic forms have been added, enabling us to describe a new species from the Lower Oolite.

Appended is a list (pp. 390 and 391) of all the Cretaceous and Tertiary Nautili now in the Museum, together with the new Jurassic species. The species are arranged in two

TYPES OF ARM-STRUCTURE IN FISTULATA.