sodium hydroxide solution used in comparing the hydrochloric and sulfuric acids was used, for which the ratio HCl:NaOH was 1.0464. The mean of four concordant determinations was 0.9981.

Summary and conclusion. The results of the foregoing standardizations are summarized in the following table:

SUMMARY OF STANDARDIZATIONS

Method	0.1 N *factor for* HCl
Direct by Hulett and Bonner	0.9980
Direct by AgCl	0.9984
H_2SO_4–$BaSO_4$–NaOH–HCl	0.9984
H_2SO_4–$Na_2C_2O_4$–NaOH–HCl	0.9982
$C_6H_5CO_2H$–Ba $(OH)_2$–HCl	0.9984
$C_6H_5CO_2H$–NaOH–HCl	0.9981

The close agreement of these results proves the accuracy of the benzoic acid method. Moreover, benzoic acid has many advantages. Its high molecular weight permits the use of large samples, thus reducing the error of weighing; its stability and lack of hydroscopicity make it very convenient; and the method is rapid, since a single weighing and a titration are all the operations involved. These considerations, combined with the ease of obtaining it in a high state of purity, make benzoic acid an excellent material to use as a standard in acidimetry and alkalimetry.

ZOÖLOGY.—*The homologies of the so-called anal, and other plates in the pentacrinoid larvæ of the free crinoids.* AUSTIN HOBART CLARK, National Museum.

In the course of my studies upon the recent crinoids I have been able to examine many hundreds of pentacrinoid larvæ belonging to numerous species distributed in several families, and many points hitherto involved in obscurity have been made clear.

Unfortunately all of the work previously done upon the developing crinoid has been based upon one or other of the species of the genus *Antedon,* one of the most specialized of the genera in the group to which it belongs, and hence one of the least satisfactory for purposes of phylogenetic investigation.

In *Antedon* the so-called anal plate is formed at about the period of development of the IBr_2, between the two posterior radials; but it is noticeable that while the radial to the left of it is of normal shape, that to the right has its left side more or less cut away for its reception. When the anal is lifted out from the circlet of radials just previous to its resorption it is noticeable that it keeps to the right of the posterior interradial area, remaining more or less in contact with the right hand radial and first primibrach, instead of being drawn directly upward as would be expected; also the right radial is asymmetrical, more convex on the right side than on the left (adjoining the anal) though after the withdrawal of the anal this asymmetry quickly disappears.

The general tendency of the anal plate of the young *Antedon* to keep to the right of the posterior interradial area, though very strongly marked, does not appear ever to have attracted attention; but it is nevertheless a fact of the very highest importance.

In more primitive species, in which the five infrabasals are large and equal in size, the anal appears to be formed before any of the radials, occupying a position in the rhombic area between the corners of the basals and orals. Soon afterward the radial appears, just to the right of and in line with it, between the basal and oral of that side and to the right of the vertical line dividing the basals and the orals. The radial grows much faster than the anal, which it gradually surrounds so that the latter comes to lie in a deep concavity in the side of the radial to the right of it and to the right of the posterior interradius, well to the right of the midline of the posterior basal. Later this right hand radial extends itself beneath the anal and the concavity becomes straightened out and disappears, the anal concurrently being shoved diagonally forward (toward the left) and disappearing by resorption.

In certain fossils groups there may be traced a progessive variation in the position of the radianal from a primitive position directly under the right posterior radial to an oblique position under the lower left hand corner of the radial, and finally to complete elimination. The position of the so-called anal in the larvæ of the more primitive comatulids, lying within a concavity in the lower left hand portion of the radial to the right of the posterior

interradius and its migration upward and toward the left leave no room for doubt that the so-called anal of the pentracrinoid larvæ is nothing more nor less than the radianal of the fossil forms.

Since the radianal is represented in the larvæ of the comatulids we should expect also to find a representative of the plate known as anal *x*. Now in forms in which the radianal is present anal *x* lies directly over the posterior basal, always to the left of the radianal and always maintaining a closer relation with the radial to the left of the posterior interradial area than with that to the right, with which the radianal is associated. Whereas the radianal is always a single plate, anal *x* commonly forms the base of a short series of more or less similar plates.

In the so-called *Thaumatocrinus renovatus* the posterior interradial area is occupied by a large interradial plate bearing upon its distal edge a conical process composed of a series of calcareous rings; this process lies to the left of the base of the anal tube, and therefore presumably to the left of the recently vanished radianal.

The free arms of the crinoids are composed of an extension of the boundary between the primarily skeleton forming dorsal surface and the perisomic ventral surface. Although phylogenetically very complicated, ontogenetically they arise as a linear (or double) series of ossicles, each new ossicle being added at the extremity of the series; none of the phylogenetic processes by which they originated are recapitulated. In short a crinoid arm in all the forms we know is nothing but a double or single series of ossicles supporting an extension of the ventral perisome—a series of simple braces of long forgotten origin.

The fixity of the crinoid arm as an individual structure entirely distinct from the crinoid arm as a phylogenetic complex—the conception of the crinoid arm as a structure with an identity of its own and with an ontogenetically completely obliterated phylogenetic origin—must constantly be kept in mind; for when we are able to grasp this idea we see at once that *any* series of ossicles arising on the border between the dorsal skeleton forming and ventral perisomic surfaces, and being composed in equal parts of each, will assume the structure common to all the processes arising in the same region, and will take on from the beginning the struc-

ture of the crinoid arm, exactly as every process from the centrodorsal will become a cirrus and every one arising on the distal corner of a brachial will become a pinnule.

Thus while a plate if situated below the ventral edge of the perisomic surface may give rise to a simple series of more or less similar plates running up to the edge of the ventral surface, and possibly continued further along the anal tube, the same plate if situated just at the ventral surface will give rise to an arm or a group of arms exactly like those arising from the radials. The character of the ossicles following a plate is not determined so much by the character of the plate itself as by its position in reference to the boundary between the dorsal and ventral surfaces of the animal.

I have examined pentacrinoids in which both the radianal and anal *x* are present, the former dwindling, the latter increasing in size. They are situated side by side between the two posterior radials.

In some thirty six-rayed specimens which I have studied the supernumerary ray is in all cases but two inserted behind the left posterior; that is, between the two posterior radials, and receiving its ambulacra from the groove trunk to the left.

It is thus clear that in *Thaumatocrinus renovatus* we have a young comatulid just after the resorption of the radianal with anal *x* fully developed and bearing a rudimentary arm which eventually will increase in size and become indistinguishable from the other arms.

This establishes the identity of the supposed species. Since anal *x* has given rise to an additional arm it is only reasonable to suppose that all the other interradial plates, which are exactly like it, will do the same thing. There will therefore result a ten-rayed form with ten undivided arms from which IBr series will be absent. Such a condition characterizes the genus *Decametrocrinus*, one species of which, *D. abyssorum*, was the only other crinoid dredged with *Thaumatocrinus renovatus*, and *Decametrocrinus* and *Thaumatocrinus* have since been found similarly associated.

Anal x in the fossil forms may be reduplicated in the form of a series of interradials, one in each of the other interradial areas; and it therefore does not surprise us to see the same thing in the recent comatulids.

Sir Wyville Thomson notes that in one or two cases he observed about the time of the first appearance of the anal (radianal *mihi*) a series of five minute rounded plates developed interradially between the lower edges of the oral plates and the upper edges of the basals. These are strictly homologous with the interradials of the so-called *Thaumatocrinus*, and that in the posterior interradius is anal x.

In this connection it is most interesting to examine the figure published by Mr. Frank Springer (Journ. Geology, 14: No. 6, 1906, pl. 5, fig. 9; explanation p. 493) to show the probable primitive structure of the anal interradius and adjacent parts of the calyx in the whole Flexibilia type, both fossil and recent. If we should carry backward to its probable inception the course indicated by the migration of the radianal plate in the young of the recent comatulids we should arrive at a calyx structure identical with that shown by Mr. Springer and deduced from the study of the fossil forms; with the possible trivial difference that we should be inclined to assume the reduplication of anal x in the shape of interradials in all the other interradial areas, though from the data acquired from the study of six-rayed forms it would seem that we would be justified in considering these four additional interradials as a later development.

Mr. Springer has shown (Journ. Geology, 14: 496. 1906) that in the Flexibilia there is a very pronounced tendency shown by all the radial structures to turn toward the right; the radianal originates under the right posterior radial; from this position it migrates upward until it disappears, always to the right of the median line; if the arms have an asymmetrical distortion it is toward the right, never toward the left; the vertical series of plates arising from the anal x is affected by this tendency, which persists long after the radianal has disappeared.

In the comatulids the radianal follows the same course as in a succession of fossil genera; the anal tube is always to the right

of the median line of the posterior interradius; that the supplementary arm arising on the anal *x* of *Thaumatocrinus renovatus* does not turn to the left is to be interpreted purely as a secondary condition, the result of its origin on the edge of the disk and its free extension outward from the body. Were this series of ossicles following anal *x* in *Thaumatocrinus* incorporated in the perisome we cannot doubt but that it would have followed the anal tube in its migration to the right, and would therefore have come into complete correspondence with the conditions seen in the fossil Flexibilia.

In *Thaumatocrinus renovatus* the disk between the margin and the orals is completely enclosed by a pavement of small plates which later disappear, and the same is true in certain other forms. This heavy plating of the disk in the very young of species of which the adults have naked disks must be of very profound significance, and, when taken in connection with the occurrence of the radianal and anal *x*, and with various other features, strongly indicates that it is the transient vestige of the forerunner of the dome of the Camerata.

SUMMARY

1. The so-called anal in the pentacrinoid larvæ of the recent comatulids is in reality the radianal of the fossil forms.

2. Anal *x* is represented in the pentacrinoid larvæ of the comatulids by a posterior interradial which gives rise to an additional post-radial series, as in *Thaumatocrinus renovatus* and in six-rayed specimens of other species, or by a minute plate which is quickly resorbed; in the recent forms it is repeated in all the interradial areas.

3. *Thaumatocrinus renovatus* is merely the young of *Decametrocrinus abyssorum* (P. H. Carpenter).

4. The solid plating of the disk which appears in the young of certain forms concurrently with the disappearance of the orals, quickly to be resorbed, is the transient vestige of the condition which developed into the solid dome of the Camerata.