1868

**Memoir to Provide Knowledge of the Living Crinoids: A translation
of *Mémoires pour servir à la connaissance des crinoïdes vivants***

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MÉMOIRES

POUR SERVIR À LA CONNAISSANCE

DES CRINOÏDES VIVANTS

PAR

MICHAEL SARS,

Docteur en philosophie et médecine, Professeur de Zoologie à l'Université de Christiania.

AVEC 6 PLANCHES.

124227

Programme de l'Université royale de Norvège.

CHRISTIANIA.

Imprimerie de Brøgger & Christie.

1868.

Sars, M. (1868) Memoir to provide knowledge of the living crinoids. A Translation of *Mémoires pour servir à la connaissance des crinoïdes vivants*. (J. M. Lawrence, Trans.) © J. M. Lawrence. 2021. Herizos Press, Tampa.

Michael Sars

Sars was born 30 August 1804 in Bergen and died in 1869. He studied first in the lycée in Bergen and then studied natural history and theology at Royal Frederick University (now the University of Oslo). He passed the University's examination in theology in 1828 and became pastor of the church in Kinn and then in Manger. He made observations in the shallow-water marine environment during this time. In 1854 he was appointed professor of zoology at the University. In 1856 he published *Fauna littoralis norvegicae* on the invertebrates found off the shores of Norway. His son, Georg Ossian Sars, was in charge of cruises commissioned by the Norwegian government to study Norwegian fisheries. Sars's son collected *Rhizocrinus* and made some observations on living specimens. Sars referred to his son in his memoir.

Michael Sars

Translator's note:

Sarcode is a French word, coined in the first half of the nineteenth century to refer to the contents of protozoans. It was succeeded by the term protoplasm that, in turn, became obsolete. Sars refers to *sarcode*, which he describes as a thin hyaline envelope surrounding some plates. According to Sars, Carpenter called the contents of the axial canal *sarcode*. I have retained the term as used.

The title page refers to the University of Christiania in identifying Sars, apparently using the location of the University. The city was renamed Oslo in 1925. The title page refers to the "Programme de l'Université royale de Norvège". The name of the university at that time was Royal Frederick University.

Sars dissociated the articles with "natron" and "caustique kali coction". Natron is hydrated sodium carbonate. Caustique kali coction is a solution of potassium hydroxide.

I have made no changes in the transcription. E.g., Sars italicized genus and species names in the first part of the memoir but not in the latter part. Sometimes individual names and words or phrases are italicized.

I am grateful to Janessa Fletcher for providing the figures.

MEMOIR

TO PROVIDE KNOWLEDGE

OF THE LIVING CRINOIDS

BY

MICHAEL SARS,

Doctor of Philosophy and Medicine at the University of Christiana.

WITH 6 PLATES.

Program of the Royal University of Norway.

CHRISTIANIA.

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1868.

I.

Rhizocrinus lofotensis, M. Sars,

new living genus of the stalked crinoids, called sea lilies.

(Pl. 1–4).

In 1864 my son, G. O. Sars, reported from one of his excursions to the Lofoten Islands, a crinoid taken by dredge at a depth of 720 feet at the Guldbrand Islands near the Skraaven fishery (located at 68° latitude N.). This crinoid, having at first glance some resemblance to the pentacrinoid or the stalked larval state of *Antedon Sarsii* that we encounter frequently in the same location, he at first took it for the pentacrinoid of a still unknown species of the genus *Antedon*.

A more detailed examination soon made us discover, however, that we had before us a new genus and very peculiar crinoid or sea lily, to which we have given the name *Rhizocrinus* because of the peculiar branching cirri attached to the lower part of its stem. These cirri resemble the root fibers of a plant. They serve in fact to attach this animal to the foreign bodies that are found on the bottom of the sea. The name of the species recalls its existence in the well-known group of Lofoten islands inside the polar circle.

On 14 October of the same year, I presented to the Society of Sciences of Christiania (see the Discussions of 1864, p. 127), a provisional description, accompanied by figures, of the new crinoid under the name cited above. For several reasons I judged however convenient to suspend for some time its publication, hoping to be able to bring together more numerous materiel and make the description more complete. The mission entrusted by the Government to my son, namely, to make practical scientific observations on fishing in the Norwegian sea, having obliged him to visit the Lofoten Islands again during the three following years, he hastened at my request to obtain during his voyages more detailed information on the appearance, the manner of life, etc. of the new crinoid as well as collecting as many specimens as possible. Thus, without counting a large number of fragments he brought back to me no less than 75 more or less complete specimens, preserved carefully in wine spirits, and collected in very different seasons. It is this very considerable material that has contributed to decrease the great difficulty that the smallness of the animal makes for examination of its organization, especially those that, like myself, have not had the opportunity to study it in the living state and who, consequently, had to be content to make his observations on individuals preserved in the wine spirits.

It is a known fact that the greatest number of species of crinoids belong to ancient periods, and especially the Paleozoic, the oldest of all. In the Mesozoic, the number of species is still considerable, but the number of genera is much smaller. In the Cenozoic, finally, the number of genera and species continues to decrease. Of all the crinoids known to this day, amounting according to Bronn to more than 650 species divided into about 120 genera, of which certainly a

large number are still known imperfectly. We know at the present only forty and some species belonging to four genera. Two of these genera, *Antedon* with nearly 40 and *Comaster* with 1 species, are free in the adult state. The genus *Holaster* with 1 species that is however still very imperfectly known has no stem but attached. The genus *Pentacrinus* with 3 species is attached by a multi-articulated stem. The stalked crinoids or sea lilies that, in ancient geological periods form that greater part of the genera and species, are thus represented presently only by a single living genus, *Pentacrinus*. We see consequently the great interest provided by the discovery of this new genus, our *Rhizocrinus*. Knowledge of the few living genera of crinoids studied thus far is only of the genera *Antedon* and *Pentacrinus*, the latter of which is very rare, is of greatest importance in itself and in that it alone is the key to understanding fossil forms, so much greater in number. In proportion to known sea lilies, *Rhizocrinus lofotensis* is extremely small and has a length or height of nearly 80 mm. It is uniformly pale gray-brown or gray-yellow and even whitish-gray, without patches or zones. The disk membrane is transparent and colorless, showing in the interior the round visceral mass, deep brown in color.

We can divide *Rhizocrinus*, like other crinoids, into three principal parts, namely: the stem, the corona and the arms. We must observe, however, that all the radial parts of the corona, notably the calyx, belong to the arms under both a morphological and physiological relationship.

1. The Stem (*column*).

Articles of the stem.

The stem (Pl. I, fig. 1.) is nearly cylindrical, long, thin or nearly filiform, with the exception of its summit, which is greatly flared, like an inverted cone or bell-shaped. It is composed of a series of numerous articles of calcareous nature. In general, the upper part is very straight or weakly bent upwards. The base is ordinarily more bent and lying (fig. I, c-b) on the seabed, frequently curved in an arc or even with its lower end directed upwards (fig. 16, 17). The length or height of the stem varies greatly in the different individuals. The smallest that we have observed having 12 to 13 mm, and the largest nearly 70 mm. The number of its articles varies from 22 to 67 according to the observations made until now. Although young individuals have a shorter stem and are composed of fewer and thinner articles, we often encounter some whose arms are not very developed while the stem is often larger and composed of a larger number of articles than those of individuals with much more developed arms. See for example the individual figured in pl. I, fig. 1, whose stem is 54 mm high and composed of 60 articles, while its arms are only one mm long. Another specimen with nearly completely developed arms 8 mm in length, on the contrary, whose stem is 41 mm in length, is composed of only 43 articles.

The articles of the stem are nearly all very elongated. In the largest specimens, their length or height is $1\frac{1}{3}$ to $1\frac{1}{2}$ mm long or high and $\frac{1}{2}$ mm thick so that they are 2 to 3 times higher than thick. At the base of the stem, they can even attain a thickness of $\frac{2}{3}$ mm. They are cylindrical, more (fig. 8, 9) or less (fig. 6, 7) concave in the middle and a little thicker or swollen at the two ends, nearly in the form of an hourglass, resembling consequently in an amazing manner to articles of the stalk of the pentacrinoid of the living genus *Antedon* and to those of the base of the stem of the fossil genus *Bourgueticrinus*. Their concavity can be completely uniform (fig. 6-9). This most often happens for a more or less large number of lower articles. Or there can be in the middle of the article a convex ring (fig. 39), weak but wide, that occurs notably in large individuals.

In some cases, the concavity is very great (fig. 8). This happens very rarely and only, it seems, in young individuals (fig. 19) in the lower articles. In this case, the middle of the article becomes extremely thin. In other cases, the concavity disappears in the 8 or 10 lower articles that are then everywhere of equal size. Different individuals vary greatly, moreover, in this relation. In the upper part of them stem, the articles taper successive to 1/3 mm in thickness. They finally take a little different form (fig. 1, 16, 35, 36, 38, 39). Instead of being concave, they become more and more convex in the middle, thicker than the two ends that are no longer swollen. This form, which we can also found in the upper part of the stem of *Bourgueticrinus* and the pentacrinoid of *Antedon*, is seen in a different number (from 5 to 12), according to the different individuals, of upper articles located immediately below the last widening of the stem, which will be mentioned later. At the same time, these articles are shortened little by little with increasing height. The highest (fig. 35, 36, 38, 39) is annular and is 2 or 3, and often even 5 or 6 times wider than high.

It is evident that immediately below this enlargement, new articles form, and all the series of articles of the stem have thus, to our eyes, their successive development, the upper ones being the youngest and the lower ones the oldest. In some rare cases (fig. 17, 19), the dimensions have a greater disproportion, a more or less large number of articles of the upper part becoming suddenly several times thinner than those that are found below them.

Outside this difference in form of the articles that comes with the difference in age, the last (fig 1, 6, *b*) or the lowest of the stem shows a little different from the others in that it is only approximately half the length of the preceding. In addition, although having at the top the same form and thickness as the others, this article is thinner or a little conical in its lower part. It has a truncated end, which gives it the air of being so to say only the upper half of one of the preceding articles.

What is remarkable and characteristic of the stem of *Rhizocrinus*, is its summit that has a large flared inverted or bell-shaped form. It gives our crinoid a resemblance to the fossil genera *Apiocrinus* and *Bourgueticrinus*. In individuals in which the arms are well developed, this thickened end is in general more elongated (fig. 35, 38, 39 *a*) than in the less developed young (fig. 1, 2, 16, 17, 18, 36), where it is also sometimes very slightly concave all around its middle. In the first, it has a height of 1 ½ to 2 mm (or nearly the height of the following 4 to 5 articles), which greatly exceeds that of one of the largest of the other articles). From a width of 1 to 1 ½ mm in height, it thins little by little towards its lower end, whose thickness does not exceed that of the annular article that comes immediately afterwards. This end is thus nothing other than the summit of the stem that is successively enlarged. It is evident that it really makes part of the stem and not of the corona, because we see clearly, notably in some young individuals, that it is not at all distinctly separated from the stem, but that comes from it in a kind of straight line, enlarging little by little in height so that it is difficult to say where it commences and where the stalk ends. In one of these individuals, I also noticed very near its lower end, which was not wider than the first following article, an extremely fine annular groove, commencing the formation of a new article. Like the first centro-dorsal piece of *Antedon*, with which it seems to have an incontestable analogy, the summit is composed of only one piece or article. It is possible originally it had been formed of several articles that later merged. This perhaps seems to indicate one or two extremely weak annular grooves that are visible in some cases (fig. 35, 39). It is, however, not separated into several pieces by caustic potassium hydrogen solution or by the action of a solution of sodium carbonate. Its surface always remains convex and smooth, with the exception of some weak grooves on its upper part, which we shall consider later. Moreover, its upper end, horizontally truncated, circular or slightly polygonal, shows a few small, slightly protruding prominences, triangular or angular,

at equal distance from each other between the bases of the radial articles of the crown and the same number as these.

Up to now, we have considered the articles of the stem in general as cylindrical. But, on closer examination, we have discovered that only the upper articles (ordinarily 7 to 8 or less), immediately below the thickened end, have this form (fig. 20–23), while all the others (fig. 25–27) have only the middle part or the body truly cylindrical, but their two ends, thickened a little laterally compressed, so that the two articular surfaces become a little oval or elliptical (fig. 27, 30, 31) and not circular. This compression does not take place in the same direction, but nearly in opposite directions in the two ends of each article, so that the longer axis of the ellipse of the upper articular surface crosses that of the lower surface in forming a slightly oblique angle. The compression alternates thus from article to article on all the remainder of the stem. These remarkable relations between the articles of the stem have been known up until now only in the fossil genus *Bourgueticrinus* d'Orbigny, where they have already been described a number of years ago by Miller (Natural History of the Crinoida, 1821, p. 34) and in some species of the genus *Platycrinus* (Miller, p. 75). I have however found identical ones in the *pentacrinoid of the present Antedon* (see below), where they seem not to have been noted before now.

In *Rhizocrinus*, the junction of these articles is completely peculiar. The articular surfaces are not as in *Pentacrinus*, *Apiocrinus* etc., flat, but a little and uniformly convex and strongly excavated in the middle or rather they have two large cavities (fig. 27, *bb*, 30, 31) rounded, located in the direction of the shorter axis of the ellipse and occupying nearly two-thirds of the width of the articular surface. These cavities merge however in the middle, where they surround the canal of the axis (fig. 27, *a*, see below), where they can also be considered as an enlargement. They thus form only one cavity nearly in the shape of a biscuit. The rest of the slightly convex articular surface has a line or narrow articular ridge (fig. 27, 28, *e*), protruding and straight, very shiny, following the same direction as the large axis, with a fairly large interruption in the middle of the articular surface, produced by the large cavity in the form of a biscuit in the canal of the axis, where the articular surface at the interior border of this protruding ridge forms a horizontal conical preeminence (fig. 27, 28, *d*), producing the constriction that gives this cavity its peculiar shape. These two formations, the articular ridge and the cavity, intersect thus in forming right angles, the first the long axis, the latter the short axis of the articular surface. Both sides of the ridge produce at equal intervals and at right angles some teeth (fig. 27, 28, *g*) of small straight and very short crests, like the sides of a vertebral column, which have the same shiny appearance as the articular ridge itself and alternate with those of the opposite side. We count 8 to 9 of these teeth on each side of each of the two pieces interrupted by the central cavity that make up the articular ridge, i.e., 32 to 36 in all.

The described nature of the articular surface is, as we have been able to see, quite different from that we see in *Pentacrinus*, but on the other hand rather similar to that of *Bourgueticrinus*, where the articulations are generally described as completely peculiar and separated from that of all other genera of crinoids (Lütken, om Vestindiens, Pentacriner, Naturh. Forenings Meddelelser i Kjobenhavn 1864, p. 212). However, according to the figures of Miller and of Goldfuss, and according to some of the articles of the upper stem that were given to me by Professor Wyville Thompson, the cavities of *Bourgueticrinus* seem less marked or strong (with some of the upper articles even nearly invisible), while occupying a larger space on both sides of the articular crest, i.e., up to the edge of the articular surface. Also, the ridge, which has the same direction as in *Rhizocrinus*, is itself much longer, being interrupted only at the center of the articular surface by the small circular canal of the axis. Finally, it has a groove that runs along its entire length but has

no trace of teeth on the two sides. I find, on the contrary, in the pentacrinoid of *Antedon Sarsii*, articular surfaces nearly completely similar to those of *Rhizocrinus*, so I have not been able to distinctly confirm the presence of teeth on the two sides of the articular crest.

The junction of the articles of the stem is made in *Rhizocrinus* by elastic ligaments (fig. 8, 9, *l*) composed of very fine fibers, but extremely strong or nearly tendinous, smooth, parallel and often rather long, notably the ligaments that attach to the cavity in the form of a biscuit, or they seem to form a thick straight bundle (fig. 32, *ll*) of each side of the canal of the axis. In examining nearer the stalk of individuals preserved in wine spirits, we can conclude with some probability that these ligaments must also be up a certain point a little contractile, since the articles of the stem show very often some degree of bending (fig. 9), sometimes from one, sometime from the other, but always in the direction of the short axis of the articular surface, where are located the cavities in which the ligamentous fascioles attach. In this case, the edges of the surfaces of the two contiguous articles are on one side in close contact, the bundle that is located there being contracted. On the other side, on the contrary, there is between the two surfaces a rather considerable elongated or elliptical and transverse space that is filled with the fascioles that are found there and whose fibers are stretched because of their elasticity and are therefore perfectly obvious. The stem therefore has some flexibility, undoubtedly very limited, that, due to the nature of the articular surfaces, consists essentially of a kind of oscillation or of balance of one article on the other in the direction of the short axis of the articular surfaces or the two sides of the articular ridge that is the fulcrum of movement and are the only point where the articles are truly in contact with each other. It is with reason that we suppose a parallel flexibility in the fossil genus *Bourgueticrinus*. In the pentacrinoid of *Antedon*, that according to my observations, has flexion on both sides, similar to that described in *Rhizocrinus*, Allman reports (Transact. Of the Royal Society of Edinburgh, vol. 23, p. 243): "The stem admits a slight flexure from side to side, and during life the animal may every now and then be seen swaying through a small arc." Allman has made no observation on the cause of these movements. J. V. Thompson has taken the transparent membrane (sarcode layer) that envelops the calcareous articles of the stem in young pentacrinoids for the site of contractility. But in the adult pentacrinoid, as in *Rhizocrinus*, we no longer see this envelope.

Although the smallness of the objects has not permitted me to see distinctly, there are undoubtedly found along the length of the articular ridge, probably between its teeth, interarticular ligaments whose special functions are to join the articles and that probably, more than those described above, resemble "the elastic interarticular substance" that J. Müller has found between the articles of the stem of *Pentacrinus*. In *Rhizocrinus* the junction of the articles is so strong that it is very difficult to detach them from each other. They often break at other points than the articular surfaces.

A central canal, "the so-called food canal", extends through the axis of the entire stem. Rather narrow, it is never completely round, but angular, sometimes square (fig. 26, 27), sometimes pentagonal (fig. 21, *a*) or hexagonal (fig. 22, *a*), so that, according to the examination that I have made on several individuals, seems to depend on the division of the corona into 4, 5 or 6 rays. The canal of the axis is filled with a soft cord, more solid and rather strong (fig. 33, *st*) that, in *Antedon*, Carpenter believed composed of sarcode and that, in my specimens of *Rhizocrinus* in wine spirits, seemed to contain fairly strong longitudinal fibers, similar to those of the ligaments. In the thick summit of the stem, the canal of the axis enlarges successively in ascending (fig. 45, *a*). From this widening it sends to each of the rays of the corona a branch (fig. 45, *a'*), canal of the axis, which runs through the radial articles (radialia) and brachials (brachialia), and a single branch to the disk.

Finally, as for the structure of the articles of the stem, it is like those of other parts of the skeleton (the radial and brachial articles, etc.). I.e., it consists of a trellis or network of hyaline calcareous rods, most often very irregular. But on the surface of the youngest articles (fig. 20), on the median part of the older ones and on the interior surface of the central canal, very regular (fig. 24) and composed of long, longitudinally parallel rods that are completely straight (which can even be isolated over a great extent), connected to each other by crossbars that alternate with each other on the two sides of these rods. They have between them round meshes that are staggered, whose diameter does not exceed the thickness of the longitudinal rods.

Besides, here, as in all the other sea lilies, the stem is only an appendage of the radial skeleton, without continuity with the viscera that are not only surrounded by this skeleton.

Cirri

One of the most remarkable peculiarities of *Rhizocrinus* is that it is not, as in some fossil crinoids (the mode of fixation of present *Pentacrinus* is still unknown) and the pentacrinoid of Antedon, attached directly or with the lower end of the stem to objects located on the sea bottom, but means of filaments (fig. 1, 6, 7, 16, 17, 19, *c*) that resemble root fibers of a plant, often over a fairly long part. Now, the lower article (fig. 1, 6, *b*) of the stem that, as we have already said above, is shorter and has a little different form than those immediately above. It has at its lower free and truncated end, several of these filaments (ibid. *c*) (generally from 3 to 9, of which one is in the center and the others all around the periphery) go out freely and separated from all the sides. In addition, at the upper thick part of this article, are found 2 more of these filaments (fig. 10, *c*), that are placed opposite to each other, each on its side of the article. Similar articles are also found without interruption on a more or less large number of articles located above it. But we always find them there at their thick upper part near the articular face, never on any other part of the surface of the articles. They come out (fig. 6, 7 *c*) at the upper part of the lower article of which we have just spoken, from 2 points opposite or located opposite each other, each on its side of the article. In general, a single filament from each of these points, more rarely two that, very near each other at the base have perhaps a single filament already bifurcated from its beginning. The filaments of all these articles leave in a straight or nearly perpendicular line to the axis of the stem. In examining more closely, we find that, far from being dispersed by chance, as we could be tempted to believe at first glance, they are arranged with a remarkable regularity. Now, for each article, they come out from two surfaces nearly opposite to those where they have the preceding article, and to the follow the next one, but the same surfaces that on the second upper and lower articles or, in other words, their points of origin are exactly the same every two articles and alternate regularly in crossing those of the following article. By studying them more closely, we see that the two points of exit (fig. 25, 27, 30, 31, *cc*) are each located at the end of the longest axis of the upper articular surface of the articles, not exactly at that level but a little below this surface. They thus cross those of the two preceding and following articles, not at a right angle, but oblique, conforming to that which we explained above on the alternating flattening of the articles of the stem. We have already said that the filaments are present over a more or less long extent of the lower part of the stem, or more or less numerous in different individuals. It is thus that I found these filaments, or at least their distinct traces (because, being very fragile, they are often broken at their base, which remains however ordinarily as a small knot or cylinder), in 7 different individuals at all their lower articles, at number 3, 5, 6, 15, 22, 32.

All these filaments are cylindrical in form, thickened at the base and tapering little by little towards the summit. At irregular intervals they are sometimes, in some cases, bifurcated or branched (fig. 11), sometimes at the base, sometimes at a further point. The branches, with multiple and irregular bends in all directions, attach, as the filaments of plants, sooner or later to foreign bodies that, they meet during their growth on the seabed by their terminal part (sometimes also by a more or less large part of their lateral surface (fig. 13), which is applied to them and surrounds them in part. This end is generally enlarged into an irregular disc (fig. 12, 13, 15, *rf*) from the circumference of which small, thread-like extensions (ibid, *d*), are extended over the surface of the foreign body. Now, on one of my specimens, a rather thick filament is attached a little beyond its origin to a large test of the rhizopod (*Saccamina subglossa* Sars, nov. gen. and spec.) and expanding into a disk almost double in width from the periphery of which 9 filiform extensions emerge that go onto the test of the rhizopod and unite there. Six of these extensions are very short. The 3 longest are detached, after a short adhesion from the foreign body and continue their course like the free articulated filaments that finally attach again to another further point on the same test. Other similar enlargements of the ends of the filaments are shown in plate 1, fig. 11 to 13, 15, *d*. Complete individuals of our Rhizocrinus are all thus attached to different bodies: conchiferous shells or their fragments, dentalid shells, polyzoan stems, rhizopod shells, echinus spines, sand grains or small stones, etc., and remains thus on the same bottom moored by these filaments like a ship by a large number of cables.

The filaments of the upper articles are generally short and thin, but those of 3 or 4, or of a larger number of lower articles sometimes attain a length of 8 to 9 mm and their base a thickness of 1/3 mm. Some rare cases are nearly as thick as the very article of the stem to which they are attached. Their very flexuous branches, slender at the end like a hair often form there a mixture of intertwined small filaments (fig. 16, 17, *c*), which resemble in a striking way the radical fibers of a plant of the so-called radical filaments (hydorriza, Huxley), by which a larger of Hydroids attach to other objects.

Considering this resemblance, we are only more surprised when examining more closely the nature of these filaments. Now, in several respects, they conform to the stem because, at first, they are composed of the same calcareous material, and then because they are articulated (fig. 11-13) all along their length. Moreover, they enclose an axial canal ("food canal") leaving from that of the stem, that is however is not angular but circular (Fig 34 *a*) and relatively much narrower. They are distinguished especially from the stem by their articular surfaces (fig. 34) that are completely flat and without cavities or articular crests. The articles, whose large filaments can have a very considerable number, are shorter near the base, but always a little longer than thick. As for the branches, they are even much longer. Their thin branches exceed their thickness by many times. Frequently two articles form together an angle (fig. 11), and the repetition of these angles provide the flexuosity of the filaments. Near the base, the filaments are little flexible. Farther, and especially with the fine branches, they are on the contrary flexible (perhaps because of the abundance of the interarticular substance) or they appear soft, although a more careful examination shows us that all the articles up to the end of the branches consist of a calcareous network (fig. 14) that is however more irregular and with a meshes larger in proportion to the rods.

As in different individuals, we find these filaments on an area sometimes larger, sometimes shorter along the stem, but always on its lower part. It is evident that they develop more or less numerous according to the need of the animal that, on its side, depends on the nature of the sea bottom or other causes that required a greater or smaller number of points of support to maintain

the individual in his natural position, i.e., with the upper part of the stem and the corona that surmounts it straight up and rising freely in the water.

After all the preceding, there is little doubt that we should consider the described filaments as formations homologous to the cirri (in German, "Ranken") of *Antedon* and *Pentacrinus*, with which they agree in the calcareous nature and their composition of numerous articles with an axial canal that runs through them. On the other hand, they differ from them in that they are branched and that they attach permanently or join completely by their ends to the surface of foreign bodies. In adult *Antedon*, which move freely, the cirri function like instruments to maintain or attach the animal to foreign bodies (marine plants, polypairs, etc.), but only for a time, because not finding for long periods the points of attachment meets its needs, it can detach and swim to another place. Without a fixed order, the cirri are found dispersed on the so-called "dorsal button" or centro-dorsal piece. In *Pentacrinus*, with a long articular stem, they are arranged in whorls, 5 in each, at fixed distances or on certain sections of the stem throughout its length. They resemble those of *Antedon* in form and in that the hooked, conical tip is free and can probably attach momentarily to foreign objects. By the regular location of the cirri on the stem, our *Rhizocrinus* resembles more *Pentacrinus* than *Antedon*. But the disposition is not the same because the cirri, that leave at only two points of each article and only on the lower part of the stem, are found here without interruption over a more or less large number of articles without missing a one. Among the known crinoids this arrangement of cirri is seen only in the fossil genus *Bourgueticrinus*. According to the figures of Goldfuss (*Petrefacta Germaniæ*, table 57, fig. 3, B to E), this crinoid should also have cirri on the upper part of convex articles on them stem. But I have found no trace of them in the specimens send me by M. W. Thomson.

The pentacrinoid of *Antedon rosaceus* is attached to foreign bodies by the lower article of the stem that is expanded into a flat and circular calcareous disk, of which the edge, according to M. Carpenter, is "more or less deeply divided into lobes." In the pentacrinoid of *Antedon Sarsii*, this disk sends from its periphery small irregular, filiform and inarticulated extensions that crawl on the foreign bodies.

The mode of attachment of present stalked crinoids (species of the genus *Pentacrinus*) is still unknown. In some fossil crinoids, on the contrary, it is known. Thus, in *Apiocrinus*, *Eugeniocrinus* and *Encrinus* (see the figures of the works of Miller and Goldfuss), the base of the stalk is very expanded, inarticulated and spread in the form of a piston of a more or less distinct disk by which the animal is attached to rocks and other foreign objects. The base of *Cyathocrinus*, *Actinocrinus* and *Anthocrinus* has filiform extensions, sometimes a little branched, that resemble "roots" and that doubtlessly also serve to fix the stem. The attachment apparatus of the so-called fossil crinoids that I have been able to examine only in a specimen of *Apiocrinus Parkinsonii* Schlotheim that W. Thompson gave me, is however, by the irregularity of its form and its position and especially by the absence of articles, very different from the articulated cirri of *Rhizocrinus*, although these, as we have seen above, also transform at the end into root-like or disk-like enlargements similar to those by which these fossil crinoids are attached. What is peculiar in this respect in *Rhizocrinus* is that its stem is not attached to the sea bottom directly or by its lower article that consequently is neither enlarged nor thickened, but by means of its cirri.

There is however an old genus, *Bourgueticrinus*, already often cited, that has also in some other aspects a great similarity with our *Rhizocrinus*, about which it is said (Lütken. 1. c, p. 212) that it produces at its lower end "roots" by means of which it attaches itself to the sea bottom." These "roots" or cirri that do not appear to be branched seem located in the same manner as in our *Rhizocrinus*. Now, we read in the work of Dujardin and Hupé (*Histoire naturelle des*

Echinodermes, page 177), probably after d'Orbigny (I have not been able to obtain his natural history of crinoids), "that sometimes there emerges an accessory ray (i.e., cirrus) at the end of the protruding side that follows the direction of the large diameter of each articulating surface." On the other hand, Goldfuss (*Petrefacta Germaniæ*, table 59, fig. 1, *a*) shows us a "radical piece" that he relates to *Cyathocrinus rugosus* Miller and that has articulated and branched cirri similar to those of *Rhizocrinus*.

2. The Corona.

As in the other crinoids, we can say that the corona of *Rhizocrinus* is composed of two hemispheres. The calcareous one, dorsal or apical, the calyx that forms the base of the arms, and the other membranous (covered, in some fossil genera, with calcareous plate), ventral or oral, the disk ("the cover of the calyx", Lütken), that encloses the digestive system.

The Calyx

In most crinoids, the passage from the stalk to the calyx is more or less strongly marked. In *Rhizocrinus*, on the contrary, as in the fossil genera *Apiocrinus* and *Bourgueticrinus*, the upper part of the stem thickens little by little in a way the calyx is not wider than its end.

The calyx of crinoids is ordinarily composed of basals and radials, more rarely parabasals and interradials. The pieces of the two latter types are lacking completely in *Rhizocrinus*. The basals, located between the end of the stem and the rest of the calyx and always alternating with the first radials located immediately above, also seem to be missing. At least they are not visible from the exterior. However, the investigations of Carpenter (*Philos. Transact.* 1866) having demonstrated that the basals, visible exteriorly in the pentacrinoid of *Antedon*, are also found, although in another form and interiorly, in the adult animal, it is permitted to presume that it is the same in *Rhizocrinus* where their remains seem probably to be found in the small circular plates that corresponds to the "rosette" of *Antedon*. This plate (fig. 42, 43, *r*) is located in the interior, in the central space left inside that the ring formed by adhesion of the first radials. In *Rhizocrinus*, this plate is however so adherent to the first radials as well as the upper end of the stem, that I have been unable, as is easily done with *Antedon*, to isolate it by treatment with caustic potassium hydroxide or a solution of sodium carbonate.

We pass to the radials. We encounter in *Rhizocrinus* a singularity nearly unique among all the crinoids known to this day. There is a variation or to say an uncertainty in the number of rays, which is extremely remarkable¹. With the exception of the *Cystids*, whose rays are little or not marked and the arms weakly developed or even absent, all the other crinoids (*Blastoidea*, whose arms are not free but adherent to the calyx and *Actinoidea* or the true crinoids that have well developed free arms) are, as we know, divided into rays, whose number is normally rigorously reduced to five in a way that, in numerous genera, we cite only as exceptions (Bronn, *Class. u. Ordn. d. Thierreichs*, vol. 2, p. 207) *Lecythocrinus* with 7, *Tetracrinus* *Tetramerocrinus* and *Holopus* with 4 and finally *Tricrinus* with 3 rays. However, in none of these genera or their species, do we know the variation in the number of rays indicated. We claim that sometimes *Encrinurus liliiforme* has only 4 so-called "shoulders", i.e., the last radials (*Lethæa* by Bronn, vol. 2, p. 45),

¹ My friend, Professor Steenstrup, however has advised me that it is the same of the *Cyathidium* he discovered in the limestone of Faxø, Cretaceous formation, that, it is true, has generally 5 but also sometimes 4 or 6 rays.

and that *Eugeniocrinus caryophyllatus* is sometimes found with the “crown divided into 4 instead of 5” (ibid., p. 116). *Carpenter*, who has studied with so much care and success the organization of *Antedon* cites (1, c., p. 724), it is true, several examples of the regenerative power of this crinoid, sometimes also accompanied by monstrosity, but not one appearance of the number of rays other than five. As for me, I found, among the many specimens I examined, both free and in the pentacrinoid state, only one exception to this normal state.

On the other hand, in the same species of our *Rhizocrinus*, we encounter ordinarily 5, but frequently also 4 or 6, very rarely 7 rays. By chance, most of the specimens that first reached me had 4 or 6 rays, which made me believe for a long time that the normal number of 5 was an exception. But, finally, I have found a larger number of individuals with 5 rays.

Among the more or less complete specimens that I have been able to example, the results are here:

15 with 4 rays,
43 with 5 id.,
15 with 6 id.,
2 with 7 id.

These irregularities in the normal or typical number of rays of crinoids, would scarcely be considered ordinarily as monstrosities, because they are too frequent and, on the other hand, there is nothing that suggests this in the different aspects of the different rays that, for most of the cases are regularly and equally developed. Monstrous formations, on the contrary, generally have a noticeable difference from normal ones in size and fairly often also in form. (see the specimens cited by *Carpenter*, 1. c, p. 725, plate 38, fig. 7, 8). “The monstrous formations”, says *Bronn* (1. c, p. 224) are not, it is true, rare in crinoids, but they most often arise from the division of rays into ten arms and the subdivision of these into 20 branches on some arms operates in an abnormal way and at unusual heights on the arms, or do not where they should occur, which produces the most diverse numbers. *Eucalyptocrinus* was also found with an arm too many.” It is evident from the above, and even more from the examples cited by *Carpenter*, that in general, the monstrosity does not affect the rays or the radials themselves, but only the arms, either by the appearance of too many arms or by absence of a few of them.

Thus, as we just said, *Rhizocrinus* can have 4, 5, 6 or 7 rays of vertical rows of radials. Each row is composed, as in most crinoids, of 3 articles that consequently form transversely three circles. The corresponding parts of all the rows have a uniform development, in a way that the calyx has a completely regular radial form. In the description that we are going to give, we shall adopt the number 5 as normal for the three circles.

The first circle, or the first radials, form by a narrow adhesion, a pentagonal disk that is a little concave in the middle. Invisible from the exterior, they rest internally on the upper surface of the enlarged terminal article of the stem, on which the following radial also rests in part. However, their presence is also indicated exteriorly by a corresponding number of very slight bulges that are sometimes difficult or even impossible to see. These bulges are separated around the upper third or quarter of the enlarged by slight, vertical and arched grooves (fig. 2, 35, 36, 39, 44, 48, s) at the lower point where they curve to unite horizontally. Laterally, these radials are completed joined with each other, often without visible suture, but sometimes also, and especially in young individuals, by fine but distinct sutures that are precisely these grooves. Below, they are equally united with the upper surface of the terminal article of the stem, but they cannot be separated, as in *Antedon*, by caustic potassium hydroxide or a solution of sodium carbonate. It is however easy to recognize that, as in *Antedon* and *Pentacrinus*, they have the form of small triangular wedges

(fig. 43) whose enlarged base (or the free end) that articulates with the following radial, is turned outward (obliquely inward and upward) to form one of the sides of the pentagon, and whose thin end, not pointed but truncated, turns obliquely inwards and downwards. Being truncated in their interior part, they form together a large ring leaving a round or slightly pentagonal space in the middle, filled by a plate in the form of a “rosette” (fig. 42, 43, *r*) mentioned above, probable remains of the basals. At the point where this plate meets the inner truncated or thin end of the radials, we see in each of them a small round hole, from which leaves a straight and linear groove (fig. 43, *s*), which goes along the median line of the upper surface or ventral surface of each article and continues its course in also going up the middle of the ventral surface of the following radials.

The articular surface (fig. 42, *ri*), that articulates with the second radial, is inclined a little obliquely from inside to outside and downward. It has a large triangular shape with the exterior surface uniform convex and a small indentation in the middle of its inner edge for the mentioned groove. The largest inner part of the articular surface is occupied by two large cavities or round facets (fig. 43, *mf*), located next to each other and limited on the inside by two rather high and arched transverse crests (fig. 44, 45, *cr*) that are pointed towards each other in the midline and that divides the ventral surface of the article into a central part inclining inward and a peripheral part forming the true articular surface. These two facets are the point of attachment of the two muscles that move the following facet. Outside, nearer the dorsal edge than the ventral edge of the articular surface, the muscular facets are limited by a slightly elevated line (the articular crest (fig. 43, *b*) that is transverse or direct in the same direction and the large diameter of the articular surface. In the middle of this line, and interrupting it in part, we see the small circular canal of the axis (“the food canal”) (fig. 43, *a*), that runs likewise in all the following radials and brachials, and immediately outside of this canal, a fossette (fig. 43, *lf*) that serves as the point of attachment of the elastic ligament that, by its extensibility, opposes the action of the muscles.

Thus, the first radials resemble generally those of *Antedon* if this is only the weaker or less strongly marked articular crest.

The second circle or the second radials (fig. 2, 18, 35, 36, 38, 39, 48, *r2*) form the exterior visible base of the calyx and rests on the articular surfaces of the first radials and in part on the edge of the enlarged upper article of the stem. They are, like those of the third circle, free or separated from each other by narrow wedge-shaped extensions descending from the membranous disk. They are mobile, directed sometimes upwards, sometimes obliquely outwards. In the largest individuals, they are $\frac{3}{4}$ mm in length or height and about the same width (the latter is equal to that of the articular surface of the first radial). In the younger specimens, they are a little longer than wide. Each of these radials is strongly compressed in a way to form two broad surfaces, the exterior or dorsal (fig. 39, *r2*, fig. 54) and the interior or ventral (fig. 48, 53), and two narrow lateral surfaces (fig. 48, *r2*, fig. 50), nearly reduced to the edges alone that are fairly sharp (fig. 50, *t*). Seen from one of the wide surfaces, the article has a square form with straight lateral edges. The two upper and lower edges are likewise rather straight. The dorsal surface is a little convex and completely smooth. Along the middle where the groove mentioned above is found, the ventral surface is rather protruding and laterally a little concave. Thus, the transverse section forms a wide triangle with an incision in the middle of the ventral edge. The lower or proximal articular surface (fig. 51), like the upper or distal of the first article with which it articulates, is inclined from inside to outside and down. It is also of the same nature, with two muscular facets (*ibid.*, *mf*), an articular ridge (*ibid.*, *b*) and a ligamentous fosset (*lf*). The upper or distal articular surface (fig. 42, *r2*, fig. 52), that is likewise inclined, but in the direction of the opposite proximal namely from the outside to

inside and down, is flat, with muscular facets nor articular ridge and without visible lines. It is thus, as in *Antedon*, immovably joined to the next or third radial.

The second radial of *Rhizocrinus* is, as we see it, of relatively larger dimensions and completely different form than in *Antedon*, where it is little or not at all compressed, much wider than long or nearly disk-like (although it is near *Apiocrinus*, of which I have been able to examine a beautiful specimen that W. Thomson has given me.).

The third circle, or upper radials (fig. 38, 39, 48, *r3*, fig. 55–57) are still more different from those of *Antedon* as well as from *Pentacrinus* and *Apiocrinus*, in which they have a triangular and axillar shape, i.e., that have three articular surfaces, of which the proximal is turned against the distal of the second article, while that are direct obliquely outward from each ridge serve as the base of an arm. In *Rhizocrinus*, whose rays are not divided and that, consequently, are immediately continuous in the simple non-divided arms, the third radial could not thus be axillary. It has only two articular surfaces like the preceding article to which moreover, it fairly resembles as a whole. Now, it nearly has the same square form and the same width as this article, but it is a little less long or high (about 1/2 mm). What especially distinguishes the third radial is the bony crest (fig. 55–57, *cr*) on each side of the groove that runs along the middle surface of the article. These crests end in conical protuberances diverging a little from each other and passing a little the two ends of the article. The proximal articular surface (fig. 58) that is inclined in the same direction as the distal surface of the second article, i.e., from outside to inside and downward, resembles completely the latter (it is likewise flat, without muscular facets nor articular surface). The distal articular surface (fig. 59), on the contrary, is truncated straight and has two round muscular facets (*ibid*, *mf*) and an articular ridge that is not very distinct.

In young individuals with little advanced arms, the third radial is not yet developed or, in any case, is impossible to recognize as such. The second article, on the contrary, is more elongated than ordinarily or a little higher than wide.

Like the brachials, the radials are moved by a pair of muscles located between them. These muscles, very short but large and strong, are inserted into the cavities or facets mentioned above. The muscles of the first pair are located between the second article, that is consequently mobile, and the first that is immobile after its junction already described. But the junction of the second and the third article operates without muscle by the sutures and the inarticular substance. Consequently, it is immobile. The muscles of the second pair (fig. 64, *in*) are located between the third radial and the first brachial. It is the same in *Antedon* and, according to Lütken (l. c., p. 202), in *Pentacrinus Milleri* Örsted. In *P. asteria* Linné (*P. caput medusæ* J. Müller), on the contrary, there is also, according to J. Müller, a true muscular junction between the second and third radials.

The muscles of *Rhizocrinus* have a pale brown color and is composed of numerous primitive parallel and extremely fine non-striated transverse fibers. Located on the ventral surface of the rays or the arms, they cannot flex the rays or the arms except only inwardly, a movement facilitated only to a certain degree by the soft disk, while the extensions occur by the elastic ligaments located between the articles.

The Disk (Discus)

The disk (fig. 40, 41, 85, 86, *d*), that is located nearly at the level of the third radial (fig. 86), is in its complete extension when the arms are nearly horizontally extended, circular, slightly convex and has, in the largest individual observed (2 mm in diameter, but 1 1/2 mm only or less

when the arms are closed in a bundle. During this contraction, it becomes more convex and its edge slightly swollen (fig. 41) in the intervals of the rays. It is covered with a thin membrane, thin and soft, that contains, however, numerous microscopic calcareous plates (spicules) (fig. 90, *sp*), circular or often irregular in form, composed of a network of hyalin calcareous rods, narrower in diameter than the round or polygonal mesh that separates them.

At the center of the disk is the mouth (fig. 40, 41, *m*), that is circular, but whose entrance becomes stilliform because of the corners or wedges of the interradial spaces (“the interpalmar spaces”, J. Müller) that surmount the mouth like a vault. These corners (fig. 40, 41, 85, 86, 89–91, *o*), ordinarily number 5, triangular or sometimes tongue-like in form, because their free end is round, seem here true valves that, in being raised (fig. 85, 86, *o*) separate their ends and free them from each other, opening the entrance to the mouth that is narrowly closed (fig. 40, 41, *o*) at the center when they lie down and meet (fig. 40, 41, *o*) at the center by the same ends. In examining them more closely, we discover that each of these valves consists of a calcareous plate (fig. 87) covered with a thin hyaline membrane (this plate is 3 to 4 times larger than those mentioned above, that is found distributed in the disk membrane. Seen with the microscope, this plate is formed of an elegant network, filled in a single plane, with small hyalin calcareous rods (fig. 88, *r*), forming round and polygonal meshes (*ibid*, *f*), larger in the middle of the plate and decrease little by little towards the edge, where the ends of the rods protrude in the form of extremely fine and short spines. Similar valves of “oral plates”, only relatively large are present, as we know, in the very young pentacrinoid of *Antedon*, but disappears at a more advanced stage and completely missing in the free and adult *Antedon*, as well as in the *Pentacrinus*.

In the intervals of these five valves leave from the mouth, like the rays, are as many grooves in the skin of the disk, which form here a narrow membranous crest. These grooves (fig. 40, 41, 85, 86, 89, *st*) are directed in a straight line towards the edge of the disk of the arms and run along the entire ventral surface of them and their pinnules, where they are not, as in *Antedon*, superficial or protruding, but rather deeply sunken because the ventral surface of the brachials is much more concave. The arms of *Rhizocrinus* being single and not divided, these grooves, called tentacular, are not bifurcated (the spaces called “interbrachials” by J. Müller are consequently not found on the disk). In *Antedon* and *Pentacrinus*, which have five arms bifurcated one or several times, they become forked and thus already greater than ten before attaining the periphery of the disk.

Most of my specimens kept in wine spirits have mouths tightly closed by the valves described above. Only in some, whose arms are more or less horizontally extended, are the valves open and vertically raised (fig. 85, 86, *o*) in a way to make visible the circular mouth and the tentacles (*ibid*., *t*) that surround it. The latter, that form a single circle, are located on the outer side of an annular groove (fig. 91, *sa*) between the mouth and the valves. It is these grooves that leave the 5 tentacular grooves already mentioned. In all the individuals with 5 rays, these tentacles, called oral, number 20, namely a pair for each radius and another for each interradius. The radial tentacles (fig. 91, *tr*) are soft and flexible, transparent, colorless, cylindrical, hollow, rounded at the end and very extendable because, in the individuals examined, they are raised frequently (fig. 86, *i*) well above the free end of the vertical ales. They are at the same time contractile that they can become much shorter. Some slightly opaque transverse zones, located equi-distant from each other, make them appear slightly annular (fig. 92). Their surface has papillae (fig. 92, 92, *p*), very short and thin, cylindrical, round at the end. These papillae are located on the opaque zones, consequently at fairly regular distances from each other, and, as it has seemed to me, not arranged in rows but all around in a spiral. In the skin of these tentacles we note “spicules” or thin calcareous rods that are often united to form small irregular networks (fig. 93, *sp*) with round meshes. The interradial tentacles

(fig. 91, *ti*, 94) of the mouth, located most often near the inner surface of the valves (fig. 91, *o*) of the mouth are very distant from each other at their base and nearer the radials. They are the same form as the latter, but they are shorter and their papillae (fig. 94, *p*) are closer to each other. Although flexible, they seem however little extensible. In any case, in none of the individuals examined, they do not rise above the space enclosed by the valves of the mouth (the entrance to the mouth). finally, they differ from the tentacles by the absence of the calcareous parts of the skin. It is not quite the same with the interrarial tentacles of the mouth in the pentacrinoid of Antedon. Wyville Thomson, in his excellent work on the development of this pentacrinoid (Phil. Transact. 1865, p. 527, pl. 26, fig 3, *c*), describes them as “shorter than the radials, flexible but not extensible, a little claviform towards their distal end that is fringed or with small conical tubercles.

In one of the interrarial spaces of the disk, near the middle between its periphery and the mouth, we see the anus (fig. 40, 41, 85, 89, *an*). as a very small pore in the state of contraction, as a larger circular opening (from $\frac{1}{4}$ to $\frac{1}{2}$ mm in diameter) in the state of relaxation with a slightly thickened (non-crenelated) simple edge. It seems sometimes to be located on a slight convex elevation, not protruding, round, probably produced by contraction only of the disk. In other cases, particularly in individuals with horizontally extended arms, we see distinctly that it is located immediately on the convex disk. In Pentacrinus and Antedon (the free-living as well as the pentacrinoid), on the contrary, the anus is located at the end of a long and fleshy tube that rises like a proboscis. In Antedon, the opening of this tube is crenelated or folded.

The rays of different individuals not having always, as we have already said, the number 5, but also 4, 6 or 7, we also find the corresponding number of rows of radials, of tentacular grooves and of oral valves, as well as a double number of radial and interrarial tentacles of the mouth.

3. The Arms (*brachia*)

We have already observed that the arms and radials are part of the same formation. The radials form the bases of the arms, joined to the disk by their entire ventral surface. The arms are continuations that come out of this function, freely and in a straight line. The arms thus originate on the third radials, which is not in Rhizocrinus as in Pentacrinus and Antedon, an axillary radial having two arms but a single radial that, at its distal end, has a single arm. In the different individuals of Rhizocrinus, the number of arms is thus generally 5, but frequently also 4 or 6, very rarely, 7. Thus Rhizocrinus differs, by its rays or non-divided arms, in a remarkable way from all present crinoids in which there are always one or several bifurcations. Norman characterizes them thus (Annals of Nat. Hist. 1865, vol. 15, p. 100): “five bifurcated arms in the vicinity of the base and frequently divided again several times.” Rhizocrinus agrees, on the contrary, in this respect with some extinct genera such as Ctenocrinus, Cupressocrinus, Baerocrinus and others from which, on the other hand, it is very different in nearly all other respects.

In the largest individual observed (fig. 39, 60), the arms are 10 to 11 mm long, or nearly $\frac{1}{7}$ th the length or height of the animal. Thus, in relation to the size of the stem, they are not very developed. Each arm is composed of a series of segments or articles, that on a large part of the length of the arm, or article, are nearly equal in size from about $\frac{1}{3}$ mm. But, in its upper half, they taper successively a little, to hardly $\frac{1}{6}$ th toward the end (fig. 60, *ap*) or the terminal article of the arm that forms a small conical end, much exceeded by the upper pinnules.

In general, the arms are straight. But, in examining them closely, we often find them forming a weak zigzag, being weakly flexed alternatively to the right and left at regular intervals, notably every two articles that have a pinnule. In the largest individuals examined, the arms (fig. 60) are

composed of 28, 30, 32 or 34, rarely 36 articles without counting the end of the arm (the terminal article in the process of developing. Thus, the number is very small compared to that we find in *Pentacrinus* and *Antedon*. Although successive tapering a little toward the end of the arms, the articles are however nearly of each length over the entire extent of the arm. According to Carpenter, it is the same in this respect for *Antedon*, where, however, progressive thickening, from the end of the arm to its base, is very considerable, while in *Rhizocrinus*, it is very weak. The junctures of the articles, that are especially evident on the dorsal surface of the arm, resembles more that of *Pentacrinus*, being transverse and nearly parallel, than those of *Antedon* where they are oblique. There is, however, in this relation a difference between every two articles or which we shall speak later.

The first brachial (fig. 38, 39, 60–62, *b1*, fig. 65–69), much shorter than the last radial, seems in some way to present the passage of the fornia from the radials to those of the other brachials. Now, in the inner or proximal part (fig. 65–67, *pr*), it resembles perfectly the two preceding articles (the second and third radials) by its great width that is nearly two times its width and that equals the width of the last radial, as well as by its compressed form of the ventral surface to the dorsal with sharp lateral edges. But it becomes gradually narrower above or at the distal end (*ibid.*, *dj*), which is not wider than the following article and thus approaches the semi-cylindrical thinner form of the other articles. The dorsal surface is a little convex and smooth. The ventral surface has on each side of the median cavity a protruding conical part (fig. 65–67, *cr*), directed forward and passing the distal end of the article. This part recalls the similar extensions (fig. 55–57, *cr*) of the last radial. The proximal articular surface (fig. 68) has two elongated muscular facets and an articular crest that does not exist on the distal articular surface (fig. 69), united only by sutures to the second brachial.

The other brachials (fig. 70–75) are nearly equal in width and thickness. On the largest individuals, they reach about 1 mm on the lower half of the arm. On the upper part, they taper to 1/6th mm. They have some resemblance to the dorsal vertebrae and a transverse section (fig. 70–71) is semi-cylindrical or rather crescent shaped. The dorsal surface is arched or round from one side to the other. The lateral surfaces are less convex. The center is crossed by the circular channel of the axis that runs from the stem, the radials and the brachials as well as the pinnules of the latter. The ventral surface is very concave. The cavity, which contains the soft parts, is much wider and deeper than in *Pentacrinus* and *Antedon* and limited by bony walls. These are not, as in the genera mentioned above, unequally developed on the right and left sides, but fairly equal on the two sides. They have round lateral ventral edges that are not developed into extensions. Both brachials, i.e., the first (that has, however, as we have already seen, a form a little different from the others), the third, the fifth, etc., never have pinnules, are perfectly symmetrical and their distal edge (fig. 60, 61, *sg*) more projecting or more convex on the back. The articles alternating with these, i.e., the second, fourth, the sixth etc., the distal edge (fig. 74, *di*), on the contrary, is found fairly evenly cut at the back with a small arched notch at the center. The lateral ventral edges of these articles that never have pinnules, i.e., the second and fourth (in young individuals with less developed arms and with less numerous pinnules, even on a larger number of articles), are equally symmetrical and a little longer than those of the first mentioned articles. Finally, all the articles with pinnules, i.e., the 6th, 8th, 10th etc., have at the distal part of one of the lateral edges, an arched incision, wide but not deep, to receive a pinnule (fig. 60, *p*, fig. 62, *ab*). Thus, this lateral edge becomes shorter than the opposite edge. The lateral parts of these articles are thus not completely symmetrical. We see that there is a rather notable difference in the form of the brachials of *Rhizocrinus* and *Pentacrinus*. In the latter, all the articles have the same form and have a pinnule. The pinnules

alternate from one side to the other. On the side where the pinnule is located, the ventral edge of the article is divided into two sharp extensions, thin and divergent, the distal of which is always very oblique. The proximal, on the contrary, is only slightly so. It is into this notch formed by these two extensions that the pinnule is inserted. On the opposite side, where the pinnule is lacking, the wall is narrow and forms only a single extension. This difference on the two sides regularly alternates to all the brachials. The principal mass or the body of the articles does not participate in this dissimilarity of the sides and is thus presented in this respect as in *Rhizocrinus*. In *Antedon*, on the contrary, their body is alternatively shorter on one side than on the other side so that the dorsal surface of the arms shows only the lines of articulation alternatively oblique, and the brachials, especially those of the lower part of the arm, have a series of triangles whose summit turns alternatively from one or the other side.

As a peculiarity, I must also add that in one of my specimens with more developed arms, but in this one alone, the second brachial has completely the same dimensions as the first one, and the distal part is nearly wide as the proximal part, which gives it a nearly perfect resemblance to the third radial. Because of the smallness of the brachials of our *Rhizocrinus*, it is very difficult to give a perfect account of the nature of the articulating surfaces (fig. 70, 71). In general, it seems to me, however, fairly consistent to that of the radials. The muscular facets appear shallow and the articular crest weak and straight, while at the brachials of *Antedon* and *Pentacrinus*, it is strongly marked and in general oblique.

As we have already observed, except for the first 5 articles, both brachials of *Rhizocrinus* have a pinnule. This fact, which separates in appearance that which we find in all other crinoids, will disappear if we consider the joining of both articles as a syzygy (fig. 60, 61, *sg*), the hypozygal article being then always without a pinnule and the epizygal alone being with one. This seems to confirm the opinion is that we never find either muscles or ligaments between these two articles, while they are found between all the other articles where they strike the eyes by their slightly brownish color of specimens preserved in wine spirit and placed under the magnifying glass (fig. 39). When you put an arm in a concentrated solution of sodium carbonate, the real articles soon separate from each other (fig. 62) and a mass that joins them becomes apparent. This mass is soft, but fairly strong, composed of very fine longitudinal fibers (fig. 62, *l*) and muscles (64, *m*) located on the ventral surface (which are, however, difficult to isolate from the ligaments). The syzygial articles, on the contrary, remain united for a long time and, when finally separated, they have nothing of the kind among them. However, it has not been possible for me discover on the latter no more, as we have already said, than on the articular surfaces between the second and third radials, the radial fissures, ordinarily cited as one of the distinctive marks of the syzygies and so visible in *Antedon*. Moreover, the syzygial suture is not, as usual, fine and straight or perpendicular to the axis of the arm, but very strongly marked and flexuous.

What is peculiar for *Rhizocrinus* is thus the regular and continuous arrangement of the syzygies. All along the arm there is everywhere syzygy between the two true articulations. In *Pentacrinus* and *Antedon*, on the contrary, the syzygies are at larger and unequal intervals, having between them at least 2, but more often several and up to 14 true articles. Consequently, the arms of the largest *Rhizocrinus* seem up until now, are composed of 14 to 18 double articles, not counting the tip or the undeveloped terminal article.

In individuals whose arms are more developed, about 10 mm in length, each side of them ordinarily has 6 branches, called pinnules. These pinnules (fig. 39, 60, *p*), alternately located on the left and right, are directed more or less obliquely outward and upward. In only one case, also in a very developed individual with arms 11 mm in length, there were 7 pinnules on each side of

4 arms and on the fifth, 7 on one side and 8 on the other side. The first two double articles are, according to the observations made thus far, always lack pinnules. It is not until the epizygal article of the third double article (the sixth single article) that it is found on the left side, then another on the right side of the epizygal of the fourth double article (the eighth single article) and so on, alternating on all the double articles to the small conical end of the arm (fig. 60, *ap*), (many times shorter than the last pinnule where new brachials are developed. In the largest specimen that we just mentioned, the pinnules also begin, on the arm that has 7 pinnules on one and 8 on the other side, at the sixth single article, but, on the 4 other arms that have 7 pinnules on each side, only at the eighth single article (the epizygal article of the fourth double article). From this fact we can conclude that it is probable that the number of pinnules of each arm can increase to 8 pairs at least, because it would have without doubt produced later a pinnule on the sixth single article of the 4 arms where it is still missing.

Individuals with shorter arms (fig. 38) have 5 or 4 pairs of pinnules that begin only at the eighth single article. Others, with arms still less developed, have 3. Others (fig. 17) still only 2 pairs of pinnules that also begin on the eighth single article. Finally, in individuals (fig. 1, 2, 16) with arms a little more than one mm in length and composed of 8 articles (i.e., 4 double articles, that we cannot yet recognize as such), without counting the conical end of the arm, we still cannot find developed pinnules.

If there develops also, in individuals older than those I examined, pinnules at the first or first two double articles, where they were missing in all of mine, it is then a question which it is necessary to leave the solution to new investigations. They are missing at least on the single individual with gonads (fig. 60), consequently presumed adult, that I have had the opportunity to examine. It is hardly probable that they can be present later or may form the so-called oral pinnules as in *Antedon*, where they already begin to form at an age little advanced than the larval or pentacrinoid state, and even well before there is any trace of immediately above pinnules. There does not exist any other than those that appear first near the end of the arm.

Compared to the pinnules of *Pentacrinus* and *Antedon*, those of *Rhizocrinus* are rather large (fig. 39, 60, *p*), relative to its arms. They are linear (fig. 77–81), nearly straight or slightly bent inward, especially toward their end (ibid, *ap*), and compressed on both sides. Their back (ibid, *dr*) is consequently square, the belly nearly concave, and they keep the same form and size up to their end. The largest, about 3 mm in length, is found in the middle of the length of the arm. Nearer its base and even more at its end, they decrease successively. They consist of a very variable number of articles, 11 to 12 in the largest, rarely up to 15. Small ones have 9, 8, 7 or 6 articles. The articles are a little longer than wide. At the end of the pinnule, they shorten a little and the last article (fig. 77–81) is formed of a pointed cone and more or less bent inwards, smooth, and not, as in *Antedon*, with small hooks. The first article that is thinned a little towards its base, is articulated with the brachials. There is without doubt (although, because of the smallness of the object I could not perfectly realize it) between the two, as in *Antedon*, a small muscle that causes movement or bending of the pinnule. Its extension, on the contrary, when the action of the muscle ceases, operates by elastic ligaments. The transverse section (fig. 82) shows the articles as very narrow crescents or nearly in the form of a horseshoe. The middle of the back of their true body (ibid, *dr*) is nearly triangular or keeled, the lateral parts (ibid., *lt*) very thin and symmetrical (in *Pentacrinus*, one of the lateral parts is, according to J. Müller, longer than the other.

The pinnules of *Rhizocrinus* are distinguished by their coarser shape, originating from the large plates of the groove, of which we are going to occupy ourselves, from those of *Pentacrinus* and of

Antedon. In the latter, especially, they are very narrow or nearly filiform, and those of the lower pair or the “oral pinnules” differ moreover from the others in size, structure and probably also in the relation to their function.

On the disk, as well as in all the length of the arms and the pinnules, the tentacular groove, not superficial as in Antedon, but deeply sunken because the very concave ventral surface of the articles, has on each side a continuous longitudinal row of thin hyaline calcareous plates (fig. 62–64), 76–82, *h*) that I call *lamellae of the groove*. In proportion to the articles, they are rather large, on the arms, nearly as wide as half the width of the article, and at the pinnules, where they keep the same size, nearly as wide as the full width of the articles. On the other hand, some of the lamellae near the end of the pinnules are ordinarily smaller than the others that are almost all the same size. They are oval in shape (fig. 83) and attached to the skin (“perisome”), immediately inside the very thin ventral lateral border of the articles, by their lower or posterior end (fig. 83, *b*). Otherwise, they are free and placed transversely and a little obliquely to the axis of the pinnule, so that their free border (83, *ap*) is directed forward or above and a little outward. Under the microscope, we see that they are composed of an elegant network (fig. 83, 84), expanded on a single plane, of very thin hyalin calcareous rods (84, *r*), forming the polygonal mesh (ibid., *f*). They are mostly hexagonal (sometimes also elongated). These meshes, that are large in the middle of the lamella, decrease gradually toward the edges formed by small protruding points of the calcareous rods.

The calcareous network is surrounded by an envelope of very fine hyalin sarcode, visible only at the edges between the small points. The lamellae, of which there is most often one and sometimes (notably in the pinnules) two pairs for each article, are mobile. They can be arranged nearly perpendicularly (fig. 62, *ls*) and show the tentacles between them, but usually lie down, superposed to each other like the slates on a roof, both in the same and the opposite row. These always alternate regularly, completely hiding the groove with its tender, soft tentacles.

These lamellae appear very different from the “valvular folds” or “small growing lamellae”, as Carpenter called them and a little similar, it is true, in some respects, that are present in Antedon along the two borders of the tentacular groove. These latter lamellae, relatively very much smaller than those of Rhizocrinus, each article having 3 or 4 pairs, are however, only small sinuosities of the skin (“perisome”) of the edges of the tentacular groove and consequently, parallel to these edges, membranous, sessile with a wide base, and finally immobile. Calcareous plates, also relatively small in extent, 4 or more for each brachial, also limit, according to Müller, the tentacular groove of Pentacrinus, where, however, as in Antedon, they are only sinuosities of the borders of the tentacular groove, consequently longitudinal and immobile.

Like all the rest of the skeleton of Rhizocrinus, the arms and the pinnules, as well as their thin lateral parts, are composed of a calcareous network (fig. 78*), continuous with round meshes, nearly equally large, whose diameter is generally smaller than the thickness of the calcareous rods.

As far as the arms and pinnules of my specimens preserved in wine spirit, they are most often retracted. Here and there only are they found extended (fig. 2, 62, *t*). They agree in all respects with the radial tentacles of the mouth, already described. However, it is impossible to say positively that they are accompanied by other tentacles corresponding to the interradian tentacles of the mouth of the mouth of Antedon, in which there comes out from the lateral side of each of the “small crescent-shaped lamellae) along the tentacular groove, a group of 3 tentacles, one of which is much more extensible than the other two. By the strong compression of a pinnule I distinctly saw that the groove has more tentacles than lamellae. It seems to me that, for each lamella, there is a long or extensible tentacle, and, next to it, one or two much shorter ones. Finally, I must note that, in

Rhizocrinus, we find no trace of brownish-yellow or reddish-brown globular vesicles as in Antedon (free as well as the pentacrinoid state) and whose function is still problematic.

4. REPRODUCTION

Reproduction of extant sea lilies, notably that of *Pentacrinus*, is still unknown. We do not know if the genital material is formed in the pinnules, as in *Antedon*. It is thus of the highest importance to know what it is, in this regard, in *Rhizocrinus*. Examination of numerous specimens brought back during the first two years by my son from the Lofoten Islands has not given me the solution to this question. In vain have I minutely studied all their pinnules, in the hope of finding there, as in *Antedon*, traces of genital organs. Everywhere pinnules having the same aspect, without vestige of swellings of the soft parts, — similar to those that in *Antedon*, indicate the seat of gonadal matter.

The third year only, my son, to whom I had especially recommended to give it all his attention, found, at the end of the month of September, a single one of our sea lilies in which the gonadal organs had evidently begun to development. I then gave this individual, carefully preserved in wine spirit, a minute examination. It is the largest of all those found to the present. Its stem is nearly 70 mm and its arms have 10 mm in length. Each of its five arms has 6 pairs of pinnules. The lower pinnule of the one and the two lower pinnules of the other side (fig. 60, *p*, 60^l) of the has striking swellings that make them, although shorter, a little thicker than the following ones. These swellings come from what has been formed in the interior of the pinnule, an elongated, fusiform, finely graduated mass (Fig 60, 60^l, *gn*), extending nearly from the base of the pinnule up to a little more than half its length. This mass, which by its white opaque color is seen perfectly through the outer integument, consisted, according to the examination my son made on the living animal, of very small cells of elliptical elongated form or rather similar to those that Wyville Thomson (1. c, pl. 23, fig. 4, 5) has found in the testis of *Antedon*. It is thus nearly indisputable that this opaque white mass was a testis still at the beginning of its development as it was impossible to discover spermatozoids, and that the genital organs of *Rhizocrinus* agree with those of *Antedon* and occupy the same place.

Another individual taken simultaneously, whose stem is incomplete, but whose arms are still a little more developed than those of the first, being 11 mm in length, and each having 7 pairs of pinnules (one of the 5 arms with 7 pinnules on one side and 8 on the other side), however still show no trace of genital organs, the lower pinnules not being swollen, but completely similar to the others. It is moreover well known that, in some individuals, reproduction begins earlier than in others. As we know now the season when reproduction of *Rhizocrinus* begins, we shall without doubt succeed later to better know it and to have information on the development of this animal.

5. Young state and growth

Although I have no information to give on the early state or development of *Rhizocrinus*, I hope that the following observations on some of its young states will not be lacking in any interest.

1° The youngest state that I have encountered to the present of *Rhizocrinus* in regard to the corona and the enlarged upper article of the stem on which the corona is located is in an individual

(fig. 95) of 25 mm length. The stem has 28 articles, of which the well-developed lower one is not quite $\frac{2}{3}$ mm thick. The five immediately following below the enlarged upper article are much thinner (5 to 6 times thinner than the lower articles). The enlarged upper article (fig. 95, *a*) is still very small and evidently at the time of its first development. It is in the form of a cup, hardly 1 mm long and nearly the same thickness, with a weak transverse narrowing in the middle of its length. Its upper edge has 5 extensions directed above and a little outwards, rather large, triangular, located equidistant from each other. These are without doubt only the extensions similar to, but relatively much smaller (fig. 2, 35, 36, 39, 44, 48), extensions that are found at the same place in older individuals, as discussed above. Above this border is raised a circle of 5 large triangular plates, or rather tongue-shaped and convex (fig. 95, *o*), vertically or properly called obliquely directed above and inward against each other. At their base, these plates are truncated, but they narrow successively a little towards their upper round end, by which they meet at the top or at the center. I first took them for oral plates, but with a closer examination, I have seen that they are located in the intervals between the 5 triangular extensions located on the upper edge of the widened upper article, and that, consequently, they are radial. The oral plates, on the contrary, are always interradial. They cannot thus be anything other than the second radials. Very thin and lamellar, they consist of an elegant network whose form seems to have only a single plane, with round mesh whose diameter is 2 to 3 times larger than that of the calcareous rods. I have not noted any traces of the first radials, because I have not found the faint grooves that mark their place in older individuals, unless perhaps the transverse indentation around the middle of the article is not an indication. In addition, I have discovered neither basal plates nor traces of developing arms at the end of these second radials. A thin envelope of hyaline sarcodite (fig. 95, *m*) closely surrounds the two small developing articles (*ibid.*, *ar*), located immediately below the upper enlarged article of the stem. On the other articles, on the contrary, it was impossible to discover it.

In another young individual (fig. 36, 37), 29 mm in length, a stem composed of 31 articles of which the lower are $\frac{2}{3}$ mm thick, the upper widened article is already well developed, nearly $1\frac{1}{2}$ mm in length, and, at its upper part, more than 1 mm thick. The 5 triangular extensions of its upper edge have become relatively very small and short, as in older individuals. On the other hand, we already see rather distinctively the slight convexities around the upper third of the article, limited by very fine grooves (fig. 36, *s*), indicating the first radiales located inside. The 5 second radials (fig. 36, *r2*), rising perpendicularly above the upper edge of the article, are already well developed and have nearly taken the ordinary form. The third radials, on the contrary, are still not developed. But, in the middle of the upper end, obliquely truncate from outside to inside and below, each of the second radials (fig. 26, *r2*) produces a very small developing arm (fig. 37, *h*, 9, *b*). These five arms are bent inward or rolled up so to say in a spiral in the large cavity formed by the circle of the protruding second radials (the ventral disk, which occupies later the place of this cavity, not having yet started to rise). Their ends are thus encountered in the center of this cavity. Each of the arms, $\frac{1}{3}$ to $\frac{1}{2}$ mm in length, is very thin (having about the width of the second radial and having, consequently, a sudden and considerable thinning), nearly cylindrical, a little flattened only on the side turned inward of ventral, and composed of 7 articles of equal thickness, of which the first is very short (two times wider than long. The others are nearly equally wide and long. The terminal article is conical with a round obtuse end. The protruding free plates (the lamellae of the groove) along the two sides of the tentacular groove, which have recently begun their development, are very small and round.

A third individual, only 13 mm long and with a stem composed of 22 articles, is completely similar to those we just described, except that the arms, equally very short and thin with few

articles, are not bent inwards towards each other, but extend in the direction of the longitudinal axis of the animal.

In a fourth individual, 19 mm in length, whose stem has 23 articles, the arms are larger, nearly 2 mm in length and with 10 articles. But, otherwise, not more developed than in the two preceding individuals. It is the same with a fifth individual, that is 17 mm in length and whose stem has 29 articles. Its arms, 2 ½ mm in length has 12 articles, but has for the rest no difference with the 4 preceding.

2° It is in an individual 20 mm long and with a stem of 31 very thin articles, that I have seen develop the first pinnules of the arm. The arms are 2 ½ to 3 mm in length and composed of 13 articles, of which the latter is conical. At its base or rather at the side of the 12th article, it has produced a small pinnule composed of 5 articles. On the opposite side of the tenth article, another pinnule composed of six articles, nearly two times longer and thicker. Both already have lamellae of the groove along their ventral surface. I have never found a bifurcation of the end of the arm, as in the pentacrinoid of *Antedon* in a way to make “both branches nearly equally large” (Carpenter, 1. c. p. 734, pl. 40, fig. 1). The first pinnule always appears on one of the sides of the base of the free conical terminal article. Starting from the penultimate brachial, it has been, in all cases, much larger than the terminal article. The third radial, which is still not distinctly developed, cannot be recognized as such. Having only half the length of the second radial and a distal end a little thinner than the proximal, it resembles rather the first brachial in older individuals.

In another individual 23 mm in length, whose stem has 29 articles, the arms are longer, having reached 5 mm. It has on their upper part 2 pairs of pinnules or, on some arms, 2 pinnules on one side and 3 on the other side. The third radial is here well developed and has the same relative size and even the square form as in adults. Finally, as in these, the first brachial is distinguished from the others by the greater width of the proximal part (equal to that of the second and third radials). It narrows successively a little towards its distal end, which is not wider than the following brachials.

Thus, it follows from the preceding observations that the second radials are those of the plates of the corona that are the first to be visible on the outside, but rather different from their definitive form, being first more elongated, narrower at the distal end and very thin or lamellar. The formation of the basals and of the first radials still has not been observed and without doubt occurs at an anterior period. It is only much later that we can recognize the third radials, i.e., only after the second radials are considerably thickened and have taken their definitive square form and that a series of brachials is developed on top of the second radial. It is probable that the third radial develops from the first or shorter of the first brachials, and the first definitive brachial that is distinguished a little from the others by its form from the second of these brachials.

When the arms are developed enough to have 11 to 13 articles, the pinnules begin to grow at their end, notably at the base of the conical terminal article (where the formation of new brachials always takes place) or rather in the penultimate article, the youngest of all. As new brachials develop, they form a new pinnule for both (because we see alternately a hypozygal article that never has a pinnule). The formation of pinnules continues thus regularly from top to bottom, in a way that the lower ones are oldest and upper ones the youngest. However, it still produces later, below the oldest pinnule formed in this way (as we saw above from the tenth brachial), two pinnules coming out from the eighth and the sixth brachials. The 5 lower ones, on the contrary, remain, according to the present observations, lacking pinnules. The individual figured pl. 1, fig. 1, without counting other specimens, shows moreover that the corona, notably the third radials and also the arms, often develop only at a very advanced age where the stem is much larger and

composed of more articles than in the individuals already cited. The specimen in question is 54 mm long, the stem has 60 articles. The arms that have only recently started to grow are hardly 1 mm long and have only 7 articles. The second radials alone are there (fig. 2, 3, *r2*, from another individual equally developed), the third still cannot be recognized as such. In general, the development of the corona and the arms appears to depend on neither a certain age of the individual, nor, more specially, of that of the stem, which seems to be the part formed first. According to circumstances (as more or less abundant food etc.), it can take place earlier or later. What is positive is that we generally find the two first parts more developed in individuals whose stem is larger or composed of more numerous and more developed articles.

As for the growth of the different parts or organs, we must make some observations.

Of the articles of the stem, the upper ones are always shortest and thinnest, the lower ones, the longest and the thickest. The latter are the first formed or the oldest. The more we go up, the younger they are. All the series of articles has thus their successive development from top to bottom. From this general rule, it is necessary however, to except the upper enlarged article, inversely conical or caliciform, that seems to form only after the development of a series of ordinary articles. It is immediately below this article that the formation of new articles occurs (fig. 2, 35, 36, 38, 85, 86, 95, *ar*), that seem to have no limits or to continue during all the existence of the animal. However, we find the greatest variation in the number of articles of the stem in different individuals in a way that we rarely encounter two that are alike in this respect. The new article that develops has the form of a ring, often 5 to 6 times wider than long. In some cases, I have discovered this new article at the beginning of its formation, while the annular groove that must limit it, still being incomplete or did not extend all around it (fig. 35, *ar*). The following articles, that are also young, but older than this one, increase little by little rather rapidly and soon reach nearly the normal length. The other lower articles, on the contrary, are little elongated, but grow more. The new articles formed are cylindrical with a uniformly convex surface. Fairly frequently they are transversely more convex in the middle than at the two ends or barrel shaped (fig. 16, 35). With the formation of new articles, always more numerous below the enlarged upper article makes them descend more. They begin to become more or less transversely concave in the middle due to the thickening of the two ends, as we have already seen in the description of the stem. We find no trace of new articles formed by interpolation between the old ones or by division of these that, over the entire stem, with the exception of the upper part, are all of nearly equal length.

It happens, however, although rarely, examples of a development more irregular than usual of articles of the stem. However, in these individuals (fig. 16, 17, 19), a more or less large number (in 10 different individuals, I have found from 7 to 27 of these articles) suddenly become thinner than the lower articles that have the ordinary thickness. In most of these cases, the upper article of the latter has, in its lower half, the same thickness as the following lower articles, which have the ordinary form, transversely concave in the middle or thickened at both ends. The upper half, on the contrary, becomes 2 to 3 times thinner than the other or as thin as all the other cylindrical articles located above. We must without doubt search for the reason for this phenomenon of a sudden decrease in the intensity of growth of the stem, caused by chance circumstances, e.g., by a decrease in food.

As for the cirri, it is obvious that new articles are formed at their end. This is indicated by their multiple ramifications and the small diameter of the articles at the end of the branches in the

examples already mentioned, i.e., that the end of a cirrus that is attached to a foreign object can be extended either by crawling on its surface or by developing new free branches, which in turn, can finally be fixed by its end to a new point. According to Carpenter, it is quite different in *Antedon*, where the new articles form at the base of the cirri.

The second radials are, as we have already said, in the youngest of the individuals examined, narrower at the distal end than at the proximal (fig. 36, *r2*) and very thin or lamellar. Thickening later, they become more square and nearly equally wide at the two ends. But for some time, they continue to be longer (a fifth to a quarter) than wide (fig. 35, *r2*, 53, 54), until they are widened more in individuals with completely developed arms and become nearly equal in width and length (fig. 39, 48, *r2*, 49). Even in rather large individuals (e.g., in an individual with a stem 60 mm long and composed of 55 articles and with arms 5 mm long and with 3 pairs of pinnules, they are still longer than wide.

The third radials are at the beginning (fig. 18, 38, *r3*) several times shorter and also a little narrower than the second ones. They increase in diameter however little by little in the two dimensions until they become finally as wide but a little shorter (fig. 39, 61 *r3*) than the second ones. However, all the rays of the corona are not always developed equally. Thus, in an individual whose arms already have a pair of pinnules, I have found the third radial well developed only in one of its 5 rays and in size and in form nearly equal to the second. On the other 4 rays, on the contrary, it was about 3 times shorter and 1/5 narrower than the second.

The arms grow, as in *Antedon*, by the formation of new articles, not by interpolation at the base or on some other part along the arm, but only at the upper end, which rises like a small conical end (fig. 60, *ap*). At this point ("growing point" of Carpenter), it has a transverse groove that limits a new article and when this is consolidated, it has a new transverse groove etc. Moreover, in general, all arms grow regularly. It is very rare that we find an arm that has remained behind. Thus, I have found only two individuals with seven arms that are, in one (pl. 1, fig. 1) all equally long. In the other (fig. 2), one of these arms is nearly 3 times shorter and only about half as thick as the others, that are all of equal size.

The pinnules also seem to increase at the upper end by the formation of new articles. Now, it is there (fig. 78–80) and not at the base that we ordinarily find the shortest article and the smallest lamellae of the groove. The last article being, moreover, like the terminal article of the arm, a simple conical end (not being, as in *Antedon*, provided with small hooks). There is nothing that opposes the formation of new articles at this terminal part.

6. Appearance and way of life

Rhizocrinus lofotensis, as indicated by its name, was discovered in the group of islands of Lofoten, where it was found at the islands of Buldband and Brettesnes at a depth of 100 to 200 fathoms and at Skraaven, where it descended to a depth of 300 fathoms, everywhere on hard clay bottom, mixed here and there with coarse sand and small stones. All these localities are located fairly close to each other and in the polar circle at latitude 63° 11 to 15' N. Later, my son also found a dead specimen, incomplete but perfectly recognizable, at Frosten in the Gulf of Thordheim at latitude 63° 35' N at a depth of 80 fathoms, also on hard clay. In contrast to species of the genus *Pentacrinus* which is so rare in the present epoch, our *Rhizocrinus* is present evidently in groups or living, so to say, in communities like a large number of ancient sea lilies, e.g., *Apiocrinus*, *Pentacrinus briareus* and *Eucrinus liliiformis* that we often find in masses. Thus, my

son has taken, with a single cast of small dredge with a fine mesh, up to 13 living individuals, more or less complete, without counting numerous fragments.

As far as species of *Pentacrinus* of the West Indies, they have been taken at a depth of 25 to 60 fathoms, and those of Australia at 8 fathoms. Our *Rhizocrinus*, on the contrary, lives in much greater depths, namely from 80 to 300 fathoms.

The small number of extant sea lilies (*Pentacrinus* and *Holopus*) have been found until now only in tropical seas. *Rhizocrinus*, on the contrary, inhabits the North Sea within the polar circle and, to the south, to the Gulf of Trondheim. As we have already said, it is attached to different bodies that are on the sea bottom, not immediately by its lower end, but by means of its cirri. Because of this particular mode of attachment, its stem is rarely or nearly never completely straight, but in most of the cases, more or less bent, fairly often sub-spiral below with its lower end pointed up again (fig. 16, 17). The bottom part of the stem, like that of many plants, rests on a more or less long extent, lying on the sea bottom until it has found sufficient points of support by attaching to foreign objects. Then the rest of the stem straightens freely and becomes sometimes rather straight or perpendicular, sometimes twisted into one or two elongated sinuosities (fig. 1).

The numerous specimens of our *Rhizocrinus*, collected by my son, were taken by him at the Lofoten Islands in different seasons, especially from the beginning of March and during all the following months to the end of September. Finally, the last specimen mentioned, that from the Gulf of Trondheim, was taken at the beginning of October. In all these different seasons, the animal has not shown any sensible modification in regard to form or otherwise. We can correctly conclude that it is not a state of youth (as the pentacrinoid of some unknown animal similar to *Antedon*, but an adult animal, a particular sea lily. This conclusion is more confirmed by the discovery of an individual with gonads that we have already mentioned.

J. Müller concluded from his observations that *Pentacrinus* does not actively bend its stem, but that it has a certain passive flexibility, so that it can respond to the movement of the water. Lütken (1. c, p. 241) supposes "that there is a greater and probably independent (voluntary) mobility in *Bourgueticrinus*, whose articles of the stem are united to each other by the same kind of true articular joints as those the unite the articles of the arms of sea lilies."

After having called the attention of my son to the particular structure of the articular surfaces of the articles of the stem of *Rhizocrinus*, I asked him to examine the living animal to know if the stem really had the ability of independent or voluntary movement. Here is what he communicated in this regard as well as on other vital phenomena that he was able to observe in our animal.

"Despite all my attention, it was not possible for me to discover any independent movement of the stem. I have encountered fairly often, it is true, individuals whose stem has been singularly bent and twisted. But it remains thus without any change during the entire life of the animal. Consequently, the particular structure of the articular surfaces can without doubt have only the goal of making the stem flexible in several directions in order to enable it to resist without breaking, exterior movements, e.g, currents of water etc. In the state of repose, the animal attaches its extended arms horizontally or nearly in the same plane for its entire length, like the petals of a flower. Sometimes, a single arm bends fairly rapidly in a spiral inward and towards the mouth while the others remain extended. In other cases, the arms more or less come together and form a more or less deep funnel, whose central disk is the bottom. During strong irritation, all the arms close to form a tight bundle, straight and stretched forward. In active individuals, I have in general found the movements of the arms fairly energetic. A large individual, placed directly into a glass filled with fresh sea water, gave its arms such a vigorous outward movement that, in applying its arms against the bottom of the glass, he was moved fairly far many times from the place it had

occupied. However, this movement was neither as continuous nor as regular as those of swimming Antedon. It consisted only in a simple outward movement, often with only one or 2 arms.”

Among my specimens, kept in wine spirit, many have their arms tightly closed in the form of a straight bundle stretched forward. The ends of the arms are sometimes extended in straight line, sometimes a little bent inward. Thus, the radials and the first brachial are joined so tightly to their neighbors of the other rays that they surround and completely hide the disk. This is contraction to the last degree. Others (fig. 39) have more or less kept the funnel form of the arms, separated from each other like a flower that opens its petals and bends obliquely above and outward, sometimes fairly straight, sometimes forming an elongated, slightly pronounced arc whose convex side is above so that the end of the arms is either a little curved behind (i.e., in the dorsal direction), or directed above (in the ventral direction). Only two specimens have the arms extended nearly horizontally (fig. 89) and, in one only, they are strongly curved behind or in the dorsal direction and form a spiral of 1 or 1 ½ turns, as we see ordinarily in the figures of present *Pentacrinus* or in specimens of *Antedon* preserved in wine spirit. Evidently, this last individual was very weak or dying when it placed in the wine spirit because, the muscle being located only on the ventral side of the arms, the muscular force could bend the arms only inward or in the ventral direction. Their extension, on the contrary, is made by the elastic ligaments, located between the articles. However, these ligaments begin their action immediately after the muscular force decreases and even still when it ceases completely as in the dying animal.

The pinnules never extend from the arm in a completely straight or perpendicular line on the arm, but even in the state of extension, a little obliquely outward and above or a little forward (fig. 39, 30, *p*). They can be bent inward and then be applied tightly to the arm so that they extend, like the arm, forward in a fairly straight line. In addition, they are not found completely in the same plane as the arm, but always directed a little inward or towards the ventral surface.

7. Affinity and systematic place.

Rhizocrinus belongs to the sea lilies or crinoids fixed on an articulated stem. However, in them the stem persists. In *Antedon*, on the contrary, it is temporary, found only in its larva called pentacrinoid.

As we have already often observed, *Rhizocrinus* is greatly separated in most respects from the few sea lilies known to the present. It is, consequently, among the numerous and diverse genera of ancient times that we must search its nearest relations. By its most conspicuous particularities, namely the thickened upper end or enlargement of the stem that forms the base of the corona, it actually seems very near the extinct family *Apiocrinidae* of d’Orbigny. However, this enlarged upper end consists, in *Rhizocrinus*, only of a single piece or article. In *Apiocrinus*, on the contrary, it is composed of a series of very short articles. In *Bourgueticrinus*, according to Müller (*Hist. of Crinoida*, pl. 7 bis, fig. 1–4), of two long articles, or in other cases, according to Goldfuss (*Petrefacta Germanise*, pl. 57, fig. 3 R) of a single article. With the latter form, that has this less enlarged end than the first and that seems specifically different from the latter, agrees a specimen (without doubt less well preserved) of the Britannic limestone formation, that was given to me by Wyville Thomson, in that this end seems to be composed only by a single article.

Rhizocrinus, however, is separated from the known genera of the family of apiocrinnids in that the basals of the calyx that, at least in the genus type *Apiocrinus*, are well developed and large, are not visible on the outside, but seem to be found, as in *Antedon*, inside in a rudimentary or

metamorphosed way. It is also separated by its non-divided rays or arms that, in the apiocrinids are always at least once and sometimes several times divided and finally, by the non-thickened lower end of the stem, whose articles are well developed. This end, on the contrary, that in apiocrinids without exception, as we know them in this regard, is strongly thickened and the formation of the articles there more or less eliminated. Among the different genera generally included in the family of apiocrinids, there is, however, one, *Bourgueticrinus*, found in the “white limestone” of England and in the Cretaceous formation near Mäestricht and Osnabruck that, like *Rhizocrinus*, belongs to small crinoids². It is precisely with this genus, that has moreover several differences from *Apiocrinus*, type genus of the family, that our *Rhizocrinus* has so much affinity that it seems nearly indisputable that they must be placed beside each other in a natural classification.

First of all, the two genera conform with regard to the form of the articles of the stem, which in its upper part are cylindrical or sometimes somewhat similar to kegs, but, in all the rest of the stem, more or less concave in the middle. They still agree in the compression of the two terminal parts, which makes the articular surfaces more or less elliptical³, so that the diameter of the longer part of the upper articular surface crosses that of the lower articular surface of each article at an oblique angle. The fact that, in addition to *Bourgueticrinus*, is known so far that in a few species of the genus *Platycrinus* (Müller, p. 75, pl. 2, fig. 2–17, pl. 3, fig. 11–13), is also found, as we shall see later, in the pentacrinoid of *Antedon*,

In addition, this conformity is found in the peculiar joint of the articles of the stem, which are different from that of all crinoids except those we have just cited, the articular surfaces being striated neither in the form of the rays nor in the form of petals, but in having an articular ridge in the direction of the large diameter. This suggests there is more mobility or flexibility than is usually found in other crinoids. There are, it is true, some differences, although not very considerable, between the two genera in question in the nature of the articulating surfaces. However, in *Bourgueticrinus*, from the figures of Müller (1. c, pl. 57, fig. 3, *H-M, P*), with which those articles that have been sent to me by W. Thomson fit perfectly, “They are a little concave and the edges protrude all around” (Bronn, *Lethæa*, vol. 2, p. 174). But the slightly stronger cavity no longer has the peculiar form that we find in *Rhizocrinus*, where the articles of the stem do not have this protruding border, separated by a groove from the rest of the articular surface and raised above it,

² D'Orbigny believes he can relate to the genus *Bourgueticrinus* some articles and fragments of round crinoid stems, found in Guadeloupe in breaches of the present time, only because of their non-striated articular surfaces. The breaches, where these debris of crinoids are found, containing only still living species (among others even human bones) and still forming today. d'Orbigny presumes that this crinoid, which he provisionally calls *Bourgueticrinus* *Hotissianus*, exists still in the West Indian Sea. — We must certainly agree with Lütken when he says in this regard (1. c, p. 212), “that the completely negative character of these alleged articles of the stem (however, Lütken is not far from believing that at the bottom they could be “articulated roots” coming out of the lower end of the stem of one of the species of *Pentacrinus* of the West Indies), in that they are round, smooth and without grooves nor figures on the articular surfaces, can none the less authorize their closeness to the genus *Bourgueticrinus* as the typical species of those having a very particular mode of joining between the articles of the stem. and that this mode of joining, different from that of all other genera of crinoids, must be regarded as essentially characteristic for this genus as regards the stem.

³ Among the upper articles of the stem of the English *Bourgueticrinus ellipticus* that Wyville Thomson sent me, some, probably the first of the upper end, are cylindrical with circular articular surfaces, others, on the contrary, strongly convex in the middle or resembling slightly barrels. The latter already have articular surfaces a little elliptical, with the articular ridge in the same direction as the longer axis of the ellipse. As for the lower articles of the stem, concave in the middle, the two terminal parts are, according to the figures, completely similar to those of Müller and Goldfuss, more compressed, and the articular surfaces consequently more elliptical than in *Rhizocrinus*.

which surrounds their edge in *Bourgueticrinus*. Finally, the articular ridge of the latter has all along its length, a groove (that does not exist in the first), but no lateral teeth, and, in the center, it is only interrupted by the very narrow axial canal. In *Rhizocrinus*, on the contrary, it is interrupted over a fairly large area by the widening of the axial canal into a large cavity in the form of a biscuit.

The thick upper end of the stem is composed of numerous articles in *Apiocrinus*, 2 in *Bourgueticrinus* or sometimes, it seems as in *Rhizocrinus*, of a single article that may have its origin in the union of several articles. The future may provide us in this regard more positive information.

Unlike the stem of other genera of the family of apiocrinids, those of *Bourgueticrinus* has cirri. We do not know if these cirri were single or ramified. Here is what Goldfuss (1, c, vol. 1, p. 186) says: "They are placed irregularly on the articles, both cylindrical and geniculate (i.e., concave in the middle) of the stem, always on the truncated edges of two contiguous articles, and, in geniculate articles, on the protruding corners formed by the articular ridge. They also seem to have been, from the beginning, only growths of these corners and the articular ridge." It seems, however, from this description, that the position of the cirri was not irregular as Goldfuss thought, but as regular as in *Rhizocrinus*, because they would leave, otherwise, as Goldfuss thought, from the very ends of the articular ridge. at least immediately below. Moreover, according to the analogy taken from *Rhizocrinus*, it does not appear probable to me that they are also present in the middle or in the cavity of the article, as we see it in Goldfuss, pl. 57, fig. 3 F. According to the same author, they would also be found in the cylindrical articles, where they never appear in *Rhizocrinus*. In my specimens of the upper cylindrical or a little barrel-shaped articles of the English *Bourgueticrinus*, it has been impossible to discover the least trace of it.

As for the corona of *Bourgueticrinus*, Wyville Thomson, in sending me a specimen of it that has very distinctly the first radials, but no or very indistinct basals, observes: "As in *Rhizocrinus*, the basals of *Bourgueticrinus* are extremely attached to the upper article of the stem. In older individuals, they seem to coalesce." Another point of conformity between these two genera.

The arms of *Bourgueticrinus* still seem not to be known. Dujardin and Hupé (*Histoire naturelle des Echinodermes*, p. 177) say on this subject (without doubt after d'Orbigny, whose *Histoire naturelle* of the crinoids I could not obtain): "Pyriform calyx, composed of five basals and five first radials, above which two other radials form the free base of the arms. The bifurcation begins at the third radial." It seems permissible to conclude that there are 10 arms as in the other apiocrinids. In *Rhizocrinus*, it does not have bifurcation. Its arms are single, non-divided.

Likewise, it is in the form and the joints of the articles of the stem that the affinity between *Bourgueticrinus* and *Rhizocrinus* is especially striking. There is precisely in the same respect an evident conformity between the two genera and the pentacrinoid or larval state of the genus *Antedon*. Its stem, with the exception of its upper end that is not noticeably thickened, is composed of articles of very similar form, the joints of which seem completely of the same nature as in the two genera.

As for the corona, there is conformity between *Rhizocrinus* and the free or adult *Antedon* in that its basals are not visible on the outside. But, it seems, that they are found in the interior in a modified and rudimentary form (like the small "plates in form of a rosette".) But in other reports, *Rhizocrinus* differs from *Antedon* notably by the very variable number of rays and, above all, in that they or their continuations, the arms, remain undivided. By lack of development in proportion to the length of the stem, the arms have more resemblance with those of apiocrinids than with those of *Pentacrinus* and *Antedon*. It is thus not surprising that they can be undivided in a genus as close to apiocrinids as *Rhizocrinus*.

On the other hand, there are many things in *Rhizocrinus* that recall the pentacrinoid or larval state of *Antedon*, as: the persistence of the calcareous oral valves or rudimentary oral plates, the elongated shape of the second and third radial, little developed articular surfaces of the arms and their joints, the symmetrical form of the brachials (during the youth of the pentacrinoid, because, at the age of maturity, when it is at the point of detaching from its stem, the brachials of the pentacrinoid of *Antedon Sarsii*, but not, it seems, those of *Antedon rosaceus*, are already oblique and not symmetrical as in the free *Antedon*), the absence of pinnules of the basal part of the arms (as in the pentacrinoid of *Antedon rosaceus*. In those of *Antedon Sarsii*, at the age of maturity, there are also most often pinnules on this part), etc.

In a few words, *Rhizocrinus* seems, in some respects, a degraded type of the apiocrinid family, having most affinity with *Bourgueticrinus*, and forming, so to say, the transition from the apiocrinids to the present genus *Antedon*, and notably to its larval (pentacrinoid) state. It is a dwarf genus, living in the depths of the cold northern seas, of the stalked crinoids or sea lilies, so widespread during ancient times in nearly all the seas of the world, but in present times only represented by very few species, considered until now as belonging exclusively to tropical seas.

8. Characteristics of the new genus.

Rhizocrinus M. Sars, novum genus e class Crinoideorum.

Columna articulata, longa, tenuis, canali centrali angulato perforata, apice incrassato obconico uni-articulato, extremitate inferiore nec dilatata nec adnata. Articuli elongati, teretes, superiores subcylindrici, ceteri medio magis minusve constricti extremitatibus tuiididis and alternatim paulo compressis ita, ut axis longior faciei glenoidalis extremitatis inferioris cujusque articuli cum eodem extremitatis superioris angulum formet obliquum. Glenoidalis facies horum articularum subelliptica, striis radialibus nullis, linea ornata eminente (crista articulari) utrinque dentata secundum axin longiorem extensa et excavationibus duabus rotundatis, medio confluentibus, secundum axin brevioris extensis.

Cirri filiformes, cylindrici, articulati et velut articuli columnarum calcarei, canali centrali circulari permeati, dichotomo-ramosi, basi crassiores sensimque apicem versus maxime attenuati. Hi cirri in numero vario, semper autem continuo, articulorum inferiorum columnarum obuii, e duobus punctis oppositis, in parte superiore tumida cujusque articuli paululum infra extremitates lineae glenoidalis sitis et cum iisdem articuli proximi regulariter alternantibus, prodeunt singuli (interdum duo, fortasse pro ramis unius cirri basi bipartiti habendi), libere extrorsum porrecti et denique apice (saepissime in discum irregularem expanso, de cujus peripheria filicula brevissima repentina exeunt) alienis corporibus adnati. Extremitas libera articuli infimi columnae semper plures cirros emittit.

Calyx apicem dilatatum columnae crassitudine aequans, e numero radiorum compositus miro modo variabili, saepissime quidei 5, haud raro autem 4 aut 6, rarissime 7. Basalia extus inconspicua (forsan rudimentaria et irrita in spatio centrali annuli adhaesione radialium iofimorum formati relicto sita, cum his et inter se connata). Radialia intima (prima) pari modo extus haud visibilia, subtriangularia, cum columnae et inter se connata. Radiale secundum et tertium libera, sat magna, elongata, compressa, subtetragona, secundum cum primo vera articulatione (musculis duobus), cum tertio sutura (absque musculis) conjunctum. Radiale tertium non axillare. Radii calycis scilicet non sunt divisi et quisque radius in brachium simplicem continuatur, numerus brachiorum itaque velut radiorum saepissime 5, rarius 4 aut 6, rarissime 7.

Brachia brevia, apicem versus parum attenuata, ex articulis (brachialibus) haud numerosis composita, sectione transversâ semilunaribus, fere æqvè longis ac latis, subsymmetricis, margine latero-ventrali rotundato, non in processus elongato. Qvodqve brachiale altera suâ extremitate articulatione verâ (aiusculis duobus), altéra sutura (sjzygio) cum articalo proximo conjunctum, itaqvè faciès gleuoidales musculis prsedite cum iis musculis destitutis per totam longitudinem brachii regulariter alternantes.

Pinnulæ ex articulis brachii epizygalibus (duobus primis exceptis) alternatim dextrorsum et sinistrorsum prodeuntes, lineares, apicem versus parum vel fere prorsus non attenuatæ, in medio brachii longiores, ex articulis liud numerosis compositæ.

Sulcus tentacularis disci, brachiorum piunularumqve laminis calcareis (è trabeculis reticulatis compositis) marginatus sat magnis, ovalibus, basi affixis ceteroqvin liberis et mobilibus, obliqvè transversaliter positus, utrinqvè seriem longitudinalem cum oppositâ alternantem formantibus et tentacula retracta obtegentibus. Vesiculæ globosæ coloratæ (velutin Antedone obviæ) plané absunt.

Os circulare in centro disci, circule tentaculorum cinctum : duoruni radialium ad originem cujusqve sulci tentacularis et duorum interr radialium intus ad qveniqve angulum oralem. Tentacula hæc radialia, sicut ea sulcos ventrales disci brachiorumqve occupantia, longé extensilia, tenuia, cylindrica, papillis cylindricis brevibus tenuissimis obsita, spicula calcarean irregulariter reticulata in cute continentia; interr radialia illis breviora, flexilia, sed ut videtur parum extensilia, papillis similibus, sed densioribus, obsita, cute spiculis calcareis destitutâ.

Anguli orales (i.e., anguli centrales arearum interr radialium disci) laminæ prominentes, erectiles seu qvasi valvulæ sese aperientes et occludentes, lingulatæ, calcareæ, e trabeculis compositæ reticulatis. Etiam cutis mollir disci repleta est laminis sparsis calcareis similiter reticulatis, sed multo minoribus, suborbicularibus aut irregularibus et malé circumscriptis.

Anus apertura circularis areæ interr radialis medio fere inter os et peripheriam disci, non tubulosa, margiue simplice (haud crenulato).

Geitalia in pinnulis brachiorum inferioribus velutin Antedone intumescensibus inclusa.

Rhizocrinus lofotensis Sars, species unica.

Specimina 75 visa, maximum circiter 80mm longum. Columna 12—70mm longa, ex articulis 22—67 composita. Cirri in articulis columnæ 3—32 infimis obvii, maximi 8—9mm longi. Brachia in maximis 11mm longa, articulis 28—36; piunulis utrinqvè 6—7 (raro 7—8), 3mm longis, articulis 11—12, raro usqve ad 15. Color animalis pallidè fusco-cinereus aut cinereo-albidus.

Habitat gregatim ad insulas Lofoten (68° 11—15' latit. bor.), profunditate 100—300 orgyarum, nec non in sinu Nidarosiensi (63° 35'), ubi spécimen mortuum in profunditate 80 orgyarum inventum est.

Explanation of the plates.

Plate I.

Rhizocrinus lofotensis.

Fig. 1. Individual with 7 arms, with a well-developed stem *a-b*, but with three very small developing arms *d*. *a*, the enlarged upper article of the stem. *b* the lower article of the stem. *c*, cirri leaving the upper part of the articles. *c'*, cirri leaving the lower part of the lower article of the stem.

Fig. 2. The corona with the upper part of the stem of another similar individual with 7 arms. The arms *d*, of which one is much smaller than the other, are all very little developed, *a*, the enlarged upper article of the stem. *s*, arched groove of this article, indicating the first radials located inside. *ar*, article of the stem in the process of formation. *r2*, the second radial. *t*, tentacles.

Fig. 3. One of the arms *d-d* with the second radial *r2* of the same individual, seen from the side. *ls*, lamellae of the groove.

Fig. 4. The same arm seen from the interior or ventral side. Same letters as those in figure 3.

Fig. 5. Tentacle.

Fig. 6. The lower part of the stem of the individual represented in fig. 1. *b*, the lower article. *c*, cirri leaving the upper part of the articles. *c'*, cirri leaving from the lower part of the lower article.

Fig. 7. Part of the stem of the same individual approximately in the middle of its length, *c* cirri partly whole, partly more or less broken.

Fig. 8. Part of the stem of another individual with articles very concave in the middle. *l*, elastic ligaments that connect the articles.

Fig. 9. Part of the stem of a third individual, whose articles are bent in all directions. *l*, ligaments.

Fig. 10. The three lower articles of the stem, *c*, cirri leaving from the upper part of the article. *c'*, cirri leaving from the lower part of the lower article.

Fig. 11. Cirri whose two branches are attached at the end to fragments of shells.

Fig. 12. One of the thinnest branches of a cirrus *c* whose two ends are spread out into a disk *d*, attached to a shell (*Kelliella abyssicola* Sars) *x*, and a fragment *x* of the same species. From disk leave some filiform extensions *d'* that extend by crawling onto the foreign body.

Fig. 13. One of the thinnest branches of another cirrus that it connected by its lateral surface to a spine of an echinid and *y* and to a shell of a Rhizopod *z*. One of these ends is spread into a disk *d*, that is attached to a fragment *x* of a molluscan shell.

Fig 14. Part of one of the thin branches of a cirrus, greatly enlarged to show its calcareous network.

Fig. 15. End of a thin branch of cirri *c*, spread out into a disk *d*, of the periphery from which filiform extensions *d'*, extend by crawling onto a polyzoid fragment *x*.

Fig. 16. Individual with 5 very little developed arms. the lower part of the stem is bent upwards. The same letters as those of figure 1.

Fig. 17. Individual with 4 more developed arm and already having two pairs of pinnules *p*. Only one arm is shown. The others have been removed. The lower part of the stem is curved even more strongly and nearly into a spiral. The articles of the upper part abruptly become thinner. The same letters for figure 1.

Fig. 18. The upper part of the same individual more enlarged, *a*, the upper article from the stem enlarged. *s*, arched groove of this article, indicating the first radial located inside. *ar*, newly formed article. *r2*, the second radial. *d*, base of an arm.

Fig. 19. Young individual, whose little developed corona has been removed. The articles of the upper part of the stem are abruptly thinned, *c*, cirri leaving from the lower part of the lower article.

Plate II.

Rhizocrinus lofotensis.

Fig. 20. Newly formed article of the stem, seen from the side.

Fig. 21. The same seen from the terminal surface, with pentagonal canal of the axis.

Fig. 22. Another similar article seen from the terminal surface, with hexagonal canal of the axis.

Fig. 23. A little older article seen from the side.

Fig. 24. Part of the calcareous network of a young article of the stem.

Fig. 25. Article of a perfectly developed stem, very concave in the middle, seen from the side, *a-a*, the upper part. *c*, the middle part. *b*, the lower part, *cc*, bases of two cirri. *ee*, the articular ridge with its teeth.

Fig. 26. The same article cut transversely in the middle of its length. *a*, square canal of the axis. *bb*, the middle cut part. *cc*, the large diameter and *dd*, the small diameter of one of the terminal ends of the article.

Fig. 27. Upper or articular surface of a perfectly developed article of the stem, *a*, square canal of the axis, *bb*, the cavity in the form of a biscuit. *dd*, The two horizontal conical prominences of this cavity. *ee*, the articular ridge with its teeth of both sides. *cc*, the bases of the cirri. *ff*, the two prominent ends of large diameter from the lower end of the article.

Fig. 28. Part of the same articular surface, more strongly enlarged. *d*, *e*, as on the preceding figure 9, the teeth of the articular ridge.

Fig. 29. Part of the articular surface, greatly enlarged to see the calcareous network.

Fig. 30 and 31. Two articles of the stem seen from their upper end, with the bases of their cirri. Weakly enlarged.

Fig. 32. Terminal part of an article of the stem seen from the side. *ll*, elastic ligaments.

Fig. 33. The terminal parts of *dd* two contiguous articles of the stem, cut lengthwise to show the axial cord, *sl*.

Fig. 34. The end of an article of cirri. *a*, the circular canal of the axis.

Fig. 35. Upper part of the stem with the calyx of an individual with 4 rays, of which 2 rather developed arms with pinnules have been removed. *a*, the enlarged upper article of the stem, much more elongated than usual, with arched grooves *s*, that indicate the location of the first radials in the interior. *ar*, newly formed article. *r2*, the second radials.

Fig. 36. Upper part of the stem with the corona of a young individual with 6 rays. Same letters as in the preceding figure. The enlarged upper article *a* of the stem is shorter here.

Fig. 37. The corona of the same individual seen from above. *r2*, the second radials from the top of which the arms *bb* begin to grow.

Fig. 38. Individual with 4 rays with an intact arm. The 3 others have been removed. *a*, *ar*, *r2* as in figure 36. *r3*, the third radial. *b1*, the first brachial. *p*, the pinnules of the arm.

Fig. 39. Individual with 5 rays with well-developed arms. The lower part of the stem has been removed. Same letters as in figure 38.

Fig. 40. The corona of an individual with 4 rays, seen from above or ventral side. The arms are removed in a way to show the distal end of the third radials, *r3*. *d*, the disk. *m*, the mouth. *o*, the corners of the mouth or oral valves. *st*, the tentacular grooves. *an*, the anus.

Fig. 41. The corona of an individual with 5 rays. Of the 3 arms removed, the first brachial *b1* remains. The other letter as in figure 40.

Fig. 42. The corona of an individual with 5 rays, seen from above after the disk and viscera that it contains have been removed. The arms and the third radials, as well as the second radial of one of the rays, have been detached in a way that, in the last ray, we see the first radial *r1*. In the 4 others, we see the second radials *r2*. The center is filled by the "plate in the form of a rosette." *rr*.

Fig. 43. The corona of an individual with 6 rays, more strongly enlarged. The third and the second radials have been removed in a way that we see all the circle of first radials, laterally joined to each other without sutures, divided by 2 bony transverse crests into two parts, of which one is central and the other peripheral (the articular surface). In the central space left by the first radial is found the "plate in the form of a rosette: *n*: At the center of this we see the opening *o* (the letter has been forgotten in the figure) of the extension of the axial canal of the stem that comes from below. *s*, the groove running along the middle of the ventral surface of the first radials. *a*, the axial canal of these, a branch of the axial canal of the stem leaving from below this last canal. *bb*, the articular ridge. *mf*, the muscular fascet, *lf*, the fossa of the ligaments.

Fig. 44. The enlarged upper article of the stem, seen from the side, with the first radials that rest on the upper surface and that are united. In raising the second radials, the distal part of the first is exposed and shows the axial canal. *a*, the fossa of the ligament *lf* and the two bony transverse crests *cr*. *s*, the arched groove.

Fig. 45. The same article of another individual, split lengthwise to show the axial canal, a little enlarged, *a*, that sends above a branch to each ray and, moreover, a central branch to the disk. In this longitudinal section is seen only two of these branches, *a'a'*.

Fig. 46. Transverse section of the enlarged upper article of the stem represented in figure 44, approximately at the point marked *x*. We see there 6 holes, sections of the branches of the axial canal, namely: 1 central and 5 peripheral.

Fig. 47. Longitudinal section, slightly reduced, of the part of figure 44 that extends from *x* to *xx*. *a*, the axial canal.

Fig. 48. The upper part of the stem with the calyx of an individual with 5 rays, seen from the side. The disk and the other soft parts have been removed, *a*, the enlarged upper article of the stem, and *s*, the arched groove of this article. *b*, two young articles of the stem. From two of the rays, the third and the second radials have been detached in a way to show the articular surfaces of the first radials *r1* at the third ray, the second radial *r2* is seen in profile and the third has been removed. At the fourth ray, the second and the third radial *r3* are seen from the interior or ventral side, where the longitudinal groove *s'* is visible. At the fifth ray, we see the second radial *r2* and the third *r3* in profile. Above the latter, we still see the profile of the first brachial *b1*.

Fig. 49. The second radial seen from the interior or ventral surface after the soft parts have been removed. *pr*, its proximal end, and *di*, its distal end. *S*, the median longitudinal groove. *a*, the axial canal. *mf*, the muscular facets.

Plate III.

Rhizocrinus lofotensis.

Fig. 50. The second radial without the soft parts, see in profile, *d*, the dorsal surface. *r*, the ventral surface. *l*, the lateral surface.

Fig. 51. The proximal end of the same radials, *a*, the axial canal. *bb*, the articular crest. *lf*, the fosset ligaments. *mf*, the muscular facets.

Fig. 52. The distal end of the same, *a*, the axial canal.

Fig. 53. The second radial of a young individual, seen from the ventral side. *pr* and *di* as in figure 49.

Fig. 54. The same from the dorsal side, *pr*, the proximal end, and *di*, the distal end.

Fig. 55. The third radial without the soft parts, seen from the dorsal side.

Fig. 56. The same seen from the ventral side.

Fig. 57. The same seen in profile. In the three figures: *pr*, the proximal end, and *di*, the distal end. *s*, the median groove running the ventral surface. *cr*, the two bony crests.

Fig. 58. The proximal end and, fig. 59, the distal end of the same radial, *mf*, muscular facets.

Fig. 60. Well-developed arms seen from the dorsal side, *b1*, first brachial. *b2*, second brachial. *sg*, syzygies. *ap*, the end of the arm. *p*, pinnules. *gn*, genital organs. In the interior of the lower pinnules.

Fig. 60*. One of the lower pinnules with the genital organs *gn*, seen from the side.

Fig. 61. The lower part of an arm with the radials, seen from the dorsal side. *r2*, the second and *r3*, the third radial. *b1*, the first and *b2* the second brachial. *sg*, syzygies. *p*, the bases of the removed pinnules.

Fig. 62. The lower part of an arm united with the third radial, very greatly enlarged, seen from the side. Held for some time in a solution of concentrated sodium carbonate, the arms are a little detached from each other. *r3*, the third radial. *b1*, the first, and *b2*, the second brachial. *sg*, syzygies. *l*, elastic ligaments. *p*, pinnules. *ab*, basilar article, and *ap*, terminal article of a pinnule. *ls*, lamellae of the groove. *t*, tentacles.

Fig. 63. The dried lower part of an arm united with the third radial, seen from the ventral side. *r3*, the third radial. *b1*, the first brachial. *b2*, the second brachial. *mv*, the ventral lateral border of the brachials. *ls*, lamellae of the groove.

Fig. 64. The base of an arm held for a short period in a solution of concentrated sodium carbonate, seen from the ventral side. *r3*, part of the third radial. *b1*, the first brachial. *sg*, syzygies. *m*, muscles. *ls*, lamellae of the groove. *l* (*m* higher in the figure), elastic ligaments.

Fig. 65 to 75. Dried brachials without soft parts.

Fig. 65. First brachial seen from the dorsal side.

Fig. 66. The same seen from the ventral side.

Fig. 67. The same seen in profile. In the three figures: *pr*, the proximal end, and *di*, the distal end. *cr*, the two bony crests.

Fig. 68. The same seen from the proximal end, and fig. 69, the distal end.

Fig. 70. Second brachials, seen from the proximal end, and fig. 71, from the distal side, with two lamellae of the groove *ls*.

Fig. 72. Third brachial seen from the dorsal side.

Fig. 73. The same seen half of the ventral side, half of the profile, *pr*, the proximal end. *di*, the distal end.

Fig. 74. Second brachial seen from the dorsal side.

Fig. 75. The same seen from the ventral side, *pr* and *di* as in the preceding figures.

Fig. 76. Part of an arm *bb*, seen from the side, with an entire pinnule *p-ap* seen from the ventral side, and a part of another pinnule *p*, seen in profile, *ap*, end of the pinnule. *ls*, lamellae of the groove.

Fig. 77. Pinnule seen from the side, *dr*, dorsal part, and *lt*, the lateral part of the articles. *ap*, the terminal article. *ls*, lamellae of the groove.

Fig. 78. Part of an arm with a pinnule, seen obliquely from the side and a little from the side of the back. *b*, epizygial article of the arms. *ab*, basilar article of the pinnule. *mc*, ventral lateral edge of the articles. The other letters as in fig. 77.

Fig. 78*. Part more strongly enlarged of the dorsal part of a pinnular article, to see the calcareous network.

Fig. 79. Smaller pinnule seen from the side. The letters as in fig. 77.

Plate IV.

Rhizocrinus lofotensis.

Fig. 80. Dried pinnule, seen half from the side, half from the back.

Fig. 81. The same seen from the ventral side.

Fig. 82. Transverse section of the same with 2 lamellae of the groove. The letters as in fig. 77.

Fig. 83. Lamella of the groove, *ap*, the free end. *b*, the attached base.

Fig. 84. Part of the same, more strongly enlarged. *r*, the calcareous network. *f*, the mesh or holes of the same. *m*, the edge of the lamella.

Fig. 85. The upper end of the stem with the corona and the base of the arms of an individual with 5 arms, not perfectly developed, seen obliquely from the side and a little from above. *a*, enlarged upper article of the stem. *ar*, newly formed article. *r2*, the second radial. *d* (forgotten in the figure). the disk. *st*, tentacular grooves. *o*, oral valves. *t*, oral tentacles. *an*, anus.

Fig. 86. The same of an individual with 6 arms of the approximately the same age as that represented in fig. 85 but seen in another position of completely from the side. *s*, arched grooves of the enlarged upper article of the stem. *ls*, lamellae of the groove. The other letters as in fig. 85.

Fig. 87. Oral valve, *bb*, the base. *ap*, the free end. *m*, lateral edge.

Fig. 88. Part of the oral valve of another smaller individual, more strongly enlarged. *r*, the calcareous network. *f*, the mesh or holes of the network.

Fig. 89. The upper part of the stem with the corona and the base of an individual with 6 arms, seen obliquely from the side and above. The arms are extended nearly horizontally and the disk consequently is very spread out. *v*, the lower part of the visceral mass that is seen across the calcareous skeleton. The other letters as in fig. 85 and 86.

Fig. 90. Part of the skin of the disk *d* with two oral valves *o*, seen from the side of the exterior surface. *sp*, calcareous spicules. *tr*, radial tentacles and *ti*, interradial tentacles of the mouth.

Fig. 91. Part of the edge of the mouth, spread out and seen from the interior side, with three oral valves, *sa*, annular groove. The other letters as in fig. 90.

Fig. 92. Radial tentacle. *P*, papillae.

Fig. 93. Part of the same, more strongly enlarged. *cc*, the interior cavity. *sp*, calcareous spicules of the skin. *p*, papillae.

Fig. 94. Interradial tentacle of the mouth. Same letter as in fig. 92 and 93.

Fig. 95. The upper part of a very young individual with 5 rays, whose arms are not yet developed, seen from the side. *a*, enlarged upper article of the stem. *pr* (forgotten in the figure). the five triangular prominences of its upper edge. *ar*, newly formed article. *m*, sarcode envelope. *o*, the second radials.

Fig. 96. The corona of a little older individual with 5 rays at the same stage of development as in fig. 37 but executed with more care. Seen from above. *r2*, the second radials. *b*, the arm in process of development.

II.

On the Pentacrinoid of *Antedon Sarsii*

(*Alecto*) Düben and Koren.

(Pl. 5 and 6.)

These observations, made during the year 1864, were to accompany the preceding work on *Rhizocrinus* as a supplement to the remarks on the pentacrinoid of *Antedon Sarsii* that I communicated to the Congress of Scandinavian Naturalists at Christiania in 1856 (v. discussions pp. 212 to 216). Since the excellent works of Wyville Thomson (*Philos. Trans.* 1865) and Carpenter (*ibid.* 1866) have appeared on the same subject, it seemed useless to publish observations much less complete and taken from examination of specimens preserved in wine spirit, and which offered nothing new. As they concern however another species than this (*Antedon rosaceus*) that was the object of the research of the English scholars, and that they present, consequently, some modifications in the development of the pentacrinoid coming without doubt from this difference, while confirming these researches in all essential points, we shall perhaps find some interest to know these observations whose principal goal is moreover to make know the similarities and differences indicated in the preceding work between the pentacrinoid and the new genus *Rhizocrinus*. The material on which these observations are based is composed of a number of pentacrinoids at different stages of development and collected by my son from the beginning of March to the middle of July at different places in Lofoten Islands at a depth of 100 to 300 fathoms, and of an individual by myself in March at Manger near Bergen at a depth of 50 fathoms. They all belong to the same species, namely *Antedon Sarsii*, the only one of our two Norwegian species of this genus found in the Lofoten Islands. They represent a series of developmental stages grouped in the following description according to age.

1. Plate 5, fig. 1, represents the youngest pentacrinoid of the individuals examined. It was taken at the July at Trettesnes in the Lofoten Islands at a depth of 100 to 120 fathoms. It is attached by the lower end of its stem to a *Halilophus mirabilis* Sars (new genus and species of polyzoan) crawling on the length of a stem of a *Rhizocrinus lofotensis*. Its height or length is 4 mm, the stem being a little more than 3 ½ mm and the corona a little less than ½ mm. The very thin stem has a row of 18 articles composed of the ordinary more or less regular network of longitudinal and transverse calcareous rods of crinoids. The two or three upper articles are nearly spherical, or rather, lenticular, being a little compressed from top to bottom. They are, at the same time, a little wider or thicker than the following articles, which are cylindrical and elongated successively towards the middle of the length of the stem, where they are 6 to 7 times longer than the thickness. Toward the lower end of the stem, they shorten a little again. With the exception of 2 or 3 upper articles and the lower article, they have all around their middle, which is a little narrower than the two ends, an annular line, sometimes a little raised. From the observations of W. Thomson, this line is the annular part of the articles, which is formed first. The end of the lower article is spread out in a small nearly circular hyalin disk (fig. 1, *d*), joined by its lower surface to foreign bodies to

which the animal is found attached. This disk is nearly filled with a fine calcareous network, a continuation of that of the article itself, with irregular contours and lobules.

The corona is composed of a circle of 5 large immobile plates (*ibid.*, *b*) (joined by sutures), trapezoidal with a convex surface, called basal plates, forming together a calyx. Above them is another circle 5, equally large plates, but triangular and mobile (*ibid.*, *o*), called oral plates. The upper right edge of the basal plates is not completely as wide as their height. Descending, the two lateral edges always come closer together, or, in other words, the plates are narrowed successively in descending so that the lower border becomes very short. The oral plates have nearly the same size as the basal plates and their surface is likewise convex. Each of them rests with its lower large right edge on the upper surface of one of the basal plates and narrows little by little toward the end or upper rounded and a little curved inside end. In the contracted state of the animal, as in my specimen in wine spirit, the oral plates are applied closely to each other by their lateral edges and the end. They thus form an ensemble like a closed lid on the calyx in the form of a pentagonal pyramid with convex surfaces. Thus, the entire corona has the aspect of two pyramids, nearly equal in size, placed against each other by their base. When the living animal is spread out, the oral plates can be more or less separated by them or open like the petals of a corolla. All the plates of the corona are composed of the ordinary calcareous network, fairly regular and pierced by small round holes (fig. 2), which on the round edge of the oral plates (fig. 2) has very small prominent conical ends. We still see no trace of the 5 “intercalated plates” or first radials or, consequently, of arms. This stage of development greatly resembles, as we have been able to see, that of the pentacrinoid of *Antedon rosaceus* represented by *Wyville Thompson* (1. c, pl. 26) and by *Allman* (Transact. of the Royal Society of Edinburgh, Vol. 2, Tab. 13). The stem is however thinner and composed of a larger number of calcareous elements. An envelope of sarcoderm that surrounds them is visible only on the 3 or 4 upper articles to which it is tightly applied (fig. 1, *m*). In the latter species, on the contrary, it is very thick, as is seen in the cited figures, as well as other older ones by I. V. Thompson. Finally, there is still, as we have noted, no perceptible trace of radials or of arms in process of development.

2. Fig. 3, pl. 5, represents the corona and upper part of the stem of another individual taken at the same place and time as the preceding. It is attached by its lower end (fig. 4, *d*) to the stem (*s*) of a much older dead individual of the same species. The latter is, in its turn adherent to a branch of *Crisia denticulata* Lamarck. Although this individual is not larger than the preceding, being like it 4 mm in length, its corona, ½ mm in length, is however a little more developed. The stem is composed of 19 articles, of which the upper 4 or 5 are more strongly compressed from top to bottom than in the preceding individual, being two times thicker than long. The following articles are cylindrical and elongate successively in a way to become, in the middle of the length of the stem, 5 to 6 times longer than thick, a little concave in the middle and thickened at both ends and, at the same time, a little narrower than the upper and lower, the last of which are successively shortened a little. The end of the lower article is spread out into a small disk with a convex surface (fig. 4, *d*). From the periphery of this disk leave 4 extensions, short, thick and digitiform that extend by crawling on the foreign body (here an article of the stem of a larger individual) to which the animal is attached and surrounds in part. The disk and its extensions are composed of a fine calcareous network like that of the articles of the stem, except it is only more irregular. In the pentacrinoid of *Antedon rosaceus*, the organ of attachment is a circular disk having only very rarely some very short digitiform extensions, which, on the contrary, are generally always found in the pentacrinoid of *Antedon Sarsii*, and that, attaining a much more considerable size, seems also to have more need of these points of attachment.

Between each pair of oral and basal plates of the corona is above a first radial (fig. 3, *r1*), which thus separates these plates, formerly joined by their base. The basal plates appear a little smaller than at the preceding stage and now, their upper edge, previously straight, forms in the middle by the first intercalated radials, an obtuse angle. These first 5 radials, nearly as high as wide and having a hexagonal form, are already so large that they are nearly in contact with the others at the lower end of their lateral edge, that are moreover separated from their neighbors by a descending or vertical narrow fissure. Moreover, on the upper right border of each of the first radials, there develops a second radial (ibid., *r2*) that is elongated and as high, but hardly half as wide as the first. Finally, in the interrarial spaces, at the height of two of the first radials and between them, a small plate develops (ibid. *an*), nearly oval (in the vertical direction), unpaired or non-symmetrical, that touches below the upper corner of a basal plate and enters above in the lower part of an oral plate. This single plate, non-symmetrical, is the anal plate as Carpenter has demonstrated.

3. Three individuals, also taken at the beginning of July at the same place and the same depth as the preceding, and of which one is attached to a tube of a *Pectinaria hyperborea* (*Cistenides*) Mahngren and the two others to the stem of a *Cellulria ternate*, var. *gracilis* Smitt, have reached a more advanced stage of development. The corona and the upper part of the stem of one is shown in pl. 5, fig. 5. The length of the animal is 10 mm. In one of these individuals, the stem is composed of 27, in the two others of 29 articles. the upper 5 are strongly compressed from top to bottom. The other articles are as in the preceding stage. The new articles are formed, evidently, as in *Rhizocrinus*, at the top of the stem where they are always shorter than anywhere else and often annular or “nearly composed only of the primitive ring: (Carpenter). The corona, which is $\frac{3}{4}$ mm in length, has several changes. The first radials (*r1*) are found joined by their lateral edges by sutures. On the upper edge of the second radial, still very narrow (*r2*) has developed a third radial (*r3*), *R. axillare*, which is approximately the same height and width as the second and whose upper edge has in the middle a protruding angle or corner, forming thus two descending oblique surfaces on the sides. On these two surfaces are inserted the two arms (*a*) in the process of development. The second and the third radial are free laterally and (like the second of the preceding stage) separated from their neighbors from other rays by a very long interval. The arms are $\frac{3}{4}$ mm long, directed upward or sometimes more separated, with a pointed or slightly bent end inside, and still composed of only 6 articles longer than wide and already fairly similar to those of the adult and free *Antedon*, where they are however, wider than long, notably in the basal part of the arm. The dorsal part of the articles or their true body (pl. 6, fig. 20, *dr*), whose distal edge exceeds a little the proximal edge of the following article, and has very small conical points, is thick, semicylindrical and composed of a tight calcareous network of small rounded meshes. The two lateral parts (ibid., *lt*), on the contrary, are very thin and membranous, and the distal part of their edge turned inward or ventral forms a round sinuosity (in the pentacrinoid in the state of maturity, fig. 31, *lt*, and in the free *Antedon*, this edge has several, 2 or 3, similar sinuosities). Each of these lateral parts is supported by a long and thin calcareous rod or spicule (fig. 20, *sp*) located in the interior, most often having a weak form of an S and directed obliquely above and inside, whose end, located nearly at the ventral convex edge of the article, is a little enlarged and pierced by a more or less large number of small round holes. The other end, on the contrary, located near the dorsal calcareous network, is pointed or sometimes bifurcated. Here is what Carpenter (l. c, p. 740) says of these spicules: “Besides the radial skeleton of the arms, we ordinarily find that their perisome of condensed sarcodite encloses irregularly branched spicules forming a kind of incomplete reticulation that serves to support the raised folds of the edge of the ventral grooves. These are evidently the rudiments of the dermal plates, that according to I. Müller, form in

Pentacrinus a complete armor on the ventral perisome and on its extensions along the ventral surface of the arms. It is remarkable that this perisomatic skeleton of the arms, like the oral plates, undergoes later an absorption so complete that it is impossible to find the least trace of it in the adult *Antedon*.” I have, however, found it perfectly similar to that of the pentacrinoids, i.e., composed of 21 or 2 spicules in each of the ventral lateral parts of the articles of the arm, still persisting in the free individual 1 ½ mm in length and in the pinnules of adult individuals of *Antedon Sarsii* 3 to 4 mm long. Along the ventral groove of the arms (tentacular groove) are located 2 rows of tentacles (fig. 5, 20 *t*) and 2 rows of colored vesicles (ibid., *c*), so characteristic of the genus *Antedon*. There are still only two pairs for each article (in the adult there are several, ordinarily 3 pairs). The tentacles are cylindrical, with very slight constrictions at equal distance from each other, and with very small tactile tentacles, thin, cylindrical and round at the end. The colored vesicles located on the exterior side of the tentacles are spherical and red-yellow or opaque red-brown as in the free *Antedon*. On the disk are also a pair of these vesicles (fig. 5, *v*) above the base of the second radial. We know that the function of these colored vesicles is still problematic. Dujardin took them for glands that secrete the reddish fluid that the animal releases profusely when we irritate it. For his part, W. Thomson is more disposed to consider them as “glands that operate to secrete a calcareous solution that serves in the develop and nourishment of the skeleton.”

4. We have then four individuals taken at the beginning of March from the Guldbrand Islands at 300 fathoms depth. Two are attached to the stem of a *Halilophus mirabilis*, the two others to the shells of rhizopodes. The largest is represented in pl. 5, fig. 6. It is 20 mm long, including 4 mm for the crown and the arms. The stem is composed of 38 articles. The 3 other individuals are a little small (13 to 16 mm long). As a result of the digestive organs and the soft ventral disk that covers them, the calyx is much enlarged, and the oral plates (fig. 6, *o*), separated by first radials that are strongly developed, are still, it is true, rather large, but seem now to become little by little rudimentary. At the same time, the first radials (*r1*) have considerably changed form, their upper edge, formerly short and straight, having become very wide and concave to receive the base of the second radial (*r2*), which has also become much wider. At the upper edge of the first radials are formed at their meeting points (the upper lateral corners) all around the calyx, 5 very protruding triangular corners (*f*), bent a little inward, with round ends. The third radial (*r3*), also widened, is nearly as wide and high as the second. The considerably elongated arms (*a*) are, each, composed of 14 to 15 articles. In the largest individual, but not in the 3 others, some of the arms are bifurcated at their upper end. In examining them more closely, we discover it is the first formation of the pinnules (fig. 6, *p*, 7, 8), one or sometimes two of these pinnules in process of development, showing one behind the other and each on its side near the end of the arm (*ap*) (according to Carpenter, the first trace of the development of the pinnules begins to be seen in the pentacrinoid of *Antedon rosaceus* when its arms are composed of about 12 articles.” They are still very short and filiform, having at their base about half of the thickness of the arms and tapering successively toward the end. They are composed of articles few and indistinct. The 2 lower ones already have colored vesicles (fig. 7, *v*), that are however still much smaller than those located on the arm itself.

5. Pl. 5, fig. 9, we find represented a pentacrinoid with a state of development still more advanced, seen with the magnifying glass (3 times enlarged). Fig. 11, the corona with the arms and the upper part of the stem attached at two points to a foreign body. This individual, taken in middle of the month of April at Skraaven at 300 fathoms depth, is 21 mm long, the corona with the arms, 4 mm. The stem has 48 articles. It forms in its lower half a fairly pronounced S. This individual is attached, not only as ordinarily, by the lower article (fig. 12, *d*), but also by two higher plates (fig. 9, *d*, *cl*; fig. 12, *e*) of the stem to a foreign body (*Rhabdammina abyssicola* Sars, new

Rhizopoda). In another individual at the same stage of development as this, there emerge from a lower article of the stem (fig. 10, *d*), some digitiform extensions, of which two are bifurcated one or several times. In a third individual belonging to the following stage, the disciform enlargement (fig. 15, *d*) of the lower article of the stem has an irregular form and surrounds some spicules of a sponge (*x*). Some other articles of the lower part of the stem can also send from their surface tuberculiform or digitiform extensions (fig. 9, *e*; fig. 13 and 15, *e*), by which they attach to foreign objects.

The 3 upper articles (fig. 11, 1 to 3) of the stem have become much more flattened than before, or nearly disciform, that is still more striking in the following stage, that we are going to consider in more detail.

In the interradian space of the soft ventral disk (fig. 11, *d*), whose volume is considerably increased, the anal tube (*ibid.*, *an*) has made its appearance. It already extends far above the surface of the disk. It has a cylindrical, a little oval or pyriform form. At its top, a small round and sunken patch indicates the place of the anus. As in the free *Antedon*, the anal tube is found nearly in the middle between the mouth and the periphery of the disk consequently a great distance from the place (fig. 3, *an*), occupied originally by the old anal plate. Immediately below its base is found in the skin of the disk, 2 small round calcareous scales (fig. 11, *sg*). The interior one covers with its upper edge the lower edge of the upper scale. The two are found a little standing as if they had been separated by the anal tube in the process of developing. These calcareous scales seem to be the remains of the old anal plate, now disappeared.

In the annular groove between the calyx and the visible upper article of the stem. It begins to produce cirri (fig. 11, *c*) and, with them, the centro-dorsal plate, to which they are fixed. This plate, still very narrow or annular, rises to the next stage very rapidly in the form of a basin that soon hides the basal plates. Cirri first appear in the number 5, arranged in a ring at equal distance from each and in the direction of the 5 rays of the calyx or under the radials and in the same line. In the pentacrinoid of *Antedon rosaceus*, on the contrary, the cirri of the primary circle alternate, according to Carpenter, in their position with the rays (that which is still clearly seen in my specimens of this species preserved in wine spirit) in a way that one of them is opposite the anal plate.

The newly formed cirri are directed above, tightly applied to the lateral sutures of the basal plates, cylindrical, nearly straight or slightly bent (following the slightly convex surface of the basal plates), still smooth and inarticulate, with a round end with a hook or claw and all about the same size. The end hardly passes the upper edge of the basal plates.

The radials have not undergone sensible modification.

The arms are elongated a little. Composed of 18 to 20 articles, they still have only one pair of pinnules (*p*), longer however than before, narrow and pointed at the end.

In another individual not more developed in other regards, the 5 original pinnules are 4 to 5 times longer than in the specimen we just mentioned. They are composed of 7 to 8 well-developed articles, of which the last already has 2 claws. A third individual has 5 primary cirri still more developed and composed of 9 to 10 articles. It has still between two of these cirri, immediately above them, a sixth filiform cirrus directed upward, without distinct articles and simple conical end, the claw still not developed. This cirrus that appeared after the others is interradian. The 5 primaries, on the contrary, always keep their position in the direction of the rays of the calyx.

6. There are finally seen perfectly developed individuals representing the state of maturity of the pentacrinoid. 6 of these individuals were taken in March, April and the beginning of May at Skraaven and the Islands of Guldbrand at depths already indicated. They are attached to shells of

different rhizopods or small conchifers etc. The seventh is that I took in the middle of the month of March at Manger near Bergen at 50 fathoms depth, and that I described in 1856.

Figure 14, pl. 5, represents the corona with one of the arms and the upper part of the stem of the largest complete or entire individual. It is attached to a *Crisia denticulata* and 28 mm long. The corona with the arms occupies 8 of them. The stem is composed of 44 articles that seem generally shorter than those of the preceding stages (the longest are nearly 4 times longer than thick), have considerably increased in thickness. The 3 upper articles (fig. 14. 1 to 3) are, as we have already noted for one of the preceding individuals, nearly disciform, separated from each other by narrow and deep constrictions, and have an articular nature (see also pl. 6, fig. 23, 1 to 4) in that their surface has fairly large transverse grooves, irregular and a little sinuous, as if they were composed of thin transverse lamellae. It seems that the looser structure of these articles prepares the moment where the pentacrinoid is going to detach from its stem. These are the 2 upper articles of the individual in question that are more disciform, being 2 to 3 times wider than long and very much wider than the other articles of the stem. The third article is a little less wide and the fourth tapers a little toward its lower end that is wider than the following articles. As usual, these cylindrical articles increase successively in length. All these long articles have here (pl. 5, fig. 16) very distinctly (this was more difficult to recognize in the preceding stages because of the smallness of the animal) completely the same nature as that described above in *Rhizocrinus*, namely: their two thickened terminal parts are a little compressed laterally, so that the articular surfaces become a little elliptical. This compression takes place in a direction nearly opposite in the two terminal parts of each article. I.e., the large axis of the ellipse of the upper articular surface crosses that of the lower surface, forming an oblique angle. Finally, the compression alternates regularly from article to article the entire length of the stem. The articulating surfaces (pl. 6, fig. 18), also convex, have two large round cavities (ibid. *bb*) in the direction of the small axis. these cavities are joined at the middle on the circular axial canal and nearly take the form of a biscuit. The articular side (*ee*), that follows the direction of the large axis of the ellipse, appears much less marked, even indistinct in examining the articular surface from above (fig. 18). It exists however and even seems provided with teeth as in *Rhizocrinus*, because, in considering the article from the side (fig. 17), we discover there approximately 6 very small conical teeth (ibid. *ee*) on each side of the biscuit-shaped cavities. This cavity serves also for the insertion of a large number of soft parallel filaments, very fine and strong, the elastic ligaments (fig. 16, *l*). As in *Rhizocrinus*, we frequently see in the specimens of our pentacrinoid preserved in wine spirit, a bending of the articles of the skin, sometimes in one direction, sometimes in the other, and notably always in the direction of the small axis of the articular surfaces. On the centro-dorsal plate that now passes the basal plates, new cirri have still developed (fig. 14, *c*), in a way that we see 9 large and 5 small ones. The longest are well-developed and composed of 10 articles, of which the last, as in the free *Antedon*, already has two hooks or claws. The 5 small cirri, located immediately above and between them or in the interrarial spaces, are very short (4 to 5 times shorter than the longest), with indistinct articulation and with a round end without claws.

The disk (fig. 14, *d*, pl. 6, fig. 19) with its 5 tentacular grooves (fig. 19, *st*) leaving from the mouth bifurcates near the edge into two branches continuing onto the corresponding arms. The anal tube (fig. 14 and 19, *an*), much longer than at the preceding stage and cylindrical with a more or less crenelated end (the edge of the anus), resembles perfectly those of the free *Antedon*. It is the same for the angles of the mouth (fig. 19, *o*), or the five corners of the interrarial spaces, the oral plates having been completely resorbed. The second radial (fig. 14, *r2*) is considerably

enlarged and thus appears shorter than the preceding stage, being nearly two times wider than long. The third radial (*r3*) is also a little wider or nearly as wide as long.

New pinnules have also developed (fig. 14, *p*), namely: 5 on one side and 6 on the other side of each arm that occupy a little less than the upper half of the length of the arm. They are longer or more developed and composed of a larger number of articles with their tentacles and their colored vesicles than before. On the ventral lateral edge, each of the articles has 2 round sinuosities. Each of these encloses for support a calcareous rod (spicule), as we have already said. Finally, there is on the outer side of the second brachial article a pinnule in the process of development (*p1*) that did not exist in the preceding stage. It is still very short, hardly longer than the width of the brachial article, filiform, inarticulated, with a round end and without tentacles. This is what we call the oral pinnule, that Carpenter has also seen developing in the pentacrinoid of *Antedon rosaceus* while the arms still had pinnules only at their top, just as that at a more advanced stage of the pentacrinoid of this species, no pinnule develops on these intermediary brachial articles. The articles located between the second and the twelfth (in another individual, the tenth), that has the lowest developed pinnule, still having no trace of pinnules.

We can already recognize distinctly syzygies (articles only joined by sutures and consequently immobile) at the third and eighth brachial articles (*sz*), as in free *Antedon*.

Another individual 22 mm in length, whose corona with the arms occupy the 6, and whose stem is composed of 37 articles, is a little less developed than in last described. The centro-dorsal plate has only 10 cirri, of which the 5 large or primary, located in the direction of the 5 rays, is composed of 8 articles, and whose 5 small ones are located immediately above them in the interradiar spaces. There is still on each arm only 2 to 3 pairs of pinnules.

A third individual, more developed than that of fig. 14 and with a stem composed of 34 articles, 20 mm in length, but incomplete, the ten arms all being more or less broken. With two of these arms, there remains only the first 3 articles. On these two stumps of arms, one is represented in pl. 6, fig. 21. It has regenerated at the end of the third article, a new arm that resembles in a striking way a young shoot grafted onto a tree. It occupies the normal position in following the same direction as the stump, but it is very short and thin, only 2 mm in length, having hardly at the base half the thickness of the stump and tapering successively toward the end that is curved inward. It is composed of 11 to 12 articles and lacks pinnules, but already has tentacles (*t*) and very small colored vesicles (*v*), 1 pair for each article, with the exception of the 4 or 5 last articles where they are still missing. The third brachial article (*b3*), where the regenerated arm is located, is a syzygy, or rather a hypozygal article (we can see the characteristic radial stripe of its terminal surface of the two broken arms of another individual, pl. 6, fig. 24, *s*). This phenomenon seems to confirm the opinion newly expressed by Lovén (*Om Crinoideslsegten Phanogenia, Öfversigt af Vetensk. Akad. Forh.* 1866, p. 227), that "syzygies are important for the regeneration of a broken arm, i.e., that the fragment of arm that remains in front of the nearest hypozygal article is nearer, detaches and the new articles develop on the latter." Carpenter (l. c, p. 723) believes, on the contrary, that the frequency of fractures near syzygies depends on the greater fragility of the arms at these points, the syzygeal segments being joined only by the sarcode substance and not, as usual, by ligaments and muscles. According to my experience, it seems to me, however, that is at the syzygies the arms are most solidly joined or least fragile than at other points. The oral pinnule (*p1*) is much developed and is divided into 6 to 7 articles.

A fourth individual finally, the largest and the most developed of all that that I have observed of our pentacrinoid, is that I described in 1856. The upper part of its stem, with the corona and the bases of its arms, is represented in pl. 6, fig. 24. Unfortunately, it is not quite complete. The lower

end of the stem and the upper part of the arms being broken, some of the latter even up to the third article. In its present state, it is 30 mm long. The corona with the part that remains of the arms is 20 mm. But the complete state, to judge from the preserved parts must certainly have been nearly 40 mm in length.

The present part of the stem has 32 articles. The 2 upper ones are disciform with large transverse grooves or, so to say, lamellae, the third in the form of a basin, and the following as usual, cylindrical and successively longer, at the middle of the length of the stem 3 to 3 1/2 times longer than thick and thicker at the two ends. The lower articles, finally, become successively a little shorter. This agrees as a whole with the description that I have given of the preceding stages. The centro-dorsal plate (fig. 24, *cd*), that is developed in hiding the basals and the first radials, has 20 to 30 cirri (*ibid.*, *cir*) (I have positively counted 26 of them), that cover it everywhere without visible order. This number exceeds greatly that of the cirri that we find in the pentacrinoid of *Antedon rosaceus* at the state of maturity. However, here is what Carpenter says of the latter: "First a corona of 5 cirri is formed on the centro-dorsal plate (whose position alternates with that of the rays), not abruptly, but successively. Later, it develops in the same way another corona of cirri between the first (with which they alternate in position) and the base of the calyx. Finally, a third corona is formed generally before the detachment of the pentacrinoid, so that the young *Antedon* has 10 cirri in different stages of development and 1 to 5 still rudimentary.

The cirri that surround the median part of the height of the centro-dorsal plate of our pentacrinoid are the longest and most developed, with a length of 5 mm and a thickness of about 1/5 to 1/6 mm. Going down toward the stem, their length decreases to 1 1/2 mm and the upper ones are still less developed as we are going to see. It is the same in this regard in free and adult *Antedon Sarsi*, whose centro-dorsal plates have cirri to the number of 30 to 40 everywhere with the exception of a very small round place in the middle of its lower end where the pentacrinoid was attached to its stem.

The cirri extend in a more or less straight line from the centro-dorsal plate and are more or less arched, especially at their end that, most often, is directed downward (aborally) and a little inward. The largest (Pl. 6, fig. 25) is composed of 13 articles (in adult *Antedon*, from 13 to 19) cylindrical and, except the articles nearest the base, a little laterally compressed. Moreover, the articles already have the elongated form characteristic of *Antedon Sarsi*: "the first 2 are short, the third, much longer, the fourth, fifth and sixth longer than the others (about 3 times longer than thick)" (Düben and Koren, *Öfversigt af Skandinaviens Echinodermer*, p. 231). They are, notably in the proximal half of the cirri where they become also little by little a little thinner than in the distal half, slightly concave in the middle. Their distal end is a little thicker than the proximal and the finely toothed dorsal edge (fig. 26) passes a little the proximal end of the following article, which gives the cirrus a slightly tubercular aspect. As in the adult *Antedon*, the last article ends in a hook (fig. 23, *a*), strong, conical and pointed, a little curved downward (aborally), separated from the article by a fairly marked transverse groove and having the appearance of a separate article, but united to the former at the bottom by a suture (the transverse groove). Consequently, it is immobile or inflexible. At the base of this hook or claw, on lower or aboral side, is a similar claw (*ibid.* 6), but shorter and less bent or nearly straight. This is not, however, separated from the article by a groove or suture, but a direct extension of it. J. Müller thinks that the formation of new articles of the cirri occurs "at the base as well as the top of the cirri, where the articles are shorter than in the other parts". But, according to Carpenter, this formation of new articles takes place only at the base. As for me, I have also always found the shorter articles at the base and not at the top.

The smallest cirri (fig. 27, 28), located at the bottom or near the stem, are composed of only 7 articles. In all other regards, they agree perfectly with the large ones that we just described. However, a form (fig. 29) that differs from that of all the other cirri, occurs above the large cirri near the upper edge of the centro-dorsal plate. They number 5 and each is located in an interradiar space. Nearly as long and thick as the small of the ordinary cirri, they are uniformly cylindrical and smooth, and not tubercular in all their length, without distinct articles, surrounded only by very fine transverse annular lines. Their end forms an obtuse cone with claws. In other words, they resemble perfectly the five primary cirri (fig. 1, *c*) of the preceding stage and the young cirri (fig. 14) that form later above, after these have reached their normal form. Perfectly similar cirri also occur in the same area in adult *Antedon* and, it seems, throughout its life, but always in small numbers and of different sizes. It is evident they are cirri still incompletely developed destined to replace old ones that are frequently lost and whose point of attachment is indicated by a small round fosset. These observations indicate new cirri emerge regularly above and between the old ones.

The second radial (fig. 24, *r2*) has become much wider, which makes it appear shorter than before or nearly annular as in adult *Antedon*.

The third radial (*r3*) has also reached the same width as the second, which has given it its definitive form, nearly rhomboidal. The largest of the remaining part of the more or less broken arms is 10 mm in length with a thickness of $\frac{1}{2}$ mm at the base and $\frac{1}{3}$ mm at the end. We can thus conclude with certainty that the absent part had at least the same length. The stump of the arm, composed of 20 articles, has 9 pinnules on one side and 10 pinnules on the other side. Thus, pinnules have developed in all the length of the arm. In this regard, there is thus a notable difference the pentacrinoid of *Antedon Sarsii* and that of *Antedon rosaceus*, in which, at the moment when it is going to detach from its stem, there develops (according to the figure of Carpenter, pl. 39, fig. 1*E*) only 5 pinnules on each arm (2 on one side and 3 on the other side). Moreover, Carpenter observes (1. c, p. 746): "It is remarkable that the basal part of the arm, that is developed before the first appearance of the terminal pinnules, continues to lack these appendages until the end of the pentacrinoid state, except in the second article, where it develops an oral pinnule."

The brachial articles have distinctly the oblique form characteristic of the genus *Antedon*, alternatively shorter from one side to the other, so that the arms seen from the dorsal side (fig. 24, 30) shows only lines of oblique articulation. They are, however, still longer than those of adult *Antedon* where, at the base of the arms, they are even little thicker than long, and only higher longer than thick. In the pentacrinoid of *Antedon rosaceus*, at the moment when it is at the point of detaching from its stem (Carpenter, pl. 39, fig. 1*E*, pl. 40, fig. 1), the brachial articles, the same as in the preceding stages, are not yet oblique.

The syzygies (fig. 24, 30, *sz*) occur on the 3rd, 8th, 12th, 15th, and 18th brachial articles, absolutely as in adult *Antedon Sarsii*, where they are found only very rarely on the sixteenth instead of the fifteenth and on the nineteenth or twentieth instead of the eighteenth article, while their appearance on the third, eighth and twelfth articles is perfectly constant. It is the same in *Antedon rosaceus*. There thus does not exist as much variation in this regard that we would be tempted to believe from the indications of Düben and Koren (1. c, p. 231).

Several arms are broken at the syzygy of the third article, where the articular surface of the hypozygal article (fig 24, *s*) shows the ordinary radial stripe. The 3 or 4 lower pairs of pinnules (fig. 24, *p1-p4*) are very thin and setaceous. The first or lowest of the pinnules (fig. 24, *p1*, fig. 22)), located on the exterior side of the second brachial article (there is never a pinnule on the fit), is very long and composed of 12 to 14 articles (in adult *Antedon Sarsii*, I have found 22 to 35. MM

Düben and Koren reported about 20 of them, without tentacles, and with some very small reddish-brown scattered vesicles that, sometimes, in pairs very near each other, form however on a single row. This is what Carpenter called the oral pinnule, differing from the other by its great length and by the absence of a tentacular apparatus. The following 2 or 3 pinnules are nearly half the length of the first that, in adult *Antedon*, is often 3 times longer than the first. I find in the free, more or less adult *Antedon Sarsii*, that the two pinnules on each side of the arm, that come after the oral pinnule, are also very thin, nearly setaceous, without tentacles, and even in some cases, without genital organs, which, like the tentacles, do not appear until the fourth pair of pinnules.

The fifth pinnule (fig. 24, *p5*) of the same individual has about the same length as that immediately preceding, but like the following ones, they have the ordinary form, thick at the base, tapering toward the top. They are composed of 9 articles and, as all the following, they have tentacles (*t*) and 6 pairs of reddish-brown vesicles in 2 alternating rows. The sixth pinnule (fig. 31) has thirteen pairs of them (*v*). Moreover, it ordinarily has on the same arms 1 or 2 and, on the pinnules, 2 or 3 pairs of the vesicles on each article. The following pinnules elongate successively a little. At the end of this stage, the completely developed pentacrinoid is ready to detach from its stem to live freely. It is not missing any of the essential organs of the free *Antedon*, although several are not as numerous as they will become later.

There is, however, reason to believe that, at the moment of detaching from its stem, the pentacrinoid is not always as completely developed as the individual from Manger that we just described. Now, from March to June, was found at the Lofoten Island (from Guldbrand at 100 to 120 fathoms and at Skraaven at 200 to 300 fathoms depth) some very small individuals of free *Antedon Sarsii* among a large number of average size, of which however none had genital organs developed in their pinnules. Of these small individuals, the largest, which is complete, has arms only 14 mm long, all with 13 to 14 pairs of pinnules along its entire length up to the second article. The centro-dorsal plate has about 20 cirri. The smallest, on the contrary, whose arms are broken in their upper part, is nearly equal in size to the last pentacrinoid already described (pl. 5, fig. 14) from Lofoteen or a little smaller than that of Manger (pl. 6, fig. 24). The parts that remain of the arms are completely similar to those of the latter. Only, on the centro-dorsal plate, there are only 15 cirri of which the largest has only 11 articles. This individual evidently had just detached from its stem. A third individual, what exceeds the latter only very little in size, still lacks some pinnules on the lower part of the arms with the exception of the oral pinnule that, which we have already seen, develops before the pentacrinoid detaches from its stem.

In making a succinct summary of these stages of development of our pentacrinoids, we will refer to the most important phenomena.

First stage. The young animal is composed first only of the stem and the calyx, the latter with five basal plates and 5 oral plates. There is still neither rays nor arms. The basal disk of the stem is circular.

Second stage. The first and second radials are in the process of development. By the development of the first radials, the oral plates are separated from their junction with the basal plates. The simple or non-symmetrical anal plate makes its appearance. From the periphery of the basal plate of the stem emerge small digitiform extensions.

Third stage. The third radial is formed and at its end begin to be developed the two arms with their tentacles and their vesicles.

Fourth stage. The calyx is widened by the development of the ventral disk. The oral plates are separated from their junction with the first radials and begin to become rudimentary. The first pinnules begin to form at the end of the more elongated arms.

Fifth stage. The 2 to 3 (rarely 4) upper articles of the stem become disciform with large transverse grooves or, to say, lamellae. The anal tube is present and the anal plate disappears. The first cirri, still inarticulated is seen forming an annular centro-dorsal plate that is in the process of developing.

Sixth stage. The centro-dorsal plate is rising in covering and hiding finally the basal plates as well as the first radials. An always, larger numbers of cirri are present, covering finally nearly all the surface of the centro-dorsal plate and taking in its development the characteristic form of the species. The pinnules are developing, always more numerous from top to bottom, often on the entire length of the arm to the second article where one (the oral pinnule) has already formed.

By these observations, as well as the statement already given by Carpenter, it is evident that the development of the pentacrinoid proceeds constantly and regularly, without abrupt changes and that, consequently, there can be no question of a true metamorphosis when the young animal separates its larval organs from the articulated stem.

I shall add here some observations on the pentacrinoid of *Antedonn rosaceus* that I still have not been as fortunate to find on our littoral. I have some, however, 17 specimens from Belfast and the Firth of Clyde that have been given to me by Professor W. Thomson and by the Reverend Crosskey. The most developed of these individuals is 10 mm long. The stem, composed of 16 articles, is 4 ¼ mm long. It is thus very much larger than the size according to Carpenter, who gives 1/7 of an inch "the total length of the pentacrinoid at the mature stage from the base of the stem to the end of the closed arms." In 3 other individuals of nearly the same size, the stem is composed of 16, 21 and 27 articles. In one of these three, whose length is equal to 10 mm and whose stem is relatively longer than that of the others, being nearly 8 mm in length and being composed of 27 articles, the corona with the arms that hardly exceeds 2 mm, is little developed, without pinnules and still without cirri. The individual whose arms are the most developed and has 2 or 3 pairs of pinnules near their upper end, have a centro-dorsal plate with 5, 7 or 9 cirri of different sizes. In one individual, it still has a small tubercle or the beginning of a tenth cirrus in the process of development. The 5 primary cirri are, as Carpenter said very well, located in the interradian spaces. The oral pinnule begins likewise to develop, while the rest of the arm has only 2 or 3 pairs of pinnules near its upper end. In one of these individuals, the largest, we see emerge from the periphery of the small circular disk by which the stem attaches to foreign objects, some very short digitiform extensions, as in the pentacrinoid of *Antedon Sarsii*. A phenomenon that I have never observed in the latter occurs quite often in the pentacrinoid of *Antedon rosaceus*, however, i.e., several (in general 2, in one case 3) individuals apparently emerging from the same base, their disks being fixed so near each other that they are in mutual contact, a phenomenon that I. V. Thomas has already indicated and represented.

In comparing the pentacrinoid of *Antedon Sarsii* to that of *Antedon rosaceus*, we find, according to the preceding observations, the following differences between the two.

1° The pentacrinoid of *Antedon Sarsii* which in the adult and free state does not become larger than *Antedon rosaceus*, reaches a size much more considerable, exceeding 3 to 4 times in length that of the latter species and having a relatively longer stem. But the arms are shorter.

2° The stem is composed of a larger number of articles, about 40 (in some cases, even 44 to 49). Carpenter observed (1. c, p. 732) that "the total number of articles of the stem of the completely developed pentacrinoid of *Antedon rosaceus* is subject to much variation. I have seen

it increase to 24 and decrease to 16. We can fix the average number at 20.” Thompson has found up to 24 of them. In one of my specimens, I have even found 27. The basal disk of the pentacrinoid of *Antedon rosaceus* seems only very rarely to produce digitiform extensions. They are always present, on the contrary, in those of *Antedon Sarsii* that, because of its greater size seems to have need of stronger means of attachment.

3° As I have already said in my first observations of 1856, it reaches generally, before it detaches from its stem, a state of development more complete than the pentacrinoid of *Antedon rosaceus*, the arms have a number of much larger pinnules that sometimes line the entire length of the arms and the centro-dorsal plate having a much larger number of cirri. It also seems that we can apply to some degree the remarks of Carpenter on the pentacrinoid of *Antedon rosaceus*: “The precise stage of development where the body of the animal is detached from the stem varies according to circumstances as that when the ripe fruit detaches from the tree. I have encountered specimens still fixed to their stem, larger and more colored than others already free. The normal moment when the pentacrinoid should detach does not seem to come before the dorsal cirri are quite developed to provide the functions of the stem in furnishing the animal the means to attach to fixed objects.”

4° Finally, it detaches from the stem in another season, namely, according to our present observations, from the end of March to May, while the pentacrinoid of *Antedon rosaceus*, according to the consistent observations of J. V. Thompson and W. Thompson, detaches constantly between mid-August and mid-September. My youngest pentacrinoids of *Antedon Sarsii* have been taken at the beginning of July, the oldest in March, April and May at the same time that the young free individuals that evidently had just detached and that are neither larger nor more developed in any respect than the oldest pentacrinoid observed. Some of them were even positively less developed than the latter. Thus, on the assumption that the development of the genitals of *Antedon Sarsii* takes place in the beginning of summer (I myself recall have found eggs in the pinnules in June), and not in several or other seasons, which is, however, still not completely shown, it seems that the development of the pentacrinoid of this species occurs much more slowly than in that of *Antedon rosaceus*, extending to almost the entire year.

The pentacrinoid of *Antedon Sarsii*, a species of the deep-sea, is found on our littoral at a depth of 50 to 300 fathoms. The pentacrinoid of *Antedon rosaceus*, which occurs with us in the free state at 20 to 100 fathoms depth, is found, on the contrary, according to J. V. Thompson, in Ireland at 8 or 10 fathoms depth. We encounter it, like that of *Antedon rosaceus*, to objects that vary with locality, namely: to shells of rhizopods, to polyzoans, to tubes of annelids, to shells of conchifers, sometimes also to the stem of an individual of the same species. In general, we find also individuals of this species of pentacrinoid dispersed, never, as those of *Antedon rosaceus*, in groups or several attached so closed to each other that the disks of their stems are in mutual contact.

Explanation of the plates.

Plate V.

The pentacrinoid of *Antedon Sarsii*.

Fig. 1. The animal at the youngest stage observed, greatly enlarged. *d*, the disciform base of the stem. *m*, sarcodite envelop of the upper articles of the stem. *b*, basal plates; *o*, oral plates.

Fig. 2. The upper part of the oral plates, of which 3 are visible, more strongly enlarged.

Fig. 3. The corona and the upper part of the stem of an individual a little more developed, or in the second stage. *b*, *o*, as in figure 1; *r1*, the first and *r2*, the second radial; *an*, the anal plate.

Fig. 4. The lower part of the stem of the same individual. *d*, the basal disk with the digitiform extensions that leave it and the extend and surround article 5 of a dead individual, much older.

Fig. 5. The corona with the arms and the upper part of the stem of an individual in the third stage. *r3*, the third radial; *a*, the arms; *t*, the tentacles of the arms; *v* colored vesicles. The other letters as in figure 3.

Fig. 6. The same parts of an individual in the fourth stage. *f*, the triangles formed by the upper lateral corners of the first radials that are encountered; *ap*, (forgotten in the figure), top of the arms; *p*, pinnules in process of development. The other letters as in figures 1, 3 and 5.

Fig. 7. The end of an arms of same individual, seen from the side, *ap*, top of the arm; *p*, pinnule, and *v*, colored vesicles.

Fig. 8. *ap*, top of another arm, seen from the dorsal side; *p*, pinnules.

Fig. 9. An individual in the fifth stage, slightly enlarged (approximately 3 times). It is attached not only to fragments of a shell of Rhizopod as usual by the lower article of the stem *d*, but also by two higher locations *dd* of the stem; *e*, tuberculiform or digitiform extension of an article still higher on the stem.

Fig. 10. The lower part of the stem of another individual, attached to a foreign body *x* by its lower article *d*, of the lower enlarged part from which there leave some digitiform extensions, or which the two are bifurcated one or several times.

Fig. 11. The corona with the arms (of which only two are represented as a whole) and the upper part of the stem of the individual represented in figure 2, greatly enlarged. *1 to 4*, the four upper articles of the stem; *c*, the first 5 cirri; *d*, the ventral disc; *t*, tentacles; *an*, the anal tube; *sq*, calcareous scales of the disk at the base of the anal tube. The other letters as in figures 1 to 6.

Fig. 12. The lower part of the stem of the same individual (fig. 9), greatly enlarged. *d*, lower article with its digitiform extensions attached to a fragment of shell of a rhizopod *x* (*Rhabodammia abyssicola* Sars; *e*, digitiform extension of another higher article, likewise attached to the same shell.

Fig. 13. A fragment still higher (fig. 9, *e*) of the stem of the same individual, greatly enlarged, *e*, tuberculiform or digitiform extension.

Fig. 14. The corona with the arms (of which only one is represented in entirety) and the upper part of the stem in the sixth stage or the state of maturity, *1 to 4*, the 4 upper articles of the stem; *cd* (forgotten in the figure), the centro-dorsal plate; *c*, cirri; *p1*, the oral pinnule in the process of development; *sz*, syzygies. The other letters as in figure 11 and the preceding.

Fig. 15. The lower part of the stem of another individual in the same stage. Disciform enlargement *d* of the lower article having an irregular form and surrounding some spicules of a sponge *x*. From a higher article, there leaves likewise an extension *e*, that also surrounds a spicule of a sponge *x*.

Fig. 16. Some articles, taken approximately at the middle of the length of the stem of the individual represented in fig. 14, greatly enlarged, to show the regularly alternating compression of their two ends and the elastic ligaments *l* that join the articles.

Plate VI.

The pentacrinoid of *Antedon Sarsii*

Fig. 17. Half of one of the articles of the stem from fig. 6, seen from the side. *c*, the thinnest part of the article; *a*, its thick end; *e*, the teeth of the articular side.

Fig. 18. The articular surface of the same article, *c-c*, its long axis; *a*, the axial canal; *bb*, the cavity in the form of a biscuit; *e-e*, the articular side.

Fig. 19. The ventral disc of the individual represented in pl. 5, fig. 14, seen from above. *o*, the angles or oral corners of the 5 interradial spaces; *st*, tentacular grooves with their tentacles *t*; *an*, anal tube; *b*, base of the arms.

Fig. 20. Fragment composed of 3 articles of an arm of the individual represented in pl. 5, fig. 5, seen from the side. Only the article of the middle is shown completely, *dr*, the dorsal part or the body of the articles; *lt*, their sinuous ventral parts with the enclosed calcareous spicules *sp*; *v*, colored vesicles; *t*, tentacles.

Fig. 21. Ray of an individual still a little more developed than that represented in figure 14. The two arms are broken at the third article, from the end of one is regenerating a new arm. *r2*, the second and *r3*, the third radial; *b1* to *b3*, the 3 first brachial articles; *p1*, the oral pinnule; *v*, colored vesicle, and *t*, tentacles of the new arm.

Fig. 22. The oral pinnule of the individual represented in fig. 24.

Fig. 23. The upper part of the stem of an individual of about the same development as that represented in fig. 21. *1* to *4*, the 4 upper articles.

Fig. 24. The corona with the basal part of the arms and the upper part of the stem of the most developed individual of all that I have observed. *cd*, centro-dorsal plate; *cir*, cirri; *r2*, the second and *r3* the third radial; *st*, tentacular grooves; *an*, the anal tube; *z*, the upper articular surface of the hypozygal article of the third brachial; *sz*, syzygies of the 3rd and 8th brachial articles; *p1* to *p5*, the 5 lower pinnules.

Fig. 25. One of the largest cirri of the same individual, seen from the side, *a*, the terminal claw; *b*, the second claw (aboral).

Fig. 26. Fragment of the same cirrus near the middle of its length, seen from the dorsal side.

Fig. 27 and 28. Two small cirri, seen from the side.

Fig. 29. Cirrus in process of development of the same individual.

Fig. 30. Fragment of an arm of the same individual, near the middle of its length, seen from the dorsal side, *sz*, syzygy; *p*, the base of the pinnules.

Fig. 31. The sixth pinnule of the same individual, seen from the side, *dr*, dorsal part or body of the articles; *lt*, their sinuous lateral ventral parts; *v*, colored vesicles; *t*, tentacles.

L. vander Lee.