OBSERVATIONS

ON

POLYZOA

SUB-ORDER PHYLACTOLÆMATA

WITH NINE PLATES.

BY

ALPHEUS HYATT.

SALEM:
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ERRATA.

Page 4, for "175°" in second paragraph of note, read "75°."
" 13, " *trunk*, read *trunks*.
" " " *shallows*; read *the shallows*.
" 23, expunge "(Pl. 9, fig. 14)."
" 27, for *Fig.* 3, read *Fig.* 2.
" 33, " (*Pl.* 12, *fig.* 2), read (*Pl.* 12, *figs.* 1 *and* 2).
" " " *P. vitrea*, read *P. diffusa*.
" 35, " *dorsal*, read *ventral*.
" 37, fifth line from bottom of page read *retentors*, for *retractors*.
" 43, in description of figures, for *T*, *T*, read $\bar{T}$, $T^{\dagger}$.
" 45, for *Brachialr-banches*, read *brachial branches*.
" " " (*Pl.* 9, *fig.* 1), read (*Pl.* 15, *fig.* 1).
" 46, " *page* 107, read *page* 43.
" 55, " " 151, " " 55.
" 62, " *Walcotii*, read *Walcottii*.
" 89, " *Cyclostomata* on first line, read *Ctenostomata*.
" " " " in third paragraph, read *Cheilostomata*.
" 93, " *lophopus*, read *lophophore*.

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OBSERVATIONS ON POLYZOA.

SUBORDER PHYLACTOLÆMATA.

Introduction.

The investigations recorded in the following pages are the results of observations made on the American species of the Phylactolæmata; with the intention of elucidating the structure of the genera, and of presenting the laws of their structural combination as fully as this can be accomplished within the limits of the present communication.

For this purpose synoptical tables have been given, exhibiting the anatomy of the different divisions, as far as our knowledge of the adult animals would permit.

Had such a plan been possible at the present time, the synopsis would have embraced only the anatomy of the most complicated species of each generic series; and other tables, similarly constructed, illustrating every genus, would have been prefixed, one individual of each species being selected for analysis. But the small number of species now known in each genus not affording material enough for perfecting this system, the tables include only general statements of the characters of each genus, and these are arranged in a linear series in order to show clearly their serial relations. I venture, however, to assert, that, notwithstanding these defects, the results obtained by this mode of procedure are more exact, than if the usual methods of describing the anatomy had been followed.

The advantages of thus analyzing the anatomical features of any natural division are at once apparent. Their organization, as a whole, is rendered plain; and the reader is enabled to trace, throughout the structure of the group, not only the changes of any organ by itself, but even of

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the different systems of organs, from their lowest to their highest states.

The laws, also, according to which the changes, or differences in the parts, take place, are better illustrated by such a tabular view, than by any other method.

The manner commonly pursued of describing the minute differences between species, or genera, and of simply generalizing with regard to their anatomical peculiarities, is very unsatisfactory. It does not afford the means for comparing the anatomical composition of the parts of the individual in each species, or genus, which is necessary to a complete understanding of the whole, and the differences are sought for and described, to the neglect of the agreements, that are either passed by, or only casually noticed in the descriptions of the larger divisions. Such errors are avoided by the use of analytical tables, which, besides the advantages before described, set forth the similarities as prominently, as the differences. We thus never lose sight of the initial points of the structure, while the differences, or changes, from time to time appearing, stand out even more vividly against the common background of similarities.

It is far from my intention to underrate the labors of naturalists who devote themselves to the discovery and publication of new forms; their labors are essential to the progress of science. The ordinary mode, however, of prosecuting these investigations is, perhaps, too disconnected, species being habitually regarded in the light of isolated creations, rather, than as allied to others by the larger number of their essential characters. This engenders a habit of always looking for differences, and overlooking agreements, which the study of series of species, or even of series of individuals would correct.

The facts published in these "Observations" have been verified by my own experience, with the single exception of the spermatozoa. These I have not yet seen, my observations having been made, for three successive seasons, principally during the fall and winter months.

The questions involved in the body of the paper, and the difficulties to be overcome in obtaining living European specimens have obliged me to quote extensively from

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the works of foreign naturalists. References, however, are always made to the original publications, and the statements used have been, in all cases, sifted of facts that did not correspond with my own researches upon closely allied American species.

The nomenclature of Professor Allman's exhaustive "Monograph of the Fresh-water Polyzoa" has been adopted throughout, with the exception of a few alterations, which become necessary, partly in consequence of some ideas of my own, with regard to the composition of the organs, differing from those of Prof. Allman, and, partly, because I here adopt a new view of the relations of the anterior and posterior poles of the body, originated by my friend Edward S. Morse.* In an article published in these Proceedings he homologizes the parts of the animal in the various classes of the Mollusca, and arrives at the conclusion, as surprising, as it is truthful, that the attached end of a Polyzoön is in reality the anterior, and that the peduncular end of a Brachiopod is the homologue of this, and, also, anterior.

It therefore becomes necessary to alter the commonly received nomenclature, and to denominate the attached end of a Polyzoön the anterior; the free end the posterior; the anal side the dorsal; and the opposite, or so called hæmal side, the ventral.

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*A Classification of Mollusca based on the principle of Cephalization. Proc. of Essex Inst., Vol. IV, No. VI, p. 162.

NOTE. I am indebted to Dr. Joseph Leidy, of Philadelphia, for identifying my specimens of Fredericella regina with his species, for tracings of all the species described by him, and for other valuable information. I desire, also, to return thanks to Professor H. J. Clark, of Harvard College, Professor A. E. Verrill, of Yale College, Professor Alfred Mayer, of Penn. University, Professor Theodore Gill, of the Smithsonian Institution, Mr. Elliott Smith and Mr. S. I. Smith, of Norway, Maine; to all of whom I am under obligations for important assistance.

My thanks are also due to the Officers of the Smithsonian Institution, of Washington, and the Peabody Institute, of Baltimore, for the use of books which I could not have otherwise obtained.

It is but just that I should also express the feelings of gratitude with which I cherish the memory of my father, Mr. Alpheus Hyatt, of Baltimore, whose long continued generosity, while living, enabled me not only to accomplish this undertaking, but to plan, and prosecute others of a similar kind.

Mr. Edward S. Morse perfected the drawings with the skill of an

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The unquestioning manner with which I take up these views may excite some surprise, but they are founded upon facts which calmed all the doubts I at first entertained, and satisfied me entirely of their correctness. Mr. Morse's paper, entitled "*A Classification of the Mollusca based on the principle of Cephalization*," fully illustrates the homologies, as well, also, as the general plan of that subkingdom.

Mr. Morse has, also, done me the honor of quoting from my manuscript the term *Saccata* as a new name for the Mollusca. Since it has been so auspiciously introduced to science, and, as such a definitive term seems to be needed to give uniformity and completeness to the nomenclature of the four plans, I shall make no further excuse for its employment in the future.

Bibliography and Classification.

There is no bibliography of the Phylactolæmata, or in fact of the Fresh-water Polyzoa taken together, as far as our own country is concerned, but, in Europe, they have, from the time of Trembley,* their discoverer, attracted much attention, and the list of works, that may be consulted with profit, is extensive. The principal among these are the writings of Dumortier and Van Beneden, Professor All-

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accomplished draughtsman, and with all the interest of a zoölogist and personal friend. I am indebted to him both for this, and for many other favors that have rendered it possible for me to publish at an early date. In fact, my only regret, in connection with this article, is, that a gentleman of such acknowledged ability, whose time is important to science, should not be able to devote it to his own original investigations.

The lenses employed were made especially for the purpose by Robert B. Tolles, of Canastota, N. Y. The one half inch objective having an angle of 175° and one fifth of an inch working distance was especially well suited for the examination of living animals.

Mr. J. F. Richardson, of Portland, executed the engraving of the plates with the same skill he has shown in other scientific works, and with more than usual care.

The wood cuts are very large for a black ground, and, being printed directly from the wood, required all the skill and patience of Mr. Holland to produce accurate impressions.

*Mémoire pour servir à l'histoire d'un genre des polypes d'eau douce. 1744.

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man, and Mr. Albany Hancock.* These experienced naturalists surveyed the whole field, and, armed with powerful modern microscopes, they completely disclosed the anatomy and physiology, making nearly all preceding explorations interesting only as matters of history.

Dr. Leidy is the sole authority upon this subject in America.† His observations have given us all the information we at present possess of our native species, besides adding two new and singularly interesting genera, Pectinatella and Urnatella, to the systematic catalogue. Of these two, Pectinatella alone belongs to the Phylactolæmata.

Nothing of a general nature having been published in this country, it may, perhaps, be well, before proceeding with the structural analysis of the Phylactolæmata, to give a sketch of the classification and a description of the different forms of this suborder.

The Polyzoa, for a long time confounded with the Radiata, were first definitely separated by Thompson in 1830, and called by him Polyzoa, thus taking precedence of Bryozoa, the name afterwards given them by Ehrenberg in 1831.‡

In 1834, De Blainville, although still continuing to associate them with the Radiata, set off the genera Cristatella, Plumatella and Alcyonella as a subclass, styling them "Polypiaires douteux."‖

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*Dumortier & Van Beneden. Hist. Nat. d. Polypes composés d'eau douce. Nouv. Mem. de l'Acad. Roy. de Bruxelles. Vol. 16. 1843.

Van Beneden, Recherches sur les Bryozoaires. Mem. de l'Acad. Roy. de Belgique. Vol. 21. 1848.

Dumortier & Van Beneden. Hist. Nat. des polypes com. d'eau douce. Mem. de l'Acad. Roy. de Bruxelles, comp. au tom. 16. 1848.

Albany Hancock. On the Anatomy of the Fresh-water Bryozoa, with descriptions of new species. Ann. and Magazine of Nat. Hist. Vol. 5. 1850.

Prof. Allman. Monograph of the Fresh-water Polyzoa. Ray Society, 1856.

†Dr. Joseph Leidy. Proc. Philadelphia Acad. of Nat. Sciences, Vols. 5, 7, and 10.

‡Busk. On the priority of the term Polyzoa. Ann. and Mag. Nat. Hist. 2d Ser. Vol. 10, p. 352. 1852.

‖De Blainville. Man. d'Actinologie et de Zoöphytologie. p. 489. Paris. 1834—37.

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In 1837, Gervais divided the Polyzoa into two subclasses, "Polypiaires hypocrepia," and "Polypiaires infundibulati." The first included the genera with lateral arms, and the second those with round lophophores, among which he placed Fredericella.*

In 1848, Fredericella was restored to its proper division by Dumortier and Van Beneden, but they committed the mistake of uniting it with Paludicella, a genus with a truly orbicular lophophore, and devoid of an epistome.† These authors, also, recognized the Hypocrepian division, as limited by Gervais, separating Fredericella and Paludicella as a distinct group.

Professor Allman in 1856 instituted the order Phylactolæmata, basing it upon the epistome, which is present in all the genera.‡

He divides the order into two suborders; Lophopea and Pedicellinea, the former including all the Hypocrepian forms, and the latter the marine genus Pedicellina. Although differing from Professor Allman in my estimation of the relations of Pedicellina, I have retained his name for the Fresh-water genera, from Fredericella to Cristatella inclusive.

In the Suborder Lophopea, he has two grand groups, or families, founded upon the characteristics of the cœnœcium; one the Cristatellidæ, for the genus Cristatella with its locomotive cœnœcium; and the other the Plumatellidæ, embracing all the remaining genera, that have rooted cœnœcia.

There is a partial coincidence between Professor Allman's classification and the one I advocate. He makes of his Plumatellidæ two groups; one equivalent to my first family including Fredericella, because of the obsolete arms, and another including precisely the same genera as my second family. Thus the classifications virtually agree in regard to the number of the principal groups, although not with regard to their relative values.

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*Gervais. Recherches sur les Polypes d'eau douce. Annales des Sciences Naturelles, 2d Ser. Vol. 7, p. 77.

†Dumortier & Van Beneden. Memoirs de l'Acad. Roy. de Belgique. Vol. 21, p. 5. 1848.

‡Allman. Fresh-water Polyzoa. p. 10.

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According to this view of their relations, the PHYLACTOLÆMATA comprise three families, or subgroups. First; the *Fredericellidæ*, founded upon the great differences between the lophophore and nervous system of Fredericella, and the members of the other families. Second; the *Plumatellidæ*, which differ from the Fredericellidæ in the lophophore and nervous system, and from the Cristatellidæ in their cœnœcial characters. Third; the *Cristatellidæ*, whose cœnœcia and mode of development separate them widely from both the preceding.

The following is a scheme of this classification, enumerating the families and genera by name, and the number of species at present known in America, Europe, India and Australia.

PHYLACTOLÆMATA. Suborder.	Families.	Genera.	No. of species in America.	" " Europe.	" " India.	" " Australia.	
	FREDERICELLIDÆ.	Fredericella.	3	1			
	PLUMATELLIDÆ.	Plumatella.*	5	13		1†	
		Lophopus.	1‡	1			
		Pectinatella.	1		1‖		
	CRISTATELLIDÆ.	Cristatella.	2	1			
			12	16	1	1	30

*Plumatella includes Alcyonella, which is only a variation of the ordinary form of the species.

†A species of Plumatella mentioned, but not named or described, from Melbourne, and the vicinity of Richmond. D. Oyly H. Alpin. Ann. and Mag. Nat. Hist. 3d Ser. Vol. 6, p. 454. 1860.

‡A species mentioned by Dr. Leidy. Proc. Phil. Acad. Nat. Sciences, Vol. 10, p. 190.

‖A statoblast, found near Bombay and described by Mr. J. H. Carter in the Ann. and Mag. of Nat. Hist. Vol. 3, p. 341, pl. 8, f. 8-15, 1859, supposed by him to belong to Lophopus crystallinus. It, however, undoubtedly belongs to a new species of Pectinatella, and I therefore propose for this new species, which is remarkable for its spines, furnished with many lateral hooks, growing only from the ends of the statoblast, the name of *Pectinatella Carteri*.

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FREDERICELLA.

These are plant-like animals with graceful dendritic forms, common in our brooks and ponds (Pl. 7). They cling, immovably fastened by their ectocyst, to the lower surfaces of submerged stones, or floating boards; and thrive best in the darkest places, often carpeting the dismal recesses, under the loosened bark of dead branches, with their lovely, campanulate corollas.

Nothing can exceed the exquisite beauty of these small "phytozoöns"; their symmetrical outlines, the alertness of the motions of the polypides, and the surprising complexity of the internal structure of their transparent bodies richly repay the labors of the microscopist.

Cœnœcium. This part of the colony, formed by the tubular dark brown trunk and branches, is made up of lines of little hollow twigs, or cells, each separate cell encasing a single polypide, and opening into the preceding cell, or parent Polyzoön, at the lower end. Thence the cells are generally attached for some distance to the surface, although frequently the entire branch is free, the lowest cell alone being attached. The extremities of the cells bend upwards, and are always free, but vary exceedingly in length. The color is due to the ectocyst, which is a thin gelatinous excretion, soft, and transparent when first deposited, but acquiring with age a dark brown hue and parchment like consistency (Pl. 7, figs. 4, 5, D). This excretion is the product of the cœnœcial endocyst, or true body wall of the branches and polypides (Pl. 7, figs. 4, 5, 6, E). The endocyst is continuous throughout the general system of branches or cœnœcium, and the latter may, therefore, be regarded as a common tubular cavity, more or less cut up into cells. Some scattered, partial divisions, made by ring-like folds of the endocyst, open in the centre, are found in each colony, but these are not constant, and occur only at rare intervals in the branches.*

Polypide. The free portions of the cells are capped by translucent tubes crowned with thread like tentacles radiating from the periphery of the Lophophore, or floor of the

*Similar to those of Plumatella. Pl. 8, fig. 6.

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crown. This is perforated in the centre by the round mouth, overshadowed by the tongue like Epistome (Pl. 7, fig. 5, I′, I″), which is an obtuse, upward fold of the lophophore, opening below into the neural chamber, or cavity. This cavity contains the orbicular nerve-mass suspended immediately under the epistomic opening (Pl. 7, fig. 5, S).

The surface of the tentacles, the oral side of the epistome, the lophophore and the interior of the throat in the vicinity of the mouth are covered by cilia (Pl. 7, figs. 4, H, 5, H″). Constantly vibrating towards the centre of the crown, these cilia create a vortex in the water, at the apex of which lies the mouth, always open and ready to engulph the microscopic plants, or Infusoriæ, that may be caught by the encircling current, and swept into this liquid trap (Pl. 7, fig. 5, I″).

The polypides not unfrequently form a sort of cage, by interlacing the extremities of their tentacles, and imprison the more active of the Infusoriæ, who would otherwise readily escape. Thus inclosed, however, their strength is expended in fruitless efforts to break through the tentacular bars, until finally exhausted and overcome, by the power of the miniature maelstrom, they are whirled unresistingly downward into the funnel shaped throat.

The tentacles are used not only, as above described, to catch the prey, but for a multitude of other offices. They are each capable of independent motion, and may be twisted or turned in any direction; bending inwards, they take up and discard objectionable matter, or push down into the stomach and clear the œsophagus of food too small to be acted upon by the parietal muscles. They are also employed offensively in striking an intrusive neighbor, and their tactile power, sensitive to the slightest unusual vibration in the water, warns the polypide of the approach of danger.

Between the lophophore and the cœnœcium, the internal organization is plainly seen, the pellucid wall of the tube offering no obstacle to the eye of the observer.

The alimentary canal hangs from the lophophore, occupying the centre of the polypide, and floating freely in the rapidly moving blood. The yellowish œsophagus, the stomach barred with brown, and the brownish intestine

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compose a deeply colored axis relieving and vivifying the shadowy outlines of the tube and tentacular crest (Pl. 7, fig. 5, K, K′, K″).

All these delicately proportioned members are balanced upon a fold of the endocyst, called the Invaginated Fold (Pl. 7, fig. 5, B), which is retained within the cœnœcial cell by the Retentor muscles (Pl. 7, fig. 4, 5, N, N′). These together with numerous other sets of small muscles will be described hereafter. At present it is only necessary to call attention to the Sphincter (Pl. 7, fig. 6, L), a broad, contractile band surrounding the invaginated fold, and the large retractors (Pl. 7, fig. 4, fig. 8, M, M′, M″), which are in two sets, one on each side of the alimentary canal. They arise apparently from two common bases, but each large trunk subdivides above into many bundles, which may be distinguished from each other according to the location of their attachments and divided into three branches.

The fibres of the first branch, the Gastric Retractor, are distributed to the stomach; those of the second, the Lophophoric Retractor, to the œsophagus and oral region; those of the third, the Brachial Retractor, to the bases of the arms, and to the endocyst along the line of the Brachial Collar. The crest is swayed by these muscles in every direction; or, when alarmed, the polypide may withdraw by their aid into the larger cœnœcial tube below, very much as the finger of a glove may be inverted within the empty palm. This is so quickly done, at times, as to baffle observation, and the fully expanded polypide, with every tentacle stretched to its full length vanishes instantaneously within the cœnœcium. Often, however, the invagination is more slowly performed, and the motions can then be easily followed.

The polypidal endocyst is first turned inwards, folding upon itself, and prolonging the permanently invaginated fold below. The tentacles, arriving at the edge of the cœnœcial orifice, are pressed into a compact bundle by the action of their own muscles, and, together with the lophophore, are dragged into the cell by the continued invagination of the endocyst until they are wholly inclosed and at rest within the sheath formed for them by the inverted walls of the tube. The sphincter muscle then closes the

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cœnœcial orifice above, and the process of invagination is completed.

The polypide in its exserted state is buoyed up and sustained by the pressure of the fluids within. Consequently when invaginated it displaces an equal bulk of these in the closed cœnœcium, and their reaction, aided by the contraction of the muscular endocyst, is sufficient to evaginate the whole.

The evagination begins with the relaxation of the sphincter, which permits the ends of the tentacles to protrude. These daintily feel about for the cause of the alarm, and, if they fail to detect the proximity of an enemy, the whole fascicle is cautiously pushed out, and the sentient threads suddenly and confidently unfolded.

The polyzoön reasons from the sense of touch inherent in its tentacles, and cannot be induced to expose itself above the cœnœcium until thoroughly satisfied, by these sensitive feelers, that no danger is to be apprehended. In fact, these plantlike creatures, singly mere pouches with a stomach hanging in the midst, exhibit greater nervous activity and "animality," than we find among the more highly organized Ascidia, or shell-covered Brachiopoda.

PLUMATELLA.

The species of this genus abound near the shores of our ponds, close to the surface, and are generally in company with Fredericella (Pl. 8). They may be found attached to the under sides of flat stones, or floating boards, but do not usually seek the narrow, dark recesses in which Fredericella often occurs. Better fitted to endure the sun's rays, they may, occasionally, be seen in positions exposed to their full influence. I have been so fortunate as to collect specimens of P. Arethusa which were growing from the ends of the long water grasses; their tiny branches, and living, crystalline flowers glittering in the light, and swaying to and fro in the open current without protection from the heat, even at midday.

The cœnœcium is dendritic as in Fredericella, but the growth is generally more luxuriant, extending over larger surfaces, and the cœnœcial cells are wider in proportion to

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their length. The polypide, also, is capable of more extended protrusion, and its motions, therefore, are less restrained. The arms, previously indicated in the lophophore of Fredericella, are fully developed, and stretch out on the dorsal side just above the anus, giving a crescentic, or horse-shoe shaped aspect to the disk, which is retained throughout the succeeding genera.

The ectocyst may be either transparent or brown in the same species, and the polypides may be widely separated, as in Fredericella, or be closely aggregated, the branches and cells adhering together by means of their gelatinous ectocysts.

LOPHOPUS.

Lophopus introduces us to a new class of characters. The ectocyst, in place of being a thin enveloping sheet, is a thick deposit of clear jelly in which the cœnœcium is buried. The branches are lobiform, and the cells even less widely separated, or differentiated, than in the aggregated varieties of Plumatella.

Prof. Allman describes Lophopus crystallinus as attached to the stems of Lemna, and other fresh water plants, but avoiding exposure to bright sunlight.

These positions must necessarily, however, be less shaded than those occupied by the majority of the Plumatellæ.

PECTINATELLA.

The reproductive and vital energies of the group reach their climax in the voluptuous beauty and endless multiplication of the cœnœcia in Pectinatella (Pls. 9, 10, 11, 12).

The cells of the separate polypides are wholly merged in the lobiform branches, and the gelatinous ectocyst, often several inches thick, is gathered underneath the cœnœcia (Pl. 9, fig. 5, D). It affords a common base for all the colonies, and is no longer, as in the preceding genera, confined to one cœnœcium.

The tropical aspect and luxuriant growth of the clinging masses, frequently several feet in diameter, investing the summits of submerged stumps, and the branches of

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waterlogged timber, are unequalled among the fresh-water, or even among the marine Saccata of our climate.

The communities, assembled in countless profusion upon the gelatinous ectocyst, are crowded together and being compressed become irregularly hexagonal in their outlines. The polypides upon the lobiform branches, adorn the borders of these hexagonal patterns with a dense, glistening fringe, speckled with the scarlet coloring of their oral regions; and the bare cœnœcial trunk (Pl. 9, figs. 5, 6, 7, A′) in the centre shine with a deep, opaline lustre, completing the rich, coralline effect of the fringed outlines.

The protrusion of the polypides is not limited by the invaginated fold, as in the preceding genera, but they roll out nearly the full length of their evaginable endocyst, and resemble columns supported by a simple ovolo and fillet (Pls. 10, 12). The fillet corresponds to the invaginated fold of the preceding genera, and the ovolo-like bend in the endocyst is produced by the contraction of the anterior retentor muscles.

In July and August specimens of Pectinatella magnifica are very abundant in shallows and in the depths of Pennissewasse pond, but as the fall advances, those in the shallows die, and in October they can live only upon the logs in deep, cool water, or in shaded situations. These autumnal specimens are old, and being unable to withstand the direct rays of the sun, disappear from all exposed positions, where they grow with impunity as strong and healthy adults earlier in the season. I have found them fifteen or twenty feet below the surface, showing a marked departure in this respect from the preceding genera, whose species seldom occur below two, or three feet, and are almost invariably near the shore line.

CRISTATELLA.

The Cristatellæ are by far the most highly organized, not only of the Phylactolæmata but of all the Polyzoa (Pls. 13, 14).

The cœnœcia are neither dendritic, as in Fredericella and the Plumatellæ, or lobate, as in Lophopus and Pectinatella, but naked, depressed sacks, capable of determi-

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nate motion; their interior divided by walls of reticulating muscular fibres into numerous radiating cells and tubes. The latter, however, do not meet internally, but leave a vacant space in the centre of the cœnœcial trunk unoccupied either by the polypides, or the muscular walls (Pl. 13, figs. 2, 3, A′).

The polypides extend to the full length of their evaginable endocyst, and are destitute of an invaginated fold, not even possessing a fillet around the upper edge of the cœnœcial orifice as in Pectinatella (Pl. 14, fig. 1). They are disposed in rows upon the borders, inclosing the clear, bare central spaces with an edging not unlike the polypidal fringes of Pectinatella (Pl. 13, fig. 1).

The ectocyst loses the fixed character it still possessed in Pectinatella, and is only a transient, gelatinous excretion, thrown off in great abundance from the common base of the colony (Pl. 13, fig. 3, D).

The communities are not invariably gathered upon a common ectocyst, as in Pectinatella, but are sometimes single, as in Lophopus.

There is, however, a very curious, and remarkable similarity of one species with Pectinatella.

The cœnœcia of C. ophidioidea herd together within confined boundaries from a few inches to a foot or more in diameter, covering such favorite resorts with a glairy coating accumulated upon the surface by the moving bases of the numerous colonies. The aspect of one of these settlements, supported upon this common ectocyst, is analogous to that of a mass of Pectinatellæ; especially to the old age, or degradational period of the life of a mass of the latter; where a large number of colonies still cling to a thin sheet of gelatine left from the decay of the greater part of the ectocyst.

This similarity may be explained by the fissiparous multiplication of the cœnœcia in both genera and the slow progression of Cristatella. The colonies of the last can never wander far from their place of origin, unless floated off by some accident, and, continually multiplying, they soon create a dense population in a comparatively small space.

The distribution of Cristatella is similar to that of Pectinatella, they being generally found together.

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Reproduction.

The Phylactolæmata have two modes of reproduction, one by buds, and the other by eggs. The former occurs in two ways; by statoblasts, either fixed or free, and by regular buds, which grow out from the side of each polypide. The first are the founders of new colonies. The last merely increase the number of individuals in each established community. The colonies are, however, sometimes multiplied by other processes, which cannot be classified under either of the above heads. In large specimens of Plumatella Arethusa the polypides on the old trunk die first and the remnants of the cœnœcia are gradually swept away, leaving the branches as so many independent colonies (Pl. 8, fig. 1). This, also, is not uncommon with Plumatella diffusa, and is, probably, peculiar to all the species of this genus that distribute their branches over a large surface.

I have directed, perhaps, more attention to the old age than to any other period of the growth of the individual, and among the many curious and novel facts, which this comparatively untravelled path of investigation has led me to, there are few more interesting than the above.

Specimens of Fredericella may be often observed attached near the ends of their branches by the soft ectocysts of their younger polypides, the ragged end of the branch floating freely above. These may sometimes have been torn by accident from the parent colony, but in the majority of cases they owe their liberation to the decay of the original stock. In Pectinatella and Cristatella the march of extinction is, also, from within outwards. But, in consequence of the greater width and the common occupation of the cœnœcium by the polypides, the decay of those in the interior does not effect the vitality of the trunk, and their living cœnœcia carry both the quick and the dead (Pl. 9, fig. 11).

Thus death, which is an active agent in multiplying the number of independant colonies in Fredericella and Plumatella, is, probably in Lophopus, and certainly in Pectinatella and Cristatella, of no avail; the constrictive power of the endocyst being its functional substitute in the

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three last named genera. Although the polypides of the Phylactolæmata never display any marks of fissiparity, the cœnœcia are multiplied by division. I have seen the lobiform branches of old colonies of Pectinatella divided from the cœnœcial trunk by constrictions, which, gradually deepening, finally separated them from the latter. The form, the thickness of the ectocyst, and the vast number of cœnœcia upon every mass, indicate, that this selfmultiplicative mode of propagation is of frequent occurrence among the adults.

Prof. Allman has observed similar phenomena in Cristatella and Lophopus, showing it to be common to all the genera having the thickened gelatinous ectocyst. It appears probable, that this method of multiplying the colonies would also take place in Fredericella and the Plumatellæ, if it were not for the toughness of the ectocyst. The partial divisions continually occuring in the branches of these genera and, apparently, restrained only by the stiffness of the ectocyst from becoming effective and severing the cœnœcia, wherever they occur, into separate parts, are the homologues of the permanent septa between the cells of Paludicella and of the lateral partitions in the marine Polyzoa. This homology was suggested to me in observing the readiness with which the lobes of Pectinatella were cut off; the constrictions occuring irregularly, sometimes isolating a whole branch, sometimes only a few cells. If the ectocyst was pergameneous in this genus the constrictions would either not take place at all, or form scattered partitions, as in Fredericella and Plumatella. Thus the same function that produces a constant anatomical character in Paludicella, Fredericella, and Plumatella, would seem to be the effective cause of the selfmultiplication of the cœnœcia in Lophopus, Pectinatella and Cristatella.

Prof. Allman divides the mode of reproduction by buds into two, "non sexual reproduction by gemmæ, which at once proceed to the full term of their destined development," and "by statoblasts or gemmæ in which the developmental activity remains for a period latent."*

The statoblasts bud from the funiculus, a cord like pro-

*Fresh-water Polyzoa. p. 41.

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longation of the outer membranes of the stomach, connecting the lower end of that organ with the bottom of the cell in the vicinity of the bases of the retractors.

The researches of Mr. Hancock, upon the early development of the statoblast, which he supposed, in common with other observers of that time, to be a true ovum, and those of Prof. Allman, give an almost complete history of their growth.* The former found them in Plumatella and Fredericella, in the interior of the funiculus, as large nucleated cells; and the latter, apparently begining his investigation at a later period, as a mass of smaller cells, which must have resulted from the division of the primary cell of Mr. Hancock.

They arise within bead like swellings of the funiculus, and, enlarging slowly, push out to the surface of the chord, and upwards towards the stomach, until finally they hang upon the exterior, arranged alternately on either side, the youngest being at the lower end (Pl. 8, fig. 2, W).

According to Prof. Allman the contents increase in bulk by the formation of new cells, and are enveloped in a cellular membrane (Fig. 1, a) with an outer gelatinous envelope (Pl. 8, fig. 2, W''''). Between these, two other membranes are secreted, one of which constitutes the horny sheath, and the other the annular ring of the statoblast (Pl. 8, figs. 7, 8, 9, W', W''). This sheath and the annulus gradually assume a distinct cellular structure, and a horny consistency; the former at the same time acquiring a deep brown color, and the latter a brilliant golden hue.

The contents of the statoblast are often contracted, and, while in this condition, during the earlier stages of development before the horny casing becomes too opaque, the membranes may be analyzed by the aid of the microscope.

The interior cells are large and colorless. They are surrounded by a thin, homogeneous membrane, which, when the cellular contents are reduced by contraction, seems to be drawn out into numerous, minute, conical projections at the points where it is attached externally to the overlying membrane (Fig. 1, b). I was unable on account

*Albany Hancock. Ann. Nat. Hist. Vol. 5. p. 190.

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of the opacity of the sheaths of the specimens of Fredericella regina, upon which my investigations were principally made, to determine with absolute precision, whether these conical projections were tubes, or partly solid muscular bands connecting the investing membrane with the overlying layer (Fig 1, a).

The cellular contents do not project into the interior of the cones, as they might be expected to do, if the latter were simply hollow continuations of the investing membrane. This fact may be considered as favoring the opinion, that they are partly solid, and, perhaps, muscular, connective bands, or else there must be another membrane interior to the one described, which, also, invests the cellular contents and prevents the cells from flowing into and filling up the conical projections. The overlying layer (Fig. 1, a) is exceedingly thick, and acts, in all respects, like a muscular membrane. It is unconnected with the horny sheath, and either lies closely against the latter, or is separated from it; and may be smooth and of equal thickness throughout, or corrugated and of unequal thickness, as in fig. 1, according to its state of expansion, or contraction.

The horny sheath is composed of flattened, hexagonal cells, the whole surface garnished internally with a thin coating of short, horny, brown colored setæ (Fig. 1, W'). This sheath is so exceedingly tough and hard that it is difficult to pierce it with the point of a needle.

The annuli of the statoblasts of Plumatella, and of the other genera in which they are found, are made up of more prominent and larger hexagonal cells than those of the horny sheath.

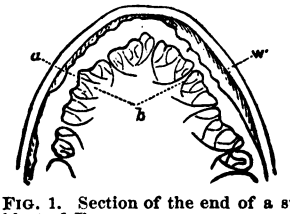

FIG. 1. Section of the end of a statoblast of FREDERICELLA REGINA; *b*, conical projections on the surface of the cellular contents; *a*, thick, muscular membrane; *w'*, horny sheath.

In Fredericella the annulus is not developed, but in all the other genera it is, and in Pectinatella and Cristatella spines are superadded.

These spines apparently arise from the annulus in Pectinatella, as described by Dr. Leidy, but they may be traced by a close

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examination of this part, by transmitted light, to their junction with the body of the statoblast. From the edges of the statoblast they pass through the centre of the annulus, coming out on the border of the seam, that divides the upper and lower sides of the annulus.

Prof. Allman describes the statoblasts of Cristatella as surrounded by a ciliated envelope before the spines begin to be developed, and remarks, that these impinge upon this membranous envelope, which gives way before them and disappears. I have been unable to detect any similar ciliated membrane in Plumatella or Pectinatella, and, in this respect, Cristatella probably differs from all the other Phylactolæmata. The gelatinous matrix of the statoblast of Pectinatella does not reach its full growth before the spines are produced, but appears to be carried up on their sides as they progress outwards. When the spines are fully developed, the reentrant spaces in the envelope between them become filled out, and they are buried in the gelatine, like those of Cristatella when they first begin to protrude from the horny sheath.

The gelatine is absent from the full grown statoblasts of Fredericella and Plumatella, which are found naked in the cœnœcial cells, whereas those of Pectinatella and Cristatella are enveloped by it until after the death of the colony; losing it only by decay. In the two first this covering is not essential, and it is absorbed before the bud is floated out of the cœnœcium, while in the two last it is needed in order to protect the parent from laceration by the pointed hooklets of the spines, and it is, therefore, retained until lost by the exposure of the bud to external influences.

Before the spines of Pectinatella appear, and often, even before the horny casing shows the deeper shades of the brownish coloring that afterwards distinguishes it, the statoblasts are detached from the funiculus. They lie loose in the cœnœcial cavity from this time until the death and decay of the polypides destroy the upper parts of the cells. Through the openings thus made, being lighter than water, they are readily floated off and pass the winter unprotected by any other covering than their cellular casings, although remaining near the surface, and consequently, in the higher latitudes, imbedded in the ice for several months.

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Growth begins at the approach of spring and the edges of the sheath are split apart by the increasing bulk of the polyzoön, which protrudes between them. The opacity of the sheath has hitherto prevented microscopists from ascertaining the early history of the development of the polypide, and we are obliged to be content with such observations as can be made during the later periods of its life, when it is partly exposed.

The organs, when the little animal first makes itself visible, are well advanced in growth and the polypide is already capable of retraction and expansion. For a time it floats freely in the water, wafted about by the cilia, which clothe the whole external surface, and increases in size until the sheaths of the statoblast can no longer contain it; then, in some appropriate locality, the gelatinous ectocyst adheres to the surface, the cilia are absorbed, and the polypide enters upon a new phase of life as the founder of a community.

The sides of the sheath and the annulus, although separated from each other, frequently cling to the bud, and may occasionally be found adhering to its sides even after the colony has attained its full size.

Besides these floating buds, which might be called free statoblasts, there are others, originating in a similar manner, but from the attached or lowermost sides of the cells instead of the funiculus. These remain permanently fixed by their external investment to the endocyst, and, on this account, I have called them fixed statoblasts. They have been described in Plumatella emarginata and Alcyonella (Plumatella) Benedeni by Prof. Allman, and by Dr. Leidy in Plumatella nitida.*

It may be well to remark here, that the location of the free statoblast in Fredericella is different from what it is in all other genera. After dropping in the usual manner from the funiculus they become soldered to the sides of the parent cells, and being of the same size, are indistinguishable from the true, fixed statoblasts.

The fixed statoblasts found in Plumatella are much

*Dr. LEIDY. Proc. Philadelphia Acad. Nat. Sciences, Vol. 5, p. 321.

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larger than the free forms, have no annulus, and in many species the walls of the cells immediately under them become so compact and hard, that they cannot be removed from the surface of the wood or stone to which the cell is attached without considerable exertion.

Certain so called exceptional forms of buds, also, previously noticed by Prof. Allman in Alcyonella fungosa and Lophopus crystallinus, are very abundant in Cristatella, on the interior of the basal membrane* (Pl. 13, figs. 2, 3, 8, 9, 10, 11, 12, X). They are at first small oval bodies near the border, jutting out from the endocyst of the tubes leading to the second or third line of polypides. Their composition is similar to that of the statoblast. They have a thick external membrane and granular contents, but are devoid of a gelatinous envelope, and, also, have a large vacant spot in the interior which is continually varying its shape and position. Simultaneously with them, and continuous with their outer envelope, a long ridge springs up from the endocyst and the outer membrane of the bud, which, becoming membranous, splitting into two portions, and connecting with the upper side of the cœnœcium, eventually incloses them in a tube (Pl. 13, figs. 8, 10, 11, Q). This ridge sometimes passes directly over the centre of the bud, and sometimes to one side, but is almost always present. It occasionally retains the cord like embryonic character, and freeing itself from the endocyst, except at the extremities, forms a pseudo-funiculus, suspending the bud in the cœnœcial cavity. The thick external membrane becomes in course of time differentiated from the walls or ridges, and acquires the horny consistency of the casing on the free statoblast, but is never so opaque, or deeply colored. As the outer membrane stiffens no change seems to be made in the granular contents, but the more convex face of the envelope sinks, forming an elliptical depression, and the greater number of the buds become free (Pl. 13, fig. 12, W'). Prof. Allman found them to be hollow, and described this elliptical depression as an aperture. I was, however, unable to substantiate either of these con-

*ALLMAN, Op. cit. p. 40.

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clusions in Cristatella. The rupture of the sheath and the consequent escape of its contents is not an uncommon occurrence among the fixed statoblasts of Plumatella; and this seems to have been the cause of the emptiness of the specimens described by Prof. Allman. From their mode of development, and the place they occupy in the cœnœcium, it is probable that they are the same as the fixed statoblasts of Plumatella. They differ, however, from the fixed statoblasts in being unattached to the endocyst when fully grown, but this not being an invariable character, and the elliptical depression, which is nothing more than the accidental sinking in of one side of the sheath, being quite common, even among the free statoblasts of Plumatella, I see no reason for considering them exceptional forms.

At an early stage of growth, while still floating freely in its native element, the statoblastic polypide begins to multiply by the process of budding. An internal swelling of the endocyst, on the lower side, in the vicinity of the bases of the anterior retentor muscles, first shows the position of the coming polypide. This elongates into a little hollow sack with a thickened rim (Pl. 7, fig. 5, Y), upon the upper edge of which, in the Hypocrepian Polyzoa, a slight notch is formed by the duplication and pushing out of its sides into two loops joined along the centre (Pl. 13, fig. 4, Y). A series of minute folds of the membrane on the upper sides of the loops are the incipient tentacles, and, as they enlarge, the intervening membrane is drawn up with them like a thick web; but this, however, eventually recedes externally and becomes the calyx. The loops growing outward augment their longitudinal diameter at the expense of the transverse, and the inner sides of each, approximating and at last coalescing, make up the lophophore and arms. Preceding the beginning of the tentacles, a transverse constriction of the body of the little sack draws the line between the œsophagus, and the stomach; and the subsequent deepening of this constriction divides off the internal cavity, establishing the cardiac and pyloric valves. The muscles, which become well differentiated at a very early period, are divisible into three pairs: one pair attached to the rim, the Brachial Retractors; one to the region

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of the œsophagus, the Œsophagal Retractors; and one to the region of the stomach, the Gastric Retractors. They are active from the first, and appear to drag the polypide inwards, stretching the endocyst of the parent, which is joined to the loops, into a tube. This tube is the future evaginable endocyst of the polypide; and, as the various organs are developing, it is everted little by little, becoming gradually capable of the adult evagination.

The tentacles of Cristatella ophidioidea are not fully grown, nor the arms divaricated, until long after the evagination of the polypide is completed (Pl. 13, fig. 3, Y'). At this period the tentacles of the external rows near the mouth are the longest, decreasing regularly to the mere tubercles on the ends of the arms, and the internal tentacles are not separated from each other, exhibiting only two closely appressed lines of tubercles all of about equal length. The division of the arms begins internally, and its progress outwards may be followed by the gradually increasing length of these interior rows, which retain their tubercular character until this division commences (Pl. 9, fig. 14).

The mode of reproduction by true ova, although detected by Dumortier and Van Beneden, was first fully described by Prof. Allman. They are produced from the gemma dot, a bud-like mass on the upper side of the endocyst in the neighborhood of the orifice, which, during the fall, when not filled with ova, becomes opaque and granular.*

The testicle, first described by Dumortier and Van Beneden, arises from the funiculus, resembling in its mode of formation, according to Prof. Allman, a true bud. The

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*Prof. Allman thus describes the earlier periods of the development of the ovum. Monograph Fresh-water Polyzoa p. 33.

"*Development of the Ovum.*—I have succeded in tracing the development of the ovum through most of its stages in Alcyonella fungosa.

In this polyzoön the mature ovum consists of a granular vitellus, surrounded by a very evident vitellary membrane, on whose internal surface the contents appear frequently to be aggregated in a coarse granular layer. It presents a large germinal vesicle, and a very distinct germinal spot. After a time the germinal vesicle and the germinal spot disappear, and the vitellus undergoes segmentation, and after the mulberry-like condition thus induced has in its turn vanished, we find the contents of the egg have assumed the form of a roundish or oval body, richly ciliated on its surface, and provided with a large cen-

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nuclei of the cells are of large size and in due time are converted into spermatozoa. These have been observed swimming freely in the perigastric cavity into which the full grown ova are, also, discharged from the ovary.

After the segmentation of the vitellus, the egg appears as a hollow oval body clothed externally with cilia, and it is at this period that most observers have seen and described its peculiarities.

Mr. Albany Hancock, although confounding it with a statoblast which he supposed to be an egg, speaks of one, an undoubted ovum, which, he observed forcing its way through the closed orifice of the cell, rending and destroying the parent polypide in its course.*

I have, also, seen them during this stage in Plumatella

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tral cavity, which as yet does not open externally. When liberated from the outer membrane of the ovum, which still confines it, it swims actively through the surrounding water by the aid of the cilia with which it is invested.

As development proceeds, we find the ciliated embryo while still confined within the coverings of the egg, presenting in some part of its surface an opening, which leads into the central cavity; and through this opening an unciliated, hernia-like sac is capable of being protruded by a process of evagination. The unciliated protrusible portion would seem to have been derived by a separation from the walls of the central cavity, and appears therefore to originate by a process of unlining, a true chorization.

Towards the opening, which leads from without into the central cavity, the chorization is incomplete, the membrane as it separates being here still held to the walls of the cavity by irregular transverse bands; these bands check the entire evagination of the membrane, but after a time they disappear, and then the unlining and evagination are perfect. In the interior of the protrusible portion, and before the disappearance of the transverse bands, a polypide is developed." The further development of this polypide, as described by Prof. Allman, does not differ materially from those produced from the regular buds of the adult cells.

The same authority thus describes the testicle of Alcyonella (Plumatella) fungosa on page 32 of the work above quoted.

"The testicle is composed of a mass of spherical cells, each of which contains within it numerous secondary cells, "vesicles of evolution." The visible contents of the vesicles of evolution consist, at first, of nothing more than a well-defined spherical nucleus, and this is subsequently transformed into a spermatozoal filament, which finally escapes by the rupture of the containing cells. The spermatozoal filaments, in this genus, are simple vibrioid bodies without any terminal enlargement."

*HANCOCK. Op. cit. p. 186, note.

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Arethusa, squirming in the perigastric cavity, and tossing the stomach of the polypide about, as if it had been a plaything. They certainly, in this species, evinced sufficient power to open a passage through the thin membrane of the polypide, although such did not seem to be their object at the time.

No orifices for the expulsion of the ova have been as yet positively demonstrated. Meyen chronicles the escape of the eggs of Alcyonella (Plumatella) stagnorum from an opening in the vicinity of the anus.* But this is, probably, erroneous, since, as observed by Mr. Hancock, "the great size of the egg forbids the possibility of its escape without the destruction of the polypide."

From the preceding account it may be seen that there are four localities, all within the cœnœcium, devoted to the function of reproduction. These are, the ovary on the dorsal side of the orifice; the free part of the endocyst of the cell on the abdominal side, bringing forth true buds; the attached portion lower down, giving birth only to fixed statoblasts; and the funiculus, generating spermatozoa and free statoblasts. The true buds of Fredericella and Plumatella are numerous, although only one usually matures and prolongs the stem: when two or three mature, at the same time, the lateral branches are produced. These buds grow slowly, forming the ordinary tubular cells. In some varieties of Plumatella, however, the buds mature more rapidly and in greater numbers, while the branch assumes a lobe-like form, the polypides, with the cells but half developed, crowding the upper surface. This mode of formation, which is only a variation of the species in Plumatella, is of generic value in Pectinatella, where the polypides are invariably arranged upon lobiform branches. In Cristatella the true buds are more numerous than in any other genus, and they mature until the cœnœcium is full grown.

The gradual increase in the number of the buds, that reach *maturity*, coincides with the decrease in the toughness of the ectocyst, and its final obliteration in the higher

*MEYEN. Isis. 1828, p. 1228.

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genera; and the absolute number of the buds to the expansion of the bud producing surface. As has been shown in the preceding paragraph, the number of the buds reaching maturity, and their absolute number in each cell of Fredericella, is generally less than in those varieties of Plumatella that have a gelatinous ectocyst; and they are less, in the latter, than in the Pectinatellæ, which have no ectocyst; and less in the Pectinatellæ than in Cristatella, where the ectocyst is wanting, and where the bud producing surface is of the greatest extent.

Composition of the Endocyst.

In the foregoing remarks the anatomy has been discussed, so far as was necessary, in order to give clearness to the descriptions of the different genera and the subsequent notice of the modes of reproduction. It now remains to consider more fully the composition of the body, together with the relations and functions of the various organs.

The endocyst is made up of four layers: (1) an outer large celled membrane (Pl. 11, fig. 1, E′, Pl. 12, fig. 2, E′, Pl. 13, fig. 16); (2) an inner one of smaller cells (Pl. 11, fig. 1, E″); (3) one of muscular fibre (Pl. 11, fig. 1, E‴); (4) an epithelial layer lined internally with muscular fibre (Pl. 11, fig. 1, E⁗).

(1) The first membrane forms the external surface of the endocyst of the polypide and of the cœnœcium.

The cells on the cœnœcia of Fredericella and Plumatella are hexagonal containing a large brilliant nucleus and nucleolus (Figs. 3, 5). Their upper sides are depressed by the weight of the superincumbent ectocyst, and their longitudinal diameters are not so long as in the cells of the same membrane on the evaginable endocyst.

When fully expanded on the living cœnœcium the cells are closely pressed one against another; but, if treated with alcohol, they contract, and, separating from each other, leave wide intervening spaces (Fgs. 2, 4, 5). These spaces have been figured by Prof. Allman under the impression that they were anastomosing channels, perhaps blood channels; my observations, however, have been too numerous to leave any

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doubt of their being what I have stated. The larger cells are continually multiplying by division, and there result numbers of small cells which lie scattered here and there in the supposed blood channels. Fig. 3 shows a large cell undergoing the process of division, and below, near the right lower corner of the figure, there are two minute cells, undoubtedly created in a similar manner, occupying the interstices of the membrane. Fig. 5 shows a group of cells taken from a point nearer the orifice than those of fig. 2, and, also, from a different zoöid. These are not so disfigured by contraction and have more angular outlines. Fig. 4 shows a group of five cells, from another zoöid, more highly magnified than either of the above, and more widely separated. When the cells are so dispersed the intervals are usually more or less filled in by minute cells; but, in this instance, the spaces were vacant and the nucleus of immense size, the nucleolus not being visible.

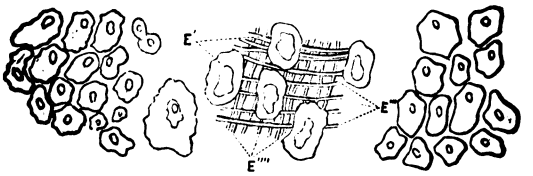

FIG. 2. FIG. 3. FIG. 4. FIG. 5.

FIGS. 2 and 5, groups of cells of the first membrane, greatly enlarged, from the cœnœcium of PLUMATELLA VITREA.

FIG. 3, one cell still more enlarged showing nucleus and nucleolus.

FIG. 4, E', cells of first membrane: E''', muscular fibres of the third layer: E'''', muscular fibres of the fourth layer.

The cells on the cœnœcia of Pectinatella and Cristatella do not differ sensibly in their structure from those of Fredericella and Plumatella. The outer sides, however, being free from the presure of an ectocyst, are more convex; and the longitudinal diameters, instead of being less, are greater than in the cells of the same membrane in the evaginable endocyst. Plate 13, fig. 16, and figures 7, 8, E' present lateral views of the membrane in the cœnœcia of Cristatella and Plumatella: in figure 8 the cellular structure is not given; but the relative thickness of the membranes may be estimated by a comparison of the two figures. The cells of the first membrane of the evaginable endocyst do not vary

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essentially from those on the cœnœcium, except in being greater or less than the latter, as mentioned above, and in having the power of expanding and contracting their parietes. They may swell to twice or three times the normal size, and contract again with considerable quickness, as if they had collapsed after parting with their fluid contents. From the evaginable endocyst they can be followed into the calyx, which, in the adult, is merely a web like fold of the first membranous layer; and from the calyx into the external ciliated membrane of the tentacles.

The cells on the calyx and tentacles are of about the same size as those on the evaginable endocyst, but they are not so distinctly hexagonal, unless contracted. The outer sides are more convex, than those on the cœnœcium; this peculiarity is, also, shared by the cells of the evaginable endocyst. The nucleus is large and brilliant. The nucleolus was not defined. The cilia are prolongations of the walls of the cells; each cell bearing one long slender hair (Fig. 6).

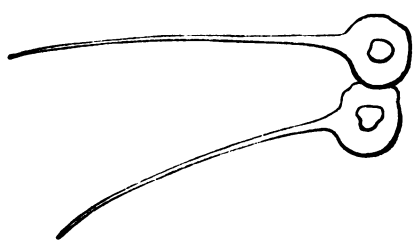

FIG. 6, two living cells, with cilia, from near the tip of a tentacle of FREDERICELLA REGINA.

The vibrations of the cilia are not constant, and, if a tentacle be severed and quickly placed under the microscope, those that are at rest can be viewed without difficulty throughout their entire length.

The cells become smaller on the lophophore, forming a denser layer than on the other parts of the zoöid. There is no break upon the edge of the œsophagus and the cells of the first membrane are continuous with the cells of the innermost layer of the alimentary canal.

(2) The second layer is made up of smaller cells. It is

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coextensive with the first, and is the principal membrane of the endocyst. The size of its cells does not vary appreciably within the limits of the group. As a general rule, however, its thickness in the cœnœcium is quite double what it is in the evaginable endocyst, and on the outer side of the tentacles. On the inner side of those organs, and in the lophophore, it becomes as thick as it was in the cœnœcium. In the arms, also, it is thicker than in the evaginable endocyst; but its greatest development in this respect is attained in the region of the sphincter muscles (Fig. 8, E″). This membrane is thicker than the first membrane in the other parts of the cœnœcia of Fredericella and Plumatella, but thinner than the first membrane in the cœnœcia of Pectinatella and Cristatella (Figs. 7, 8, E″).

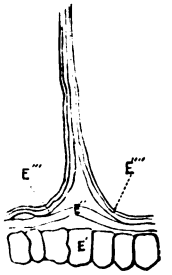

FIG. 7, base of a cœnœcial wall of a living specimen of CRISTATELLA OPHIDIOIDEA viewed from the base, the specimen being inverted: E′, first membrane of the endocyst: E″, second membrane of the endocyst: E‴, third layer of transverse muscular fibre: E⁗, epithelial membrane with longitudinal muscular fibres.

(3) The third layer is exceedingly contractile. The transverse fibres of which it is composed are loosely and irregularly set, but have considerable muscular power (Figs. 4, 8, E‴). The cœnœcial endocyst of Plumatella is sometimes drawn in by annular constrictions, happening, apparently at will, in any part of the wall where the ectocyst is sufficiently pliable, which are generally referable to the action of this muscular coat. Such annular constrictions can be occasionally traced to rows of small muscles extending across the cavity from the endocyst to the alimentary canal, or to the invaginated fold. These muscles, however, could not have been the cause of the constrictions in the dead Plumatella Arethusa figured in Pl. 8, fig. 10. The most careful observations of this specimen, with a high power, failed in bringing to light any such rows of muscles, and, in this case, all the plications, with the exception of those brought about by the influence of the retentor muscles (Pl. 8, fig. 5), were due to the transverse annular muscles of the third layer.

An involution of this layer aids in forming the base of

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the walls in the cœnœcium of Cristatella (Fig. 7, E'''), but it does not probably extend into their reticulated portion (Pl. 14, fig. 1, Q). Judging from the thinness of the latter, and, from the fact, that all the longitudinal muscles of the body appear to be connected more or less with the fourth or epithelial membrane, it is quite likely that the reticulated portion, or those parts of the cœnœcial walls which lie between the junctions of the walls with the upper and lower internal surfaces of the cœnœcial endocyst, are composed wholly of longitudinal fibres, encased by the epithelium. Around the invaginated fold of Plumatella the fibres are thickly disposed and form the so called sphincter muscle. This is not a narrow band, as described by Prof. Allman, encircling the lower edge of the fold, but a local development of the transverse fibres, as broad as the fold itself (Fig. 8, E''').

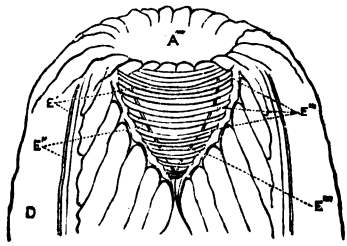

FIG. 8, Magnified view of the Invaginated fold of a living specimen of PLUMATELLA DIFFUSA.* A'''', cœnœcial orifice: D, ectocyst: E', first membrane of the endocyst: E'', second membrane of the endocyst: E''', third layer of transverse muscular fibre, constituting the Sphincter muscle. E'''', fourth or epithelial layer, accompanied by longitudinal muscular fibres.

In the evaginable endocyst this layer can be seen, by careful focussing, through the fourth membrane, but only with ease, when more or less contracted.

In the arms and lophophore it is thick, and frequently, in the former, becomes convoluted by the action of muscular bands apparently developed in its substance. I was unable to trace this membrane in the tentacles, but judging from the great thickness of the second tentacular membrane, and the slight increase which takes place in the transverse diameter of those organs when

*NOTE. Only three membranes are delineated in the cœnœcial endocyst of figure 8. This is owing to my want of success in defining the parts of the innermost layer, in the specimen figured, which is undoubtedly made up of two layers, as in the cœnœcium of Cristatella (Fig. 7, E''', E'''').

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drawn in, as they often are, to less than one third of their full length, I have ventured to assume that it also exists there (Pl. 11, fig. 1, E'''').

(4) The fourth or epithelial membrane, lines the interior, investing all the muscles and the digestive system. It is ciliated upon the perigastric region, and upon the interior of the arms and lophophore, but not in the tentacles or upon the alimentary canal. On the abdominal side, a double layer, or fold, of this membrane, which I have named the Brachial Collar, constitutes a partial diaphragm reaching about half way round the œsophagus. On the dorsal side it is disconnected from the lophophore, and hangs into the perigastric space, partitioning off the inside of the epistome, and a space below in which the ganglion is suspended. There are numerous fibres upon the inner side of this diaphragm attached to the œsophagus and endocyst, between the bases of the arms, having sufficient contractile power to deeply infold that part of the body wall.

Prof. Allman mentions but two membranes in the endocyst, one, an outer large celled layer, equivalent to my first and second membranes, and another, an inner layer, equivalent to my third and fourth membranes. Throughout its whole extent, the fourth or epithelial layer is lined by muscular fibres. These cross the transverse fibres of the third layer at right angles (fig. 4, E''''). and both were regarded by Prof. Allman as a single inner layer of reticulated muscles. The longitudinal fibres, however, are invariably next to the fourth membrane, and remain attached to it, whenever, as in the neural diaphragm, it parts from the other layers. The transverse fibres, also, never seem to be connected with the longitudinal, wherever a good definition of either has been obtained. No transverse fibres are visible on the neural diaphragm; and on the invaginated fold (Fig. 8), and the œsophagus (Pl. 11), no longitudinal fibres are visible.* In the two latter they are

*Note. Since the printing of the plates, I have, in reviewing these pages, changed my opinion and now estimate the longitudinal fibres, as of equal importance with the transverse, and consider them a fourth layer of muscular fibre, the epithelial becoming a fifth membranous lay-

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undoubtedly present, being occasionally seen in a direct view; but, when looked for in a lateral section, they are too diaphanous and closely adherent to the fourth membrane to be defined. Their incorporation with this membrane will also be justified by the description of its functions in connection with the alimentary canal of Pectinatella.

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er. The endocyst is consequently made up of three membranous and two muscular layers; all the specialized constricting muscles of the body being derived from the third layer, and all the longitudinal from the fourth layer of muscular fibre.

The inner and outer tentacular bands, as will be presently shown, are inseparable from the latter layer. The retractors, also, notwithstanding their disc like structure, can hardly be distinguished from the numerous abnormal bands, that occur in some species, connecting the endocyst and alimentary canal. These undoubtedly belong to the fourth layer, and the retractors may, therefore, be looked upon as having the same relation to the fourth layer that the sphincter has to the third.

The peculiar arrangement of the third and fourth layers retains the form of the parts, and gives stability to the entire endocyst. By the contraction of the third and relaxation of the fourth the transverse diameters of the parts may be decreased, and the longitudinal increased; or, by the opposite process, the longitudinal may be decreased, and the transverse increased. During the invagination of the polypide, the fibres of both are in a state of contraction in the evaginable endocyst and in the region of the sphincter; in the cœnœcium, however, they are relaxed. But as soon as evagination begins, they appear to reverse this condition. The cœnœcial fibres become contracted and those of the same layers in the polypide are stretched to their full length. By these reciprocal changes they materially assist the compressed fluids of the body in forcing out and expanding the polypide. I have, also, had reason to doubt the existence of a neural diaphragm. In examining a specimen of Fredericella regina from the side and from above, under very favorable circumstances, I was unable to detect the same appearance of an enveloping membrane just below the nerve mass, that led me to the conclusion mentioned; nor have I had any opportunity of verifying my first observations on Pectinatella, which, however, were faithfully made with one of Tolle's one half inch objectives. Until therefore, Fredericella is shown to be exceptional in this respect by further observations on other genera, it is, perhaps, best to regard the existence of a neural diaphragm as doubtful.

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Muscular System.

The specialized muscles are arranged in two ways, as circular bands, or longitudinal bundles. The Sphincter, and a new set which I have called the Brachial Contractors, are in the first series.

The sphincter is very broad in Fredericella and in some species of Plumatella, forming a cup shaped cavity by its contraction when the orifice is closed over the retracted polypide (Pl. 7, fig. 6, L, Pl. 8, figs. 2, 4, L). In Pectinatella and Cristatella the breadth of this muscle is much reduced, and the aperture is closed by the contraction of the edge of the orifice, no cup shaped cavity being formed (Pl. 9, figs. 12, 13, Pl. 13, figs. 5, 6, A''''').

The brachial contractors are a set of small muscles, ranged on both sides of the interior of the lophophore immediately below the junction of the bases of the tentacles (Pl. 12, fig. 2, L'), and thence they descend on the sides, like the supporting knees of a ship's deck, passing between the bases of the outer and inner tentacular bands. They act directly upon the floors of the arms, which are more or less drawn up into folds by them, and, when the ends of the arms are depressed, these folds become well marked, dividing the cavities by series of ridges rising nearly up to the lophophore.

The transverse bands of muscular fibre, which form the third layer of the endocyst, properly belong to this series also. This has been shown by the specimen of Plumatella vitrea figured on page 30.

The second series comprises all the larger muscles of the body.

The three sets of retractors, previously described,* are theinstruments by which the principal movements of the polypide are accomplished. These are distinguishable at an early age in the young, and have at all times the local distribution of the posterior attachments which led me to divide them into three sets. Three anterior attachments on either side are sometimes visible when the polypide is

*In general terms on p. 10.

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entirely retracted, but their distinctness is produced wholly by the extreme tension of the fibres. Under ordinary circumstances, the anterior attachments are not separable from each other and often single bundles seem to have distinct anterior bases. This is especially the case with the anterior branch of the gastric retractors in Pectinatella (Pl. 9,fig. 13, Pl. 10, fig. 1, M.) because of the great size and peculiar deflection of the alimentary canal from the direct line of action of the retractors.

Although this differentiation of the anterior branch of the gastric retractors may be occasionally seen in Fredericella, Plumatella and Cristatella it is not habitual, since the stomachs of the polypides in these genera, usually lie in the same, or nearly in the same plane with the retractors. When, however, complete invagination takes place and the stomach of the polypide shoots past the bases of the retractors, the anterior branch separates from the other retractors and assumes precisely the same aspect in these genera that it habitually has in Pectinatella.

The freedom of motion manifested by every minute bundle of fibres is the one great peculiarity of the larger bands. Each bundle has the faculty of acting separately in the gastric retractors, and though this independence is less noticeable in the other retractors, because of the closer association of the bundles, it is still appreciable.

In Plumatella diffusa a very singular conjunction of the retractors sometimes takes place. They are brought together on the abdominal side of the stomach, and held there as if bound by a narrow muscular band. The polypide when this conjunction occurs, is bent over towards the abdominal side, and the stomach displaced by the combined muscles.

Dumortier and Van Beneden* recognized the existence of isolated fibres attached to the endocyst at the base of the arms, and Prof. Allman† showed them to be of equal size and value with the internal branches (œsophagal re-

* DUMORTIER and VAN BENEDEN. Op. cit. t. 16, p. 86.

† ALLMAN. Op. cit.

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tractors) of the great retractors, although neither saw fit to give them different names.

The gastric retractors keep the stomach in its proper position in the axis of the tube (Pl. 7, fig. 4, Pl. 8, fig. 2, Pl. 9, figs. 12, 13, Pl. 14, fig. 1, M). While the polypide is evaginated these muscles move the digestive organs to correspond with the different positions of the lophophore, always maintaining them in the most favorable posture for the performance of their functions, and guarding against any abrupt curvatures that might otherwise occur during the movements of the polypide. It must be held in mind, also, that they are absolutely necessary in the majority of the Phylactolæmata which grow inverted upon the lower surfaces of logs, or other submerged objects. There is no provision whatever in the muscular organization of the alimentary canal enabling it to hold an upright position favorable for the performance of the peristaltic functions. The gastric retractors supply this deficiency, and, also, prevent the stomach when loaded with food, from bearing its whole weight upon the œsophagus and intestine. They, also, send off a few branches to the intestine, but these are rarely seen; and, although probably present in all the genera, I have observed them only in Fredericella and Cristatella (Pl. 7, fig. 4, Pl. 14, fig. 1).

The part played by the gastric retractors in disposing of the alimentary canal, varies in the different genera. In Fredericella, where the end of the stomach seldom passes the anterior terminations of these muscles, they continue the act of retraction; but, in Plumatella, they frequently relax again after the stomach reaches their bases, in order that it may pass still further into the cœnœcium. In Pectinatella, on the contrary, they do not relax when the invagination becomes more complete, but bind the end of the stomach down between the bases of the retractors. In Cristatella they relax again, as in Fredericella and Plumatella, permitting the stomach to pass in a dorsal direction some distance beyond their bases.

The lowest bundles, attached near the origin of the funiculus, were mistaken by Hancock, for reproductive or-

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gans; but they are undoubtedly muscular, as is shown in the figures referred to above. I found them, in all species attached to the stomach above the origin of the funiculus, and in every respect comparable with the other branches of the gastric retractors.

The œsophagal retractors, as regards their posterior fibres, can hardly be separated from the gastric retractors (Pl. 7, fig. 4, Pl. 8, fig. 2, Pl. 9, fig. 12, Pl. 10, fig. 1, Pl. 12, fig, 1, Pl. 14, fig. 1, M′). These filaments attached to the œsophagus, are, however, densely arranged, and whenever the three large muscles can be distinctly seen, as in the younger stages of growth, or in a retracted adult polypide, they invariably form part of the œsophagal retractors. They perform for the œsophagal canal the same office that the gastric retractors effect for the stomach; they hold that organ upright and unbent in its proper place. The mode in which they act is especially remarkable in Pectinatella, where they keep the posterior portion of the œsophagus from being suddenly deflected during the process of invagination, and thus protect the delicate membranes immediately around the mouth and nerve-mass from the strain to which they would otherwise be subjected (Pl. 9, fig. 13).

The filaments going to the lophophore diverge in fan-shaped attachments, reaching abdominally more than half way round the œsophagus, and extending more or less dorsally according to the generic rank of the individual, and the greater or less degree of evagination displayed by the evaginable tube.

The brachial retractors do not distribute any filaments to the alimentary canal in their passage from the cœnœcium to the brachial collar of the polypide (Pl. 7, fig. 4, Pl. 8, fig. 2, Pl. 9, figs. 12, 13, Pl. 10, fig. 1, Pl. 12, fig. 1, Pl. 14, fig. 1, M″) differing from both of the other pairs by having all the fibres attached to the endocyst in a uniform manner.

Besides being more especially concerned in producing the invagination of the polypide than any other muscles, these retractors determine the motions of the crest. They

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may incline the polypide to the right or left, by reciprocal contraction and expansion on the opposite sides of the body, or sway it towards the abdominal or dorsal sides.

In Fredericella, and the Plumatellidæ it is necessary for both the œsophagal and brachial retractors to act reciprocally in order to bring about the dorsal or abdominal flexures of the polypide; but in Pectinatella and Cristatella the brachial retractors are probably sufficient by themselves. The diffusion of the filaments of the brachial retractors is so great in these genera, that those on the abdominal or dorsal sides would have sufficient leverage and be fully competent to bend the polypide either forwards or backwards.

The muscles of the invaginated fold are in two sets. These have been previously described by Prof. Allman under the names of Posterior and Anterior Parieto-vaginal muscles; but, since I differ from him in the location of the poles of the body, I have thought it advisable to alter these names in order to avoid confusion. The first set or Anterior Retentors, equivalent to the posterior parieto-vaginals of Allman, consists of a single annular row attached to the lower edge of the invaginated fold (Pl. 7, figs. 4, 5, Pl. 8, figs. 2, 5, Pl. 9, fig. 12, Pl. 10, fig. 1, Pl. 13, fig. 5, Pl. 14, fig. 1, N).

The second set, or Posterior Retentors, equivalent to the anterior parieto-vaginal muscles of Allman, consists of smaller muscles attached to the side of the invaginated fold (Pl. 7, fig. 4, Pl. 8, figs. 2, 5, Pls. 10, 12, fig. 1, N′).

The latter are not, as has been hitherto supposed, irregularly disposed, but are arranged in rows, the bundles being placed alternately in each row. They assist the anterior retentors to retain the invaginated fold, and sustain the tentacular sheath in the centre of the cœnœcium, when the polypide is retracted. Deep external furrows are often caused in the cœnœcium by these posterior retractors, while the polypide is fully expanded (Pl. 8, fig. 5, N′). Similar folds were, also, noticed in the polypidal endocyst of Pectinatella occasioned by a few fibres, probably abnormal, which connected the œsophagus and oppo-

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site wall (Pl. 11, fig. 1, R). These were few in number, and were seen only in one specimen on the abdominal side.

There is a highly interesting series of muscles described by Dumortier and Van Beneden in the cœnœcium of Fredericella, called by them "Short Retractors," which resemble these. They are attached to the alimentary canal, and bear about the same relation to the stomach that the abnormal fibres of Pectinatella do to the œsophagus (Pl. 11, fig. 1, R). These reticulating fibres dispersed throughout the interior bear a certain likeness to the network of muscles in the cœnœcium of Cristatella. They differ materially, however, in having the posterior extremities attached to the alimentary canal instead of to the upper walls of the cœnœcium.

In the lophophore there is a pair of large muscles, one in each arm, which I have called the Lophophoric Flexors (Pl. 13, fig. 13, $\bar{M}$). They arise from the oral region, and proceed on either side to the extremities of the arms, buried in the substance of the lophophore, and bordered on their outer sides by the nerves. They elevate the tips of the arms, or bend them in an anterior direction.

The agency of a pair opposing the lophophoric flexors is recognizable every time the tips of the arms are bent anteriorly, but no bands of fibres were observed in the floor of the arms, which could have caused these movements. The lophophoric flexors have been described and figured by Dumortier and Van Beneden as a fascicle of the retractors.* This, however, I believe to be erroneous, since, in Pectinatella and Cristatella, the œsophagal retractors, although attached to the inside of the arms for some distance in advance of the mouth, do not mingle their fibres with, or approach those of the flexors in the centre of the arms, but terminate on the sides just below the bases of the tentacles.

By all other authors, who have seen them, they have been confounded with the lophophoric nerve-branches.

* Op. cit. p. 86. pl. 4.

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The peculiar elevation of the arms, however, indicates the presence of a muscle which can only be situated in the plane of the lophophore and attached at its two extremities respectively near the tips of the arms, and in the vicinity of the oral aperture. Just before entering the cœncecial cell they are thrown up posteriorly and after emerging therefrom frequently sustain this position for a considerable time, which would not be possible without the aid of strong muscles situated in the ceilings of the arms in a position similar to that ascribed to the lophophoric flexor. The great expansion of the bases of the flexors around the mouth and the coarseness of the fibres, also indicate a muscular rather than a nervous tissue. Finally I have been able to trace a continuous filament for some distance in the arms and on the outer borders of these bands, from which alone arise the nervous filaments, branching off to the bases of the tentacles.

Thus, although not so fortunate as to detect the intimate structure of their tissues, or to see them in action, I have but little doubt that the bands inclosed between the branches of the lophophoric nerve-trunks are muscular (Pl. 13, fig. 13, M).

The outer Tentacular Bands line the sides of the tentacles, two bands to every tentacle (Pl. 11, fig. 1, Pl. 12, fig. 2, Pl. 13, fig. 15, Pl. 14, fig. 1, O). Starting in pairs from the sides of the brachial contractors below the bases of the tentacles, they continue to within a short distance of their ends, and there spread out in fan shaped attachments. These attachments joining in each tentacle, when contracted, form an annular constriction, which gives a peculiar swollen, or club like aspect to the sensitive tips (Pl. 14, fig. 7). The fibres of the opposite bases on the sides of the brachial contractors also intermingle, and the spaces between, not being obscured by the fibres of these bands or the thickness of the contractors themselves, are much thinner and comparatively clear. Besides these there are inner Tentacular Bands consisting of numerous fibres descending from the inner sides of the tentacles, and running in parallel lines along the floor of the arms toward the per-

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igastric cavity (Pl. 11, fig. 1, Pl. 12, fig. 2, Pl. 13, fig. 15, O′). They divide near the bases of the arms into two broad bands, accompanying the clear tentacular spaces across the bend of the "horse-shoe" and around the œsophagus. The outer tentacular bands incline the tentacles outwards, or sidewise, the inner tentacular bands bend them towards the centre of the lophophore.

The epistome is provided with three interior muscles, a small central muscle on the side next to the mouth, and two larger ones on the opposite or dorsal side (Pl. 11, fig. 1, Pl. 13, fig. 14, P, P′). The former has its base close to the œsophagus, and is attached by the posterior extremity to the inner side of the border of the epistome on the median line, the base and attachment being quite broad and of about equal size. The two latter have their bases fixed to the lophophore close to the roots of the tentacles, thence they spread in fan shaped masses on either side, sending muscular bundles to nearly the whole of the inner surface of the border of the epistome. The single median muscle produces the ordinary jerking action of the epistome, and the two lateral muscles elevate it, or modify the outline of the border. These muscles are figured as one by Prof. Allman, probably owing to his having viewed them laterally, mistaking the two lateral bands for a single muscle, and overlooking the median band which in most lights is not visible from the side.

Nervous System.

Viewed from the dorsal side, the nerve mass of Fredericella is irregularly elliptical, or orbicular, and when expanded, lies flat against the œsophagus (Fig. 9). When contracted the anterior is drawn up in close proximity to the posterior end, giving the peculiar heart-shaped or rotund aspect, from the side, which has been previously described and figured by Dumortier and Van Beneden, and Prof. Allman in Fredericella sultana.* Hancock, how-

* Dumortier and Van Beneden. Op. cit. Nouv. Mem. Acad. de Bruxelles, Tom. 16. Complement pl. 3. Allman. Op. cit. pl. 9.

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ever, observed and figured it when expanded and having the peculiar spindle-shape represented below in Figs. 10 and 11. The contraction of the nerve-mass in Fredericella invariably takes place on the ventral side and towards the posterior end, and when in this state it is generally removed to some distance from the œsophagus. These movements of contraction and expansion occur very irregularly, and often when the former happens, the entire mass is drawn up into the cavity of the epistome. This generally precedes the invagination of the polypide in Plumatella, and the epistome, in all other genera, doubtless serves, while within the cœnœcial cell, to protect the nervous centres from compression by the surrounding membranes. During the confinement of the polypide in the cell, the epistome lies in the hollow formed by the overarching bases of the tentacles, and is admirably fitted to receive and guard them from injury. No muscles were detected in connection with the nerve-mass, which could have been instrumental in occasioning either the contractions or the subsequent elevation of this part into the cavity of the epistome.

Notwithstanding its mutability there is every reason for regarding this body as a true nerve-mass. The numerous branches from the sides, the angular junctions of these with the main body, and the evident solidity of the whole, leaves no doubt of its nervous nature. The principal nerves spring from the sides (Fig. 9), and are divisible into anterior and posterior sets according to their places of origin. The posterior set comprises the nerves distributing themselves to the epistome lophophore, tentacles and evaginable endocyst, and the anterior set those which go to the various parts of the alimentary canal. For convenience sake I have designated the larger branches and their smaller ramifications, respectively, by the names of nerve-trunks, and nerve-branches. The anterior set all arise from four large nerve-trunks near the posterior end of the nerve-mass, two on either side (Figs. 10, 11). Two of these, the branches of which are unknown, supply the epistome, and, perhaps, the oral portion of the œsophagus. They are trace-

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able to the base of the epistome, but are then lost to view in the thickness of the endocyst (Figs 10, 11, T′).

The remaining pair, the Lophophoric Nerve-trunks, are placed somewhat more to the dorsal side, but have confluent bases with the corresponding Epistomic Nerve-trunks. They divide into four branches, two on each side, one pair going obliquely and dorsally to the lophophore and the others in an anterior direction to the evaginable endocyst on the dorsal side (Figs. 9, 10, 11, T‴). The lophophoric branches separate squarely when they reach the lophophore into four smaller branches (Figs. 9, 10, 11, U). Two of these, the Oral Branches, pass abdominally, each one half way round the oral aperture throwing off filaments to the bases of the tentacles, and finally terminate in two tentacular filaments, which are lost at the junctions of the base of the central tentacle with the adjoining sides of the approximate tentacles (Pl. 15, fig. 1, U′). The remaining pair, the Brachial Branches, are much shorter, in consequence of the round outline of the lophophore. They traverse the lophophore in a dorsal direction giving off filaments to the few tentacles on that side, and terminate, also, in two tentacular filaments, at the junction of the median pair of tentacles behind the epistome.

The nervous filaments disappear at the junction of the bases of the tentacles, and cannot be traced into them, but each one probably splits into two branches which climb the approximate sides of every pair of tentacles, one branch on either side. On the dorsal side, however, where the basal junction of the central pair of tentacles comes directly upon the median line, this mode of distribution is violated. There are two filaments, respectively the ultimate nervules of the right and left brachial branches, which come together, and must be distributed at this single, median junction. They, however, do not appear to enter the cavity of the tentacles, but cross them to the opposite sides from which they came and distribute themselves to the approximate sides of the pair.

The anterior branch, or Polypidal Nerve-branch, strikes off abruptly from the main trunk (Figs. 9, 10, 11, T‴),

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and goes to the evaginable endocyst on the dorsal side. The range of individual variations in the principal branches may be estimated from figures 9, 10 and 11. They were taken from different zoöids on one colony of Fredericella regina collected at Gorham, Maine, figs. 9 and 10 being from the same zoöid. In fig. 11, the main lophophoric trunk divides close to its base, in figs. 9 and 10 the division is somewhat higher, in fig. 11, also, the lower part of the trunk is much more distinct from the epistomic nerve than in fig. 10, where they run together in one common base. The polypidal branch of fig. 9 entered the evaginable endocyst a very little above and to the left of the anal orifice, while that of fig. 10 entered the same part but a short distance from the lophophore.

FIG. 9. FIG. 10. FIG. 11. FIG. 12.

FIGS. 9 and 10, nerve-mass of FREDERICELLA REGINA from the same zoöid, viewed dorsally and laterally. FIG. 11, lateral view of nerve-mass from another zoöid of the same colony. FIG. 12, dorsal view of nerve-mass of PLUMATELLA DIFFUSA. T′, Epistomic nerve-trunk. T″, Brachial nerve-branch. T‴, Polypidal nerve-branch. T⁗, Œsophagal nerve-branch. T, Gastric nerve-branch. T, Intestinal nerve-branch. U, The Brachial and Oral branches of the Lophophoric nerve-branch.

The anterior set of nerve-branches are six in number, three on either side of the nerve-mass. Their bases sometimes coalesce in one main trunk on either side as in fig. 11, and they may then be very readily distinguished but frequently it is a matter of great difficulty to define even the œsophagal, which is the one most generally visible (figs. 9, 10, T⁗). I was unable to follow these branches further than to their points of contact with the alimentary canal, the œsophagal branch to the œsophagus, which it probably encompasses forming a true œsophagal collar, the central, or Gastric branch, to the upper part of the stomach, and the dorsal, or Intestinal-branch, to the intestine. They undoubtedly supply the walls of these organs with nervous filaments, but these were too minute to be definable among the more highly colored cells of the alimentary canal.

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The form of the nerve-mass of any of the remaining genera, in a direct view, differs greatly from that of Fredericella (Figs. 9, 12), instead of being elliptical it is elongated, and has a depression on the posterior side dividing the lateral or ganglionic centres of distribution from each other. This change is in great measure due to the different position of the mass. For instead of being upright and parallel to the œsophagus as in Fredericella the posterior end is rotated outwards until the whole becomes horizontal as in Pectinatella (Pl. 11, fig. 1, S'). During this rotation the epistomic nerve-trunk passes from the anterior to the posterior end along the side corresponding to the ventral side of the nerve-mass in Fredericella (Pl. 11, fig. 1, and figs. 10, 11, T'). The lophoric and the polypidal nerve-branches separate from each other forming four distinct, independent nerve-trunks, two from each lateral ganglion. The former may occupy any position upon the posterior sides of the ganglions from the dorsal end, which correspond to their position in Fredericella, to the neighborhood of the epistomic trunk, while the latter have an equal range on the anterior side. With the exception of the epistomic nerve-trunk there is, at least in the zoöids of Pectinatella magnifica, no regularity in the origin of the nerve-trunks within the limits above described, and, besides this, the character of the nerves themselves and the form of the nerve-mass may be greatly altered in different zoöids of the same stock. Thus in Pl. 11, figs. 1, 2, S', the two dextral ganglions are given from two different zoöids of the same colony which reverse each others outlines, the small ventral end of fig. 2, corresponding to the large ventral end of the ganglion in fig. 1, and the large dorsal end of the former to the small dorsal end of the latter.

The same figures also show the variability of the nerve-trunks. The epistomic nerve in one springs directly from the end of the ganglion, while in the other it rests on a raised pediment on the posterior side, and the lophophoric nerve-trunk in one comes from the posterior side of the ganglion and is made up of confluent nerves; in the oth-

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er it is one single trunk on the dorsal end. There is, in fact hardly any difference between the nerve masses of Plumatella and Pectinatella, taking any two individuals at random, one from each genus, which may not be equaled by selecting two zoöids from a single colony in any species. Although there are sometimes considerable differences between individuals of Pectinatella magnifica and those of Plumatella, I have yet to see a greater difference than may be found between different zoöids of the same species.

The same contractions and hoistings of the mass are as frequent in all the remaining genera of the suborder as in Fredericlla, the contraction invariably happening in the same manner and towards the posterior side, or side corresponding to the ventral side of the mass in Frederi-cella (Pl. 11, fig. 3). The nerves of the alimentary canal were not observed in any other genus than the last named, but it is probable, that in propitious lights they may be found somewhere on the anterior side between the lophophoric and epistomic nerve-trunks. The polypidal nerve-trunks of all the Hypocrepian genera are marked by the presence of one additional pair of nerve-branches, the Brachialr-banches. These part from the polypidal nerves and striking out laterally enter the endocyst either on the side, or close to the bases of the arms and undoubtedly supply them with nervous filaments (Pl. 11, fig. 1, T″).

The conditions of the brachial branches of the lophophoric nerve, are considerably altered in Plumatella, and its allies, to correspond with the extension of the arms and the larger number of tentacles to which they distribute filaments. Their length therefore is much greater, but otherwise they do not appear to have changed (Pl. 13, fig. 13, U). Prof. Allman supposes that the oral and brachial branches from the opposite sides of the lophophore join each other on the median line, thus forming a nervous collar about the mouth. I have, however, entirely failed both in Fredericella (Pl. 9, fig. 1), and in Cristatella (Pl. 13, fig. 13), to substantiate this opinion. Dumortier and Van Beneden figure nerves in the so called Alcy-

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onella fungosa,* which encircle the œsophagus, and seem to correspond in respect to location with the œsophagal nerve-branches of Fredericella.

Dumortier was the first to discover the nervous system and did his work more thoroughly than any succeeding investigator. He demonstrated the existence of two lateral ganglia in the nerve-mass of Lophopus crystallinus, and, although I have been unable to see these ganglia with the same distinctness with which they are represented in Dumortier's figures, I have been able to verify his observations in great measure by collateral evidence.

That there are two ganglia united by a commissure in all the Hypocrepia can hardly be doubtful. The equality in the number of the nerves on each side and their distribution, not irregularly from any portion of the mass, but from the two swollen lateral ends, show that these are two ganglionic centres. In Fredericella, however, the commissure appears to be wanting and further observations are necessary in order to prove that the nerve trunks are invariably derived from the sides of the mass. If this is the case, as it appears to be in Fredericella regina, we shall be obliged to regard the nerve-mass of this genus as composed of two large ganglia, united by a branchless commissure as large, if not larger, than the ganglia themselves. The size of the commissure, however, seems to be immaterial since I have frequently seen it in Plumatella, Pectinatella and Cristatella of the same thickness as the ganglia themselves (Pl. 12, fig. 1, S). It must also be remembered, in comparing the nerve-mass of Plumatella and Fredericella, that the depression shown in fig. 12, page 107, is on the side which corresponds to the ventral side of the mass in Fredericella and would be hidden from view in a dorsal view of the mass in the last named genus, even if it existed there.

Dumortier mentions a peculiarity of Lophopus, which indicates the existence of a colonial nervous system, such as

*Dumortier and Van Beneden. Op. cit. Pl. 4, fig. 5.

†Dumortier. Recherche sur les Polypes Comp. de l'eau douce, Bull. de l'Acad. Bruxelles, 1835, 2, p. 422.

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has been discovered by Fritz Müller in Seriolaria.* He remarked in fact the same phenomena in Lophopus crystallinus, which led Müller to begin his investigation; namely, that when the cœnœcium was touched all the polypides were alarmed, whereas, when a single polypide was disturbed it alone retracted.

I have examined with care all parts of the evaginable endocyst in other genera in order to find this colonial system, but without success. The only nerve-branch which might connect the nerve-mass with a general stalk would be the polypidal nerve-branch. This, however, appears to spread itself out on reaching the evaginable endocyst into a multitude of filaments too minute to be successfully followed.

The tentacles are the only tactile organs, and, as previously described, are the only means possessed by the polypides of receiving impressions from without.

The polypides are not sensitive to light. At ordinary temperatures even the darkness-loving Fredericella may be exposed for a time to the direct rays of the sun without any visible result, although but just removed from the perpetual shade in which it had previously lived. The loudest noises prove equally ineffectual; in a word, they remain fully expanded and confidently at ease until the water is agitated.

The epistome has been thought to be an organ of taste, and certainly, besides its position, it has a pliability which would seem to confirm such an opinion. The border is capable of a tactile motion similar to that of the human tongue, and it takes cognizance of what passes into the mouth by frequent and repeated jerks towards the aperture. Although used in closing the mouth in order to retain the food, I have never yet seen it prevent the entrance of anything. This duty, as previously explained, falls to the lot of the surrounding tentacles.

Digestive System.

The layers of the alimentary canal are the same in number and have very nearly the same character as those

*Fritz Müller. Das colonialnerven-system, Archiv für. Naturg. Bd.1, p. 311, 1860.

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of the endocyst. There is (1) an inner, large celled membrane (Pl. 11, fig. 1, J′); (2) one of smaller cells (Pl. 11, fig. 1, J″); (3) one of muscular fibre (Pl. 11, fig. 1, J‴); and (4) an epithelial layer lined with muscular fibre (Pl. 11, fig. 1, J⁗).

(1) The cells of the first membrane, like those of the first membrane of the endocyst, are large and resemble hexagonal prisms with rounded ends. They have not, however, the power of contracting and expanding individually, as in the first membrane of the evaginable endocyst, and the thickness of the membrane is greatly increased only when the cells are forced out in folds by the contraction of the walls. In the œsophagus they are of a yellowish color, owing, probably, to the elaboration within them of buccal secretions. In the stomach, this membrane is permanently plicated, and the cells upon these plications probably, in the absence of any specialized hepatic organ, subserve the functions of a liver. They contain a brown fluid described by Allman as an hepatic secretion, which is liberated when needed by the rupture of the walls of the cells.

The membrane between these folds being of clear yellow color, the stomach appears externally, as if striped with alternate longitudinal bands, of yellow and brown. It is of a light brown color in the intestine of all the genera, with the exception of Cristatella where it has a bluish tint.

(2) The second layer is made up of small cells, and retains about the same dense character throughout its whole extent. A definite line of demarcation was found above the funiculus, and this layer probably, does not enter in the composition of that organ which appears to be composed solely of the third and fourth layers.

(3) In the third layer the fibres or muscular cells are arranged transversely. A lateral view in section shows them, like flattened cubes, resting upon the second membrane. These transverse cells or fibres, compress the walls, producing the peristaltic movements of the œsophagus, stomach and intestine.

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Whenever any sudden contraction or expansion of the alimentary canal or the evaginable tube occurs, this membrane stands out distinctly, contracting and expanding evidently by the aid of its own muscles.

(4) The fourth, or epithelial layer envelopes the canal, as a whole, but is not adherent to the exterior. It passes in a straight line over the depression between the œsophagus and stomach, and is carried from the œsophagus to the intestine with but a slight anterior flexure (Pl. 10, fig. 1, Pl. 11, fig. 1). This adaptability of the fourth layer shows that it is accompanied by the same longitudinal muscular fibres which were observed to be associated with it in the endocyst of the polypide, and in the cœnœcium.

During the retraction of the polypide of Pectinatella the alimentary canal is bent upon itself towards the abdominal side, and the fourth layer contracts, so that when viewed laterally it appears in a straight line spanning the space between the lower portion of the œsophagus and the end of the stomach (Pl. 9, fig. 13, J''''').

Allman defines three layers in the stomach; (1) an internal layer of easily separable spherical cells, filled with colorless fluids, in which float secondary cells with yellowish brown contents; (2) a more compact layer of smaller simple cells with colorless contents and brilliant nuclei; and (3) a thin membrane of an undoubtedly cellular structure. Of this last he says, "Delicate circular striæ may generally be distinctly observed in it; they may be seen surrounding the stomach, and are probably muscular fibres; they become less distinct as we ascend towards the œsophagus, and totally disappear from this tube and from the rectum."

The same author describes but two œsophagal membranes, which he considers the equivalents of the middle and external layers of the stomach. Although greatly advancing our knowledge of the tissues, this experienced observer did not see the fourth membrane, and failed in tracing his first membrane, equivalent to my first two, in the œsophagus, where, according to the description given above, it is quite as distinct as in the stomach, differ-

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ing, however, in having cells with contents of a lighter color,

My observations with regard to the universality of the transverse striæ are confirmed by Hancock, who found them in both the stomach and œsophagus; whereas Allman, in the sentence just quoted, thinks that they are absent in the latter and in the walls of the intestine.

The digestive canal is simpler than in many of the lower polyzoa; it has neither the crop of Laguncula, or the cœcal appendages of Flustra, and is without special organs of secretion, except in so far as their places may be supplied by the cells of the first membrane.

The œsophagus is an open cylindrical cavity, invariably shorter and narrower than the stomach, the lower portion somewhat enlarged, the oral or upper part funnel shaped and ciliated (Pl. 7, fig. 5, Pl. 11, fig. 1, Pl. 12, fig. 1, K). The stomach may be typically considered as a single tubular cavity with an anterior flexure near the pyloric end, and the anterior side of this flexure prolonged into a gourd-like cœcum of great size and length (Pl. 7, fig. 5, Pl. 11, fig. 1, Pl. 12, fig. 1 K′).

The intestine varies more in form than either the œsophagus or stomach, but is universally broad below and tapering towards the anus (Pl. 7, fig. 5, Pl. 11, fig. 1, Pl. 12, fig. 1, K″).

Two valves intercept free communication between the gastric cavity, and the œsophagus, and intestine (Pl. 7, fig. 5, Pl. 11, fig. 1, Pl. 12, fig. 1, K‴, K⁗).

The first of these, the cardiac, or Œsophagal Valve, is a perforated coniform projection of the walls of the canal at the point of union between the œsophagus and stomach. The longer part being within the cavity of the stomach, and the apex directed anteriorly, it is usually sufficiently strong to prevent the regurgitation of the food. The second, the pyloric, or Intestinal Valve, has a similar structure, but is not so thick, and forms a flat partition between the two compartments.

The reception and elimination of nutritious material by this simple apparatus is among the most striking of the phenomena exhibited in the structure of these animals.

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The food is gathered in the funnel-shaped part of the œsophagus until the increase in bulk enables the transverse muscular fibre of the third membrane to act. It is thence carried rapidly into the stomach by a peristaltic motion of the walls, the dividing valve opening for its admission.

The peristaltic motions still continuing push it to the fundus of the cœcum, and then passing over it reverse the direction of the motions, sweeping the whole mass back again to the œsophagal valve. Thus the food is alternately rolled from one end of the stomach to the other, or, rather, from what may be homologically designated the centre of the anterior side to the œsophagal end. Occasionally when transported with extraordinary violence against the upper barrier the valve gives way, becoming inverted, and the food pours into the œsophagus. It never, however, reaches the mouth, being invariably and almost instantly restored to the stomach.

The momentary pause of the annular wave at the anterior end of the huge cœcum and the fading out of the longitudinal rugæ and deep brown color of the internal layer in this part, induced Prof. Allman to describe it as differing in structure and function from the rest of the stomach. The fundus of the cœcum, however, resembles in these features, except in so far as they are modified to accord with its rounded surface, the intestinal and œsophagal extremities. The pause of the "hour-glass constriction," momentarily separating this region of the cavity, is consequent upon the large size of the cavity, and the peristaltic motions of the walls. These following up the food jam it against the bottom and cause a globular distension, which the contractile energy of the muscles cannot overcome until the diameter of the swelling is lessened; and while this is being effected by the forced return of part of the contents through the neck of the hour-glass, the anterior motion of the wave is necessarily arrested and a delusive aspect of permanence given to the constriction, which it does not really possess. Similar globular distensions do not characterize the posterior region of the stomach, because of the smaller diameter of that part, and

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the weakness of the valve, which gives way before unusual pressure.

The eliminated nutriment transudes through the membranes of the stomach and intestine into the perigastric chamber, and there mingling with the circulating medium is conveyed by it to all parts of the body.

The residuum of the digested food is admitted gradually to the intestine through the intestinal valve, and assuming a more solid appearance, it is slowly discharged from the anus by the agency of the transverse parietal muscles.

These excrements are oval, and compounded of brownish colored refuse cemented by transparent gelatinous matter. They correspond in shape with the intestine, and have different forms according to the genus of the species, from which they are thrown off, being very much elongated in Fredericella, broader in proportion to the length in Plumatella, and very broad in Pectinatella, thus agreeing exactly with the gradual increase in the transverse diameter of the intestine from Fredericella to Pectinatella. In Cristatella they were not closely observed, but probably are more or less flattened in correspondence with the very flat intestine of that genus.

Circulation.

The interior of the polypide and cœnœcium is filled with a colorless fluid which is kept in circulation by the cilia on the epithelial membrane. They cover the entire surface of the endocyst, including the ceiling of the lophophore; but, as previously observed by Professor Allman, do not occur upon the alimentary canal. There are two principal currents maintained in each polypide by these cilia, one passes posteriorly along the dorsal side, enters the arms, and, being deflected upon itself at their extremities, courses along the ceiling of the lophophore, and returns to the cœnœcium along the ventral side. These currents can be readily observed by the aid of the numerous organisms, many of them probably parasitic, which float in the fluid, sometimes in such numbers as to interfere with the examination of the inter-

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nal structures. The intimate composition of the circulatory fluid is not accurately known, although supposed by Prof. Allman to consist mainly of water charged with the chyliferous exudations of the alimentary canal. This is the most reasonable view, though it is not known by what means the water enters the cœncecial cavity. Prof. Allman observed, that the cœncecium of Lophopus and Cristatella readily emptied themselves when taken out of water, and I have observed the same phenomenon in Plumatella vitra, which like Lophopus has a soft ectocyst.

The cœncecia of these species, when exposed for any length of time, shrink to an almost imperceptible film, but upon being again returned to the water they expand to their former dimensions. The dessication must have been occasioned by the flow of fluid through the pores of the cœncecial endocyst and the superincumbent ectocyst, since all the polypides were closely retracted. These facts show, that it is not necessary to look for an explanation of the admission of the water to any specialized orifices in the evaginable endocyst of polypide, but that in all probability the entire endocyst is pierced to a greater or less degree by aquiferous pores. These, however, in common with other observers who have sought for them, I have failed to detect.

Respiration.

Our knowledge of this function and of the organs by which it is performed is also very limited.

Beyond the very probable fact that the tentacles are the principal respiratory organ, but little is definitely known. The structure of the first membrane of the endocyst investing them, covered as it is with cilia, and the homological identity of these parts with the well-known respiratory fringes of the Brachiopoda and the respiratory sack of the Ascidia show them to have similar functions. The first membrane, however, also extends over the external surface of the entire colony, and, although devoid of cilia, probably aids in aerating the circulating medium, whenever it is uncovered by the ectocyst. The admission of water to the interior is another means for keeping the

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blood in a healthy state. It would be exceedingly interesting to determine precisely what part each of these plays in the aeration of the blood, but so far nothing has been done towards so desirable an end.

Homologies.

A Polyzoöid, reduced to its simplest form, is a closed sac, the walls bent inwards forming an annular fold dividing the neural or posterior region from the reproductive or anterior region. The posterior end bears the lophophore, a disk bordered by the tentacular organs of respiration and prehension, and perforated by a circular edentulous mouth, from which hangs the digestive system in the antero-posterior axis of the sac beneath. The alimentary canal has a simple, dorsal flexure, the anus opening on the dorsal side near the mouth.

Animal compound; nervous system compound, each zoöid furnished with two large dorsal ganglia; * principal muscles distributed in pairs on either side, attached posteriorly to the alimentary canal and lophophore, and anteriorly to the walls of the reproductive region; circulation unconfined by special vessels; reproduction takes place by buds and by the ova.

Many malacologists consider the Polyzoa more nearly related to the Ascidia than to the Brachiopoda. The class characters of the Brachiopoda, however, and the special homologies, which may be traced between the organs of a Brachiopod and those of a Polyzoöid, show closer affinities than exist between the last and an Ascidian. The higher Brachiopoda, such as Terebratula and Rhynconella, have the respiratory tentacles similarly situated around the disk, or lophophore, which is perforated at the centre by the mouth, and from which the alimentary canal hangs in the visceral sac beneath, the mouth and anus approximate, the canal having a dorsal flexure.

The extension of the lophophore into two or three spiriform arms, the complex structure of the tentacles and

* The existence of a complete nervous collar is doubtful.

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of the muscular and nervous systems are all more or less foreshadowed by the condition of these systems among the higher Polyzoa.

Hancock, in his admirable memoir on the structure of the Brachiopoda, has described with great clearness the different steps in the complication of the arms. Beginning with their simplest aspect in Fredericella, and tracing them to Plumatella, he shows, that, if the tentacles of the latter were approximated, forming a double line on one side, and the arms elongated and twisted spirally, they would be essentially like those of the spiral armed Brachiopods.* In the same memoir he also homologizes the retractor and opercular muscles of Paludicella with the adjustor muscles of the Brachiopod on account of their similar functions, and the parietal band of the former genus with the parietal muscles of Lingula.

Although I regard functional resemblances as having but little weight in determining homologies, especially where organs, as in the case of the muscles, necessarily change their special office with every change in the position of the bases of attachment, I, nevertheless, agree with Mr. Hancock in his homologies with the exception of the retractors. These, as I shall presently endeavor to show, are the homologues of the occlusor and divaricator muscles of the Brachiopod.

Huxley, in his comprehensive article on the Molluscan Archetype, compares an Avicularian with a Brachiopod, remarking the sameness in the position, proportions, and articulations of the valves, and of the divaricator and occlusor muscles in both. He also agrees with Mr. Hancock in regarding the arms of the Polyzoöid and Brachiopod as identical, but shows that they grow in opposite directions.† This opposition is better understood if we begin our comparison by imagining the Terebratula to be, as it really is, comparable with a permanently invaginated Polyzoöid, and endeavor to modify an invaginated Plumatella accordingly. For this purpose the lophophore of

* Hancock. Brachiopoda. Phil. Trans. 1858, also Ann. and Mag. Nat. Hist. 1850, p. 198.

† Huxley. Encyclopedia, Art. Mollusca.

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the Plumatella must be rotated anteriorly until it is parallel, as in the Brachiopoda, with the antero-posterior axis of the body; and this rotation must be towards the dorsal side, since upon this side lie the anus and the principal ganglia in both animals. After this operation is effected, there is no longer any room for the growth of the arms anteriorly, and they must extend, if developed at all, from the free posterior side of the disk.

The nearest approach to the Ascidian that can be attained by modifying, in a somewhat similar manner, the organization of a Polyzoöid, is very clearly exhibited by Prof. Allman in two imaginary sections taken respectively from a Clavellina and a Plumatella.* He has faithfully preserved the natural peculiarities of the Polyzoöid, and the comparison of these figures beautifully illustrates his homologies. Nevertheless, they do not appear to prove so close a resemblance as we have just shown to exist between the Terebratula and Plumatella. The arms, the single orifice, the tentacles, the lophophore, and the simple dorsal flexure of the alimentary canal, are necessarily retained in his diagram of the Plumatella. All of these are incompatible with the structure of the Ascidian, the general characters of the homologues of these parts in the latter being widely different. The flexure of the alimentary canal in the Ascidian is not simple but twisted on itself, the first flexure being towards the ventral instead of towards the dorsal side as among Polyzoa; and the only genus, Appendicularia, in which the canal has a simple flexure, as in Polyzoa, has the intestinal opening on the ventral instead of the dorsal side. The lophophore, fringed with tentacles and prolonged into brachial appendages, is also so obscurely represented, that it becomes difficult to trace out the homological parts. The construction of the sieve-like gill-sac of the Ascidian with its two orifices for the admission of pure water, and its emission mixed with the excrements, after passing through the meshes of the respiratory bars, could only be imitated in a diagram of a Polyzoön by radically altering the structure of the type.

* Allman, Op. cit.

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We are, also, obliged to abandon any comparison between the muscular systems, which, although so complicated and prominent in the polyzoön, is entirely wanting in the Ascidian.

No such radical differences occur in the Brachiopod. It is only necessary to shift the positions of the various organs and follow out to their consummation in the higher group the structural changes indicated in the prototypical Polyzoön. The arms, the lophophore, the tentacles, the muscles, the simple dorsal flexure of the alimentary canal are all present, and occupy about the same relative positions.

By means of his diagrams Prof. Allman proves, that the organs of the Plumatella, equivalent to those of Clavellina, are respectively as follows: the ectocyst to the external tunic, the endocyst to the internal tunic, the calyx to the investing membrane of the branchial sac, the tentacles to the transverse respiratory bars of the branchial sac, the epistome to the "languettes."

Besides the homologies already quoted from Hancock and Huxley, I may add that the ectocyst, and endocyst also, are found in the Brachiopod.

If a section of a Terebratula be made along the antero-posterior axis, and compared with a similar section of an invaginated Polyzoöid, the number of tunics are the same. The shell is identical with the ectocyst, and has besides the columnar structure of the columnar, calcareous ectocyst of Eschara, which is similarly perforated by minute follicles.*

The mantle proper lining the shell is the same as the endocyst, which carpets the interior of the ectocyst in Polyzoön, and the inner side of the mantle corresponds to the invaginated polypidal endocyst, or tentacular sheath,

* Milne Edwards. Ann. des Sciences Nat., vol. 6, 1836. The Ascidia, also, have similar processes, but these have afferent and efferent canals, and, as Dr. Carpenter in the Proc. Royal Soc., vol. 7, p. 36, 1854, has pointed out, they do not resemble them closely in structure. The cœcal tubes of Terebratula, according to Hancock (Op. cit.), are only prolongations of the outer membrane, whereas those of Eschara open into the visceral cavity; thus neither in Ascidia or in Brachiopoda are they closely alike, although probably homologous organs in both.

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the mouth of the shell being but an indefinitely widened cœnœcial orifice. The innermost membrane of the mantle surrounds the digestive organs of the Terebratula forming large blood sinuses on the œsophagus very much as it does in the cavity of Pectinatella, except that in the last no blood sinuses are defined.

The lophophore of Terebratula bends upwards at the base of the tentacles into a muscular ridge which incloses the mouth passing round it on the posterior side. This serves to convey the threads of food to the mouth, and would be the homologue of the epistome if it were properly situated.

The epistome of Plumatella is immediately over the ganglia and between the anus and mouth, whereas this fold, which so nearly resembles it in other respects, is on the opposite side of the mouth, and cannot, therefore, be its equivalent. It may be the homologue of the calyx, which has the same position with reference to the tentacles, and is, in like manner, a fold of the lophophore. Where there is such divergence in structure, however, the only conclusive facts are to be found in embryology, and until the solution of this difficulty is sought by the study of development, it will be difficult to determine, whether an organ corresponding to the calyx exists or not among the Brachiopoda.

The muscles of the Terebratulæ are in three sets, the occlusors, the divaricators, and the adjustors.* These sets are placed with reference to the alimentary canal and to each other as follows: the occlusors next to the canal, the divaricators intermediate, and the adjustors outside. These are their normal positions within the visceral cavity as determined by their bases of attachment. The ventral (dorsal) bases of the lower pair of adjustors are inside of the ventral bases of the occlusors; but this is not their normal condition, since the dorsal or corresponding pair of adjustors on the dorsal (ventral) side, the pedicle ends in all the allied genera, and the whole length of the ventral pair in Waldheimia australis

*Hancock, Op. cit.

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and Rhynchonella psittacea may be looked upon as relatively outside of the divaricators.

The similarity between these three sets and the retractors and retentors of a Plumatella may be readily shown, if we bear in mind that the invaginated specimen compared on page 151 with a Brachiopod was rotated towards the dorsal side. If we suppose that only the muscles attached to the lophophore, the retractors, partook of its rotation, it is evident, that the posterior lophophoric extremities of the retractors became dorsal, and the anterior ventral, while the retentors were left comparatively unchanged, running in the direction of the antero-posterior axis.

The occlusors of Terebratula are in two distinct pairs on the ventral side, but each lateral pair blends into one stock and inclines inwards as it passes dorsally, and they have the alimentary canal between them. The gastric and œsophagal retractors of Plumatella make up two distinct pairs more or less intimately connected throughout, but widely separated at the anterior end, and inclining towards each other as they pass posteriorly; they also have the alimentary canal between them.

The divaricators of Terebratula are an independent pair next to the occlusors, spread out, however, in allied forms into two pairs on the dorsal side.

The brachial retractors of Plumatella are also an independent pair, spread out into numerous fibres at the posterior end, and closely gathered together below, and are next to the œsophageal.

The adjustors are in four pairs, arranged in nearly parallel bands outside of all the other muscles, and run towards the posterior end.

The retentors of Plumatella are arranged in nearly parallel bands, but are not separated into pairs because the cœnœcial orifice is not widened laterally, and, therefore, does not divide them into a dorsal and ventral set as in Terebratula. They are also outside of all the other muscles, and run towards the posterior end.

Mr. Hancock, as previously remarked,* also homolo-

*Hancock, Ann. and Mag. Nat. Hist., 1850.

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gizes the parietal muscles of Paludicella with the parietal muscles of Lingula.

The parietal muscles of the former genus are merely local developments of the transverse muscular fibres of the third layer similar to the less prominent bands occasioning the annular folds in the cœnœcium of Plumatella (Pl. 8, fig. 10). Mr. Hancock, although he has pointed out the identity of the adjustors of the Brachiopod with the so-called opercular muscles (retentors) of Bowerbankia and Paludicella, denies the existence of the opercular muscles in Fredericella. He describes and figures the retentors, but does not consider them, although similarly situated in the neighborhood of the orifice, to be the equivalents of the opercular muscles of Bowerbankia and Paludicella on account of their great functional divergence. I have failed to find any great functional divergence between the muscles of the orifice in Paludicella and Fredericella. The only difference between them appears to be, that in Paludicella they are fewer in number and retain two folds of the endocyst from complete evagination instead of one, and in Bowerbankia they do not retain any fold, only becoming active when the polypide is invaginated. They perform nearly about the same function in all these genera, the invagination of the lower part of the evaginable endocyst, the differences are those of degree only.

Facts of position, being always of determinate value, are more reliable than functional resemblances, however close they may be; for although the latter often afford a clue to the true homology, they furnish, in the present state of our knowledge, but a very precarious means for estimating the degree of similarity between the parts of different animals. Functionally, for example, the muscles of an Avicularian are as widely separable from those of the normal forms on the same stock, as the occlusors and divaricators of the Brachiopod from the retractors of the Polyzoöid. They open and close the valv se of a shell instead of retracting a polypide. Such an extravagant divergence between identical organs in two zoöids of the same compound form is decisive against the adop-

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SYNOPTICAL TABLE.

		FREDERICELLIDÆ.	PLUMATELLIDÆ.			CRISTATELLIDÆ
		FREDERICELLA.	PLUMATELLA.	LOPHOPUS.	PECTINATELLA.	CRISTATELLA.
Cœnœcial, or Reproductive Region.	Cœnœcium,	single or radiatory,	single or radiatory,	radiatory,	radiatory,	radiatory.
		adherent,	adherent,	adherent,	adherent,	free and locomotive.
		natural position horizontal or erect,	natural position horizontal and erect,	erect,	horizontal,	horizontal.
		branching,	branching,	branching,	branching,	. . . . .
	Cœnœcial Branches,	diffuse or adherent,	diffuse or adherent,	. . . . .	. . . . .	. . . . .
		tubular,	tubular or lobiform,	lobate,	lobate,	. . . . .
		perfectly formed,	perfect, or beginning to be consolidated in the cœnœcial trunk,	more of their length lost in the cœnœcial trunk,	yet more of their length lost in the cœnœcial trunk,	wholly lost or merged in the cœnœcial trunk.
		distinct,	distinct or adherent,	. . . . .	. . . . .	. . . . .
	Cœnœcial Cells,	walls entire,	walls entire or partially obliterated,	large portion of the walls obliterated,	walls obliterated,	. . . . .
		irregularly divided by permanent, internal folds,	permanently divided by internal folds,	folds coalesce and multiply colonies,	folds coalesce and multiply colonies,	folds coalesce and multiply colonies.
	Ectocyst,	thin,	thin or thick,	very thick,	still thicker,	thin again.
		pergameneous or gelatinous,	pergameneous or gelatinous,	gelatinous,	gelatinous,	gelatinous.
		brown or colorless,	brown or colorless,	colorless,	colorless,	colorless.
		permanent during the life of the colony,	permanent during the life of the colony,	permanent during the life of the colony,	diminishes to a thin sheet in the old,	becomes a transient excretion.
		envelopes the entire cœnœcium,	envelopes the entire cœnœcium,	envelopes the entire cœnœcium,	found only on the underside,	found only on the underside.
	Cœnœcial Endocyst,	cells of the first layer small, depressed,	cells of the first layer small, depressed,	?	large and prominent,	large and more prominent.
		cells of the second layer fully developed,	cells of the second layer fully developed,	cells of the second layer fully developed,	cells of the second layer fully developed,	cells of the second layer fully developed.
		3d and 4th layers adhere to the 2d membrane throughout,	3d and 4th layers adhere to the 2d membrane throughout,	3d and 4th layers adhere to the 2d membrane throughout,	3d and 4th layers adhere to the 2d membrane throughout,	these layers bend inwards and form the reticulated walls.
		fifth membrane adheres to the muscular layers throughout,	fifth membrane adheres to the muscular layers throughout,	fifth membrane adheres to the muscular layers throughout,	fifth membrane adheres to the muscular layers throughout,	fifth membrane adheres to the muscular layers throughout.
	Funiculus,	fully developed,	fully developed,	fully developed,	fully developed,	fully developed.
	Statoblasts,	fixed and free,	fixed and free,	fixed and free,	only the free forms,	fixed and free.
	Fixed Statoblasts,	bean-shaped and elliptical,	bean-shaped and elliptical.	elliptical,	. . . . .	elliptical.
	Free Statoblasts,	bean-shaped, depressed or elongated ellipses,	bean-shaped, depressed or elongated ellipses,	elliptical (depressed ellipses ?),	depressed or elongated ellipses,	orbicular.
		. . . . .	annulated,	annulated,	annulated,	annulated.
		breadth .166 m m to .299,	breadth .199 m m to .383,	?	breadth .8 m m to 1,	diameter .8 m m to .833.
		length .316 m m to .5,	length .266 m m to .566,	?	length .866 m m to 1,	
	Annulus,	. . . . .	straight or slightly bent at the ends,	decidedly bent at the ends,	bent at the ends,	straight.
		. . . . .	straight on the sides,	straight on the sides,	bent on the sides,	straight.
		. . . . .	round at the ends,	pointed at the ends,	rounded at the ends,	round.
	Spines,	. . . . .	. . . . .	. . . . .	one row,	two rows.
		. . . . .	. . . . .	. . . . .	grow through annulus,	external.
		. . . . .	. . . . .	. . . . .	arise from statoblast,	arise from statoblast.
		[illegible] fully de-	membranes fully de-	membranes fully de-	membranes fully de-	membranes fully de-

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tion of similarity in function as a criterion for the decision of homologies.

The development of the Ascidia has been deemed closely analogous to the development of the Polyzoa, and the separation of the walls of the branchial cavity from those of the surrounding thoracic chamber in Ascidia has been compared by Prof. Allman with the growth of the lophophore in Polyzoa.

The recent investigations of Fritz Müller show, that at one period of its life the Brachiopod has four arms or tentacles arranged in a radiatory manner about the mouth. These parts are borne upon a retractile proboscis, which has some resemblance to the evaginable tube of a Polyzoön.*

His researches, however, did not extend to the earliest periods of growth, and it remains to be seen how far these resemblances are matters of affinity or analogy, and to what degree the young of the Brachiopod really repeats the peculiarities of the adult Polyzoöid.

EXPLANATION OF TABLE.

The three systems, as they are presented in the synopsis, may be read in two ways, either with regard to the mutual connection of organs in the individual, or with regard to their serial relations in the group. Thus by reading from the top to the bottom of any one column, a view of the structure both of the genus and of the individual is obtainable, the organs being described in regular order, according to their place in the body, from the anterior to the posterior pole. Or, by reading from left to right in the usual manner, an organ or a system may be traced through its entire series of changes in the different genera, until we reach Cristatella.

This table was made at the commencement of my investigations, with no intention of publishing it until a

*Fritz Müller, Archiv. für Anat. Reichart et Du Bois Raymond, p. 72, 1860.

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very full list of species had been consulted; but the results so much surpassed my anticipations, that I have given it now, hoping the logical sequence of the whole, rather than the perfection of the details, would justify its introduction in this place.

The genus Lophopus is omitted with the exception of the "Cœnœcial Characters," which are quoted from various European authors, every effort on my part to find or obtain a single specimen having been unsuccessful. Nevertheless, the Pectinatella on one side, and the Plumatella on the other, show very plainly that it must have an intermediate character with regard to the polypide and the parts omitted. The following pages are intended as an explanation of the characteristics noted in the table, and should be read in connection with it.

CŒNŒCIAL SYSTEM.

CŒNŒCIUM.

Single or radiatory. The young colony of any one species of Fredericella may have (1) two or more polypides growing in opposite directions and simultaneously branching, or (2) they may spring from one polypide alone. (1) In this way a colony arises growing equally from the centre, with at least two compound branches, the polypides turning the open side of the lophophoric crescent toward the centre, and is truly radiatory. (2) By the last method, however, only one compound branch is formed, and the colony is one-sided or single. Fredericella Walcotii has, perhaps, fewer radiatory colonies than any other species of that genus, Fredericella Pulcherrima and Fredericella regina being very generally radiatory. There are, nevertheless, many single colonies in both of the last-named species, but they are not so frequently met with as the truly radiatory cœnœcia.

The single colonies mingle more or less with the radiatory in all four of the American Plumatellæ. The first are most numerous and constant in variety a of Plumatella vitrea.

All the figures of Lophopus crystallinus are radiatory,

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but it cannot be said with certainty, that all the individuals of the species are the same, since no direct observations have been made upon this character. Perfect radiation is essential to the structure of Pectinatella and Cristatella. The internal divisions, and the regular outlines of the cœnœcia give a more decided radiation to the colonies of Pectinatella and Cristatella than to those of preceding genera.

This more perfectly radiatory arrangement is directly traceable to the larger number of buds developed from the original cell, since instead of one or two buds as in Fredericella, there are five or more which spring from the walls of the primary cells in Pectinatella, and in Cristatella probably even a larger number. This radiatory character, therefore, which distinguishes individual varieties in Fredericella and Plumatella, is of generic value in Pectinatella and Cristatella.

Adherent. The hardness of the ectocyst determines the tenacity with which the branches cling to surfaces. The brown, horny ectocyst of the Fredericellæ anchor them very firmly; but there are some transparent colonies in this genus, and these are not so strongly fastened; in Fredericella pulcherrima the latter are quite numerous. Among the Plumatellæ there are more or less of the transparent colonies in every variety, and Plumatella vesicularis and P. vitrea have, in all cases, transparent ectocysts.

According to Prof. Allman, the gelatinous ectocyst of Lophopus is easily detached, and the ectocysts of Pectinatella or Cristatella are by no means as tenacious of their hold upon the surface as the ordinary brown ectocyst of the Plumatellæ. The hardness of the ectocyst, also, determines the tenacity with which it and the endocyst cling together. In Pectinatella the endocyst readily separates from the gelatinous base, and Cristatella moves freely upon the surface of its own ectocyst. The ectocyst and endocyst of variety c of Plumatella vitrea invariably separate when treated with alcohol. In the brown varieties of Fredericella and Plumatella such a rupture is much more difficult to accomplish.

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Thus the adherence of the endocyst to the ectocyst, and the adherence of the latter to the surface, both depend upon the gelatinous nature of the ectocyst, which, as we have just seen, is characteristic of varieties in Fredericella of some species in Plumatella, and of the genus in Pectinatella and Cristatella.

Natural position erect or horizontal. The single colonies in any species of Fredericella are as apt to have free and erect branches, as to have them wholly attached and horizontal. The free branches, however, are rarely seen in Plumatella arethusa, and I have not observed them in P. diffusa, vesicularis, and vitrea, though it is quite probable that they may be found more or less in the brown variety of P. diffusa. They are also, doubtless, found in P. nitida, which is a luxuriant growth.

Lophopus, both in this country and in Europe, is erect. Pectinatella and Cristatella are invariably horizontal. The position of the branches is therefore of generic value in the last three genera, and of variable value in Fredericella and Plumatella.

Branching. I have not yet found an adult colony without branches either in Fredericella or Plumatella. There are, however, very few branches on the colonies of variety b of Plumatella vitrea.

Although the number of branches and branchlets in the two lower genera are often less, they are, in the majority of the full-grown individuals, more numerous, amounting in some specimens of P. Arethusa, P. diffusa, and P. vesicularis to over fifty; and in variety c, of Fredericella Regina and P. Arethusa, they probably reach hundreds.

The lobes of Pectinatella rarely exceed ten, with about two or three branchlets to each, making in all thirty branches large and small.

The indefinite multiplication of the branches in Pectinatella is prevented by the frequency of self-division, which limits the size of the colonies, while greatly increasing their number. In Cristatella this characteristic disappears.

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CŒNŒCIAL BRANCHES.

Diffuse or adherent. Variety *b*, of Fredericella Walcottii, has its branches closer together than variety *a* of the same species; but the only specimens yet described, either in this country or in Europe, that have crowded branches, are those belonging to variety *c* of Fredericella regina.

Among these, a branch may occasionally become adherent for a short space. This, however, rarely occurs, and seems to be wholly accidental. The diffusion of the branches is the ordinary character of Plumatella, but in four of the five American species, the crowded Alcyonelloid variety is developed more or less, according to the locality in which the species lives. I have been unable to determine whether the crowding of the branches takes place by the direct action of physical causes or not. In some cases the area of attachment would seem to be the only assignable cause, as in P. vesicularis, where the tip of a branch assumes the Alcyonelloid character by being crowded upon the edge of a projecting branch,* but the same variety in P. vitrea grows upon the smooth surface of a piece of tin. In P. Arethusa and F. regina, found in Tommy's Brook, near Gorham, Me., the current seemed to be in some way connected with the production of the Alcyonelloid variety; but the same varieties of the three other species of this genus developed profusely in the brackish and still water of Mystic Pond; upon broad surfaces of attachment in the still fresh water of Spy Pond, and in a small artificial lake on Mr. John Hopkins' estate near Baltimore. In fact, there is no uniformity in their mode of occurrence, the same form often appearing under the most diverse circumstances. The quantity of food may possibly influence their growth, though with regard to this I have collected no reliable data. Evidence with regard to this may, perhaps, be gathered from the ectocysts of the different species by comparing the diatoms which are left sticking to their exterior, and the contents of the water in which they live, with the contents of their stomachs.

* See description of species.

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As will be seen in the descriptions of the species, although the same varieties occur in different localities, and under diverse physical conditions, still the specimens even of different species in each locality usually have a similar character. The adhesion of the branches is owing entirely to the juxtaposition of young cells, whose softer ectocysts adhere to one another, and it is therefore a characteristic which may occur in any species when the young cells are accidentally brought in contact.

Tubular. All the Fredericellæ have tubular branches, the zoöids being arranged in a single series.

In Plumatella Arethusa the tubular characteristic is retained even in variety *b*. In variety *b* of P. diffusa, however, the branches coalesce to a considerable extent; and in varieties *b* and *c* of P. vitrea, either single branches or whole colonies may have the polypides in bunches, approximating to the mode of growth exhibited by Pectinatella. The branches of Lophopus are true lobes containing a fascicle of polypides at the end of each branch, and those of Pectinatella are also lobes, but with the polypides placed in long, double rows on the upper sides. This lobation, therefore, arises as a characteristic of the varieties or even as a peculiarity of one branch of a colony, as in P. vesicularis,* and becomes of generic value in Lophopus, Pectinatella, and Cristatella, entirely superseding the tubular form of the branches in Fredericella, P. Arethusa, and the varieties of the remaining American species.

CŒNŒCIAL CELLS.

Distinct. In Fredericella the cells are distinct from each other; occasionally by some accident, as previously mentioned, a branch may become adherent to a neighboring branch, but the cells never appear to do so. The cells of the Plumatellæ are adherent in all their Alcyonelloid varieties.

Cell-walls entire. Wherever the cells are distinct, the cell-walls must be entire. When, however, the former be

* See description of species.

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come adherent, the attached portion of the cell is shortened, and consequently the walls of the free portions of the cells approximate. In some specimens of variety *b*, Plumatella Arethusa, this approximation takes place without any sensible diminution of the lower portion of the free part of the cell-walls; but in variety *b* of P. diffusa, and in the single branches of P. vesicularis, previously mentioned, there is a very decided shortening of these walls, and in P. vitrea only the orifices project above the branch in some groups, while in others the free portions of the cells are quite long. In Lophopus the cells have similar characters, the whole lower portion of the dividing walls becoming part of the common surface of the lobe, and in Pectinatella and Cristatella the cells are entirely obliterated, the dividing walls having disappeared. Thus the entireness of the cell-walls is a diminishing characteristic of generic value in Fredericella, of specific and variable value in Plumatella, disappearing in Lophopus and Pectinatella. The only reasonable cause for this gradual obliteration of the cell is to be found in the agent which crowds the branches and cells together, making them adherent, which produces the lobes of Lophopus, and consolidates them with the cœnœcial trunk in Cristatella, and which also completes the radiatory arrangement of the polypides, namely, the increasing activity of the reproductive function, as shown in the greater number of buds produced from the mother cell. The cœnœcial trunk of Fredericella and Plumatella is made by the growth of the primary polypides. When several buds develop simultaneously, this cœnœcial trunk is broadened and becomes a common cavity containing the various polypides, as in variety *b* of Plumatella vitrea.

A farther development of the flabellate growth gives the palmate aspect of the branches in Lophopus. A greater increase in the number of buds growing from the mother cell gives, as has been said in the article on reproduction, the radiatory character of Pectinatella, and also broadens the cœnœcial trunk at the expense of the branches, which become short lobes.

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Finally, so many buds are produced simultaneously, that they crowd themselves together in quincunx order, instead of forming distinct radiatory branches, as they would do if developed singly or in pairs at intervals, the whole being a greatly distended primary cell or cœnœcial trunk. This view is sustained by the occurrence of the buds upon the border in the same place, with relation to the polypides of Cristatella, that they occupy in the single cells of Fredericella and Plumatella, and in the lobes of Pectinatella.

Irregularly divided by permanent internal folds of the endocyst. These folds are present more or less in nearly every colony of Fredericella and most of the diffusely branching Plumatellæ, but not in the Alcyonelloid varieties. I suspect, however, that variety *b* of Plumatella vitrea, has them. If so, they probably act as in Lophopus, and isolate the branch in which they occur.

The peculiar aspect of the constrictions in Plumatella, bending inwards from the stiff ectocyst and apparently prevented from coming together by its unyielding nature, their accidental occurrence in any part of the branch, and their being simply an annular constriction of the endocyst, all go to prove, as has been shown in the article on reproduction, that they are the homologues of the constrictions that divide and multiply the cœnœcia in Pectinatella and Cristatella.

ECTOCYST.

Thin. The Fredericellæ all have thin ectocysts. There is a variety of Fredericella Regina, and one species, F. pulcherrima, which have colorless ectocysts, but these are not thicker than the horny coverings of the other varieties.

The Plumatellæ have thin ectocysts, except in P. vitrea. In this they are somewhat thicker than in other species. In Lophopus it is very thick below, indicating the final withdrawal of the whole under the cœnœcium in Pectinatella. Its immense thickness, in the last genus, is directly caused by the surface of attachment

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and the activity of the fissiparous function of the cœnœcium. Even upon a level surface the continued multiplication of the cœnœcia, in course of time, crowds them together and presses the central colonies gradually upward, forcing them to excrete more gelatine, and thus the central portion of the general ectocyst becomes the thickest.

Thus the thickness of the ectocyst is not a regularly progressive character, and the fluctuation appears to be caused by the peculiarity of the base of the attachment, and the multiplication of cœnœcia by self-division in Pectinatella.

Parchment-like or gelatinous. This is the condition of the ectocyst in all the Fredericellæ, even the colorless varieties are tougher than the colorless varieties of Plumatella. The Alcyonnelloid varieties of Plumatella are more generally surrounded by a gelatinous ectocyst than the diffuse varieties.

Brown, or colorless. These characters accompany the preceding, the parchment-like being always brown, and the gelatinous always transparent.

Permanent throughout life. The parchment-like ectocysts of Fredericella long survive the decay of the polypides, but the gelatinous disappear soon after their decease. The same rule obtains until we reach Pectinatella. In this genus, the thickness of the mass causes it to commence decaying before the colonies die, and they often are found loosely scattered on the surface after it has decayed to a thin sheet. This gives to an old settlement of the Pectinatellæ a Cristatellian-like aspect, since in the latter the ectocyst is thin.

The old colonies of Pectinatella, however, do not lose the power of excreting gelatine, but readily refasten themselves after being detached. The loss of permanency in the ectocyst of Pectinatella is fittingly followed by its appearance in Cristatella as a transient excretion.

Envelopes the entire cœnœcium. This character has been treated of in mentioning the cause of the natural position of the cœnœcium. It is strictly decremental,

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since, as previously noticed, Lophopus forms an intermediate step to its passage under the cœncecium in Pectinatella.

CŒNŒCIAL ENDOCYST.

Cells of the first membrane small and depressed. This character, and its subsequent change to the larger cells of Pectinatella and Cristatella, was described in the article on the "Composition of the Body." It is due, perhaps, to the removal of the pressure of the superincumbent ectocyst from the upper side of the cœncecium.

Cells of the second membrane small. This character, which appears to be invariable, may possibly owe its equability in the size of the cells to the equal pressure of the other membranes on either side.

The remaining characters need no explanation until we reach

FREE STATOBLASTS.

Bean-shaped, depressed, or elongated ellipses. The variability of the statoblast, as will be seen in the description of the species, becomes less in Plumatella, and is of fixed value in Pectinatella.

The depressed elliptical forms are in reality orbicular forms, or are those varieties which assume a close approximation to the outline finally taken by all the free statoblasts of Cristatella.

Thus it may be said of the three forms which begin as varieties in Fredericella, of which the bean-shaped is perhaps the most common, that they all successively culminate in some one genus, and then die out. Thus the bean-shaped disappears in Plumatella, the elliptical takes its place in the latter and in Pectinatella, and the orbicular form, which only holds a place in the varieties of the different species of the preceding genera, at length predominates and is characteristic of the genus in Cristatella.

RECAPITULATION OF THE CŒNŒCIAL SYSTEM.

The synopsis itself sufficiently explains the remaining characters of this system, and we may, therefore, proceed

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without fear of misunderstanding to the consideration of its general features. There are six characters; (1) single character of the cœnœcium, (2) a character in the diffusion of the branches, (3) a character in the tubularity of the branches, (4) a character in the perfection of the branches, (5) a character in the distinctness of the cells, and (6) a character in the entireness of the walls of the cells, all of which are decremental, the decrement being traceable directly to the activity of the reproductive function, which increases, (1) the radiatory character of the cœnœcia, (2) the crowding and adherence of the branches, (3) the lobiform character of the branches, (4) the consolidation of the branches with the cœnœcial trunk, (5) the adherence of the cells to each other, and (6) the merging of the cell-walls into the common surface of the branch. All of the latter are respectively antagonistic to the former, and although produced by the same agent, and occurring primarily either upon different branches of the same colony, different varieties of the same species or different species of the same genus, finally become of generic value,* exclude the former, and change the whole aspect of the cœnœcium in Cristatella.

Secondly, there is a series of characters; (1) a character of adherence of the ectocyst to surfaces, and of the endocyst to the ectocyst, (2) the parchment-like character of the ectocyst, (3) its permanency throughout life, all of which decrease as the ectocyst becomes more gelatinous and retrogrades from a protective covering to a transient excretion. Thirdly, there is a series, (1) the erectness of the free branches, (2) the envelopment of the cœnœcium, (3) the small size and depressed form of the cells of the outer membrane, all characteristics which disappear when the ectocyst retires from the upper side of the cœnœcium. Fourthly, (1) the number of branches in a single colony, a decremental character, (2) the permanency of

* By "generic value" it is not meant that a variety may become a species, or a species a genus by evolution, but that characteristics apparently of accidental growth in the distortion of a branch, or in the variety of a species, may finally become peculiar to some species, and then an essential characteristic of a higher genus.

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the annular folds, a decremental character, (3) the thickness of the ectocyst, a fluctuating character. The decrement of the first two and the fluctuation of the last being due to the increasing functional activity of the third membrane in forming annular folds, which is apparently due to the same character as the second series, namely, the increase in the gelatinous nature of the ectocyst.

EVAGINATORY SYSTEM.

ALIMENTARY CANAL.

Membranes fully developed. The invariability of the cellular structure of the membranes of the canal is, probably, as in the case of the evaginable endocyst, due to the similarity of the circumstances and positions occupied by them with relation to the surrounding parts and fluids.

Lies straight in the cœnœcium when invaginated. The cells in Fredericella and Plumatella are not generally of sufficient capacity to admit of any doubling on the part of the alimentary canal, and, since there is room enough for it to lie straight, it naturally assumes that position.

The location, also, of the bases of the retractors are at such a distance from the orifice of the cell, that it is out of the question for the gastric retractors to act in such a manner as to double the alimentary canal on itself.

In variety *b* of Plumatella vitrea, however, the bases of the muscles are nearly opposite the cœnœcial orifice, and it would be inferred, from the similarity of their positions to those in Pectinatella, that the canal must double upon itself when undergoing retraction; but, although the lophophore is very closely withdrawn, the canal floats freely in the chamber (Pl. 9, fig. 1). The position of Pectinatella, as figured in Pl. 9, figs. 12, 13, shows that the canal is not only bent ventrally, but when completely drawn in, the anterior end of the cœcum lies between the trunks of the retractors. In Cristatella this tendency is expressed more strongly, the canal, passing between the trunks of the retractors ventrally lies in precisely the reverse position to what it did in Fredericella and Plumatella.

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The length proportionally to the length of the evaginable endocyst above the orifice. This character is very important. It shows the gradual progress of the alimentary canal out of the cœnœcium, in proportion as the evagination of the polypide becomes more extended.

Although the canal is absolutely very much larger in Pectinatella than in any other genus (vide synopsis, proportion of the greatest dorso-ventral, to the greatest antero-posterior diameter), its position with relation to the lower edge of the invaginated fold does not change as long as that fold exists. When, however, there is no fold as in Cristatella, the region of the sphincter crosses the cœcum near the end instead of its former place, just below the intestinal valve. (Pl. 14, fig. 1.)

The length, however, with relation to the length of the evaginable tube and the extent of the canal exposed by its increasing evagination, is an incremental character, and shows farther how the destruction of the walls of the cells affects the size of the canal. The Fredericellæ with their long, narrow cells, have also long, narrow canals; the cells becoming wider in Plumatella, the stomachs are correspondingly wider; and in Pectinatellæ, where the evagination removes the invaginated fold, giving a wide orifice, and where there are no cells, it attains, comparatively, an immense size.

In Cristatella, the evagination being perfected, and the amount of room in the cœnœcium very much reduced, it returns again to a smaller size, but retains nearly the same proportions of the dorso-ventral and antero-posterior diameter (see next character in the synopsis) which it had acquired in Pectinatella.

The consequence of this reduction in the absolute size renders the whole but little longer than the fully evaginated endocyst, and the canal may, therefore, be said to follow the tube out of the cœnœcium.

Proportions of the dorso-ventral to the antero-posterior diameter. This character has been sufficiently explained above, with the exception of the measurements. These were taken, the dorso-ventral just below the phyloric

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valve, and antero-posterior from the lophophore to the end of the gastric cœcum.

Œsophagus. The proportion of antero-posterior diameter to the length of the stomach from the œsophageal valve to the end of the cœcum, varied but little from $\frac{1}{3}$ in each genus. But the next character, the proportions of its own antero-posterior to its own dorso-ventral diameter, show a determinate and steady decrement in its length.

Stomach. The proportions of the dorso-ventral to the antero-posterior diameter determine the fact stated above with regard to the increase in the size of the canal to Pectinatella, and its decrease or fluctuation in Cristatella. In addition to the decrement in the length of the œsophagus, there is also a decrement in the ventro-dorsal from what it is in Pectinatella, $\frac{1}{2}$ of the antero-posterior, to only $\frac{1}{4}$ the latter, very nearly the same proportions it had originally in Fredericella. The next proportion, however, shows a curious fact. Although there is this decrease in ventro-dorsal diameter there is an increment in the dextro-sinistral diameter; or, in other words, the stomach retains in Cristatella the great breadth of the dextro-sinistral diameter, which it attained in Pectinatella: while, on the other hand, it loses the increment of the ventro-dorsal diameter. This explains the greater breadth of the alimentary canal, when seen from the dorsal side in Cristatella, as compared with its narrow look when viewed laterally.

Intestine. Only one series of measurements was made of the intestine, ventro-dorsally near the phyloric valve, and antero-posteriorly from the valve to the anus. The proportions of these two diameters appeared to be invariable; but, nevertheless, the absolute size of the intestine is greater in Plumatella and in Pectinatella, than in any other genus. In Cristatella, like the stomach, it became —when seen from the side—very narrow, but is of Pectinatellean proportions when seen in front or dorsally.

RETRACTORS.

Œsophageal Retractors. The characteristics preceding the proportional breadth of this branch of the retractors

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to the dorso-ventral diameter of the tube are plain enough in the synopsis, and need no explanatory remarks. This, however, is a fluctuating character, while all the above mentioned are incremental characters.

The breadth of the muscle was measured near the lophophore; and the breadth of the tube from the brachial collar to the junction of the arms with the tube.

The fluctuation in Cristatella is due to the sudden increase in the breadth of the tube in this genus, and not to any decrease in the absolute breadth of the muscle, compared with what it was in Pectinatella.

Brachial Retractors. The breadth was measured across the tube, as in the œsophageal retractors. All the characteristics of the retractors, as read in the synopsis, are directly traceable to the increasing evagination of the polypide.

As the polypide protrudes farther out of the cœncœcium and the invaginated fold disappears, the œsophageal and brachial retractors lose the support which it afforded them in Fredericella; and the increase in the size and diffusion of their filaments and bases is to compensate for this loss, and to enable them to govern the motions of the crest with their former facility.

The increment of the number of the bands of the gastric retractors, however, although due to the same causes that bring about the increase in the degree of evagination, are more directly affected by the greater freedom given to the alimentary canal by these changes. In Fredericella, the number of bands is at its minimum, because the stomach is confined in a narrow tube; and in Pectinatella and Cristatella at its maximum, because they are required to confine the alimentary canals of the different polypides, and prevent them from interfering with each other in the common cœncœcium.

ANTERIOR RETENTORS.

One row. These being merely the lowermost row of posterior retentors, and differing from them only in their size, there is necessarily but one row in every species throughout the group.

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The number of the bands, however, is dependent upon the width of the orifice, and since this becomes gradually broader up to the maximum in Pectinatella, and then decreases in Cristatella, they have a corresponding fluctuation in the number of the bands.

Far removed from the orifice. The distance of the posterior attachments from the orifice is measured by the breadth of the invaginated fold; and as this decreases, they of course come nearer to the edge of the opening, finally resting on the edge itself.

POSTERIOR RETENTORS.

The decrement in this series is explained by the preceding paragraph, since, as in the last characteristic, the number of rows is determined by the breadth of the invaginated fold.

SPHINCTER MUSCLE.

This being coextensive with the fold, necessarily decreases with it.

INVAGINATED FOLD.

This decreases in precisely the same proportion as the evaginable endocyst increases. And, in fact, it could not well be otherwise; since, as previously stated, the increase in the length of the evaginable endocyst or tube is wholly due to the additions made to it by the freed portions of the decreasing invaginated fold.

EVAGINABLE ENDOCYST.

The measurements were made from the anterior edge of the invaginated fold to the lophophore.

Membranes fully developed. The invariability of the cellular structure of the membranes is due, probably, to the similarity of their position, and of the circumstance surrounding them throughout the group. They are not subject to any such changes, as the removal of the ectocyst gives room for in the cœncecial endocyst, and changes

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in the size of the cavity of the cœnœcium do not appear to affect materially their intimate structure.

RECAPITULATION.

We have seen: (1) that the increase in the size of the Alimentary canal was due, apparently, to the enlargement of the cœnœcium, occasioned by the obliteration of the cell-walls in Pectinatella, and its decrease to the subsequent redivision of the cœnœcium into cells in Cristatella; (2) that this increment and decrement was confined to the stomach and intestine, the œsophagus steadily decreasing in the proportions of its length to its breadth throughout; (3) that the passage of the whole alimentary canal out of the cœnœcium, when the polypide is evaginated, is due to the increasing length of the evaginable tube, and therefore referable to the increasing evagination of the polypide; (4) that the increasing size and diffusion of the anterior bases and posterior filaments of the retractors, was also due to the increasing evagination of the tube; (5) that the increase and decrease in the number of the anterior retentors was due to the increase and decrease in the size of the cœnœcial orifice; and (6) that the approximation of the anterior retentors to the orifice, the decrease in the breadth of the sphincter, and the increasing length of the evaginable endocyst or tube, are due to the steadily decreasing breadth of the invaginated fold; (7) that this last is due to the decrease in the number of rows of posterior retentors, which decrease may in turn be traced* to the decreasing length of the free part of the cell-wall. Or, we may say: (1) that the free portions of the cell-wall becoming shorter, destroy the lower rows of posterior retentors; and thus (2) portions of the breadth of the invaginated fold are set free; (3) which are added to the length of the evaginable tube, and therefore the increase of the evagination is due to the decrease in length and final obliteration of the cell-walls.

Thus, in Fredericella, where the walls are longest, the invagination is greatest; in Plumatella, the walls are

* Vide description of "Muscular System."

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shorter, and the invagination less; in Pectinatella, where there are no free cell-walls, the invagination is very much less; and in Cristatella, which has neither free cell-walls or lobes, the invagination is nothing. Even the zoöids of the species show the action of this law. Whenever the free portions of the cells are much reduced in length, as in some zoöids of variety *c* of Plumatella vitrea, the number of rows of posterior retentors are less, and the evagination greater, than in other zoöids of the same colony, with longer walls to the free portions of the cells.

The Alcyonelloid varieties of Plumatella Arethusa have only about eight rows of posterior retentors; while the varieties with distinct cells may have as high as fifteen.

Thus, with the exception of the fluctuation or disturbance occasioned by the muscular walls in Cristatella, and the increase and decrease of the cœnœcial orifice, which causes the increase and decrease in the number of bands of the anterior retentors, all the characteristics of the evaginatory system are traceable to the decrease in the free portions of the cell-walls. In other words, to the gradual obliteration of the cells and branches. But this, as we have seen previously, is due to the activity of the reproductive function, which steadily increases the number of buds arising from the primary cœnœcial cell.

LOPHOPHORIC SYSTEM.

LOPHOPHORE.

The outline of the lophophore is an incremental character, owing its increment to the growth of the arms in Plumatella.

ARMS.

The length of the arms is the key-note of the changes in this system, and we shall find, as we proceed, that the increment of this characteristic determines the increment or decrement of nearly every variable characteristic.

Tips divergent—tips twisted outwards. These two characters go together. They are decremental; and the decrement is due to the retention of embryonic characters in the adults of the higher genera.

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The arms of the polypides of Plumatella separate at a much earlier date than those of Pectinatella; and the latter, probably, earlier than the arms of Cristatella. Be this as it may, the approximation of the tips of the arms is an embryonic character; because, as already stated (remarks on reproduction), the arms in the young divide from within outward, and the tips are the last to be separated, and the longer the arms, the longer the time necessary to complete the division. It seems likely, therefore, that the embryonic character of the arms in Cristatella is due entirely to their increased length.

TENTACLES.

The number of the tentacles are increased in the individual, as has been shown, by additions at the tips of the arms as the latter increase in length; therefore, the longer the arms, the greater the number of tentacles. This law is carried out, not only in the different individuals of the species, but it also determines the increment in the number of tentacles from Fredericella, which never has over twenty-four, to Cristatella, which, as far as we know, never has over ninety. The length of the tentacles, however, decreases; and the decrement is due, not to any decrease in the tentacles themselves, but to the comparatively greater increase in the length of the arms.

CALYX.

The breadth of the calyx appears to be a fluctuating character.

EPISTOME.

The form of the base is an incremental character, the change from an elliptical to a crescent shape taking place when the arms appear in Plumatella.

TENTACULAR MUSCLES.

The number of pairs of these must be equal to the number of tentacles on any one lophophore; and since the number of tentacles is determined by the length of

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the arms, the number of these, also, is determined by the same character.

LOPHOPHORIC FLEXOR.

This muscle, extending from the œsophagus to the tips of the arms, is necessarily very short in Fredericella, if it exists at all; and longer in the other genera, in proportion to the length of the arms.

NEURAL DIAPHRAGM.

Sufficiently explained by synopsis.

NERVE-MASS.

In Fredericella, where there are no arms, and the breadth of the lophophore inconsiderable, it is not necessary to have the centres of distribution widely separated, and, therefore, the nerve-mass has perhaps no commissure. In Plumatella, however, with its two long arms, each to be rendered capable of independent motion, and the breadth of the lophophore increased, the ganglia are probably separated by a commissure so as to correspond with these changes.

GANGLIA.

The thin, upright, spindle-like form of the ganglia, as seen from the side in Fredericella, is changed in Plumatella to a kidney-shape, lying horizontally. This corresponds precisely with increased width, which is given by development of the arms for the accommodation of the nerve-mass.

The heart-shaped appearance of the ganglia is invariable; because, when either the spindle or kidney-shaped double upon themselves by contraction, they assume the heart-shape.

The larger size of the lophophoric nerve-trunk, the greater length of the dorsal lophophoric nerve-branch and its plication, the decrease in the ventral lophophoric nerve-branch proportionally to the dorsal branch, the number of tentacular nerves, the larger size of the oral

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nerve-trunk, and the increase of the thickness and size of the polypidal nerve-trunk in Plumatella, as compared with the states of the same parts in Fredericella, are all evidently due to the greater extent of the surfaces which they have to supply in the former; and this increased extent, as we have pointed out, is in its turn due to the growth of the arms. Thus, every character in the Lophophoric System appears to depend upon the increment of the arms, and to owe its modifications to that, more than anything else. The œsophageal, gastric, and intestinal nerve-branches have been observed only in Fredericella.

RECAPITULATION OF THE CHARACTERISTICS OF THE THREE SYSTEMS.

Commencing with the cœnœcial system, we find that in this system the increase in the radiatory character of the cœnœcium, the crowding and adherence of the branches, the consolidation of the branches in the cœnœcial trunk, the adherence of the cells to each other, and the obliteration of the free walls of the cells, were all due to the increase in the number of the buds developed simultaneously from the original, or parent cell of the colony; and also, that these characteristics, primarily expressed in a slight degree either upon different branches of the same colony, or in different varieties of the same species, ultimately become of essential importance to the organization of every species and of generic value.

In the evaginatory system we found that all the characteristics, with three exceptions, were due to the obliteration of the cell-walls, and, therefore, directly traceable to the increase in the number of buds developing simultaneously from the parent cell; that the governing characteristic of the whole system, the extent of the evagination was a variable characteristic among the zoöids of the same colony in P. vitrea, although probably of fixed and generic value in Cristatella. Thus most of the principal changes in the complication of the cœnœcial and evaginatory system are traceable to one incremental characteristic, the gradual increase in the number of

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buds developed from the original, or parent cell of the colony.

Besides these, however, there are other characteristics, such as the decrease in the tenacity with which the endocyst adheres to the ectocyst, finally resulting in its ability to glide easily over the surface of the latter in Cristatella, the decrease in the pergameneous nature and permanency of the ectocyst, all traceable to the increase in the softness and gelatinous nature of the ectocyst. And still following in the same category we find that the decrease in the number of branches to each colony, the great increment in the thickness of the ectocyst in Pectinatella, and the disappearance of the permanent annular folds, is due to the greater functional activity of the third layer in forming annular folds, traceable in turn to the increase in the gelatinous nature of the ectocyst, which permits these folds to coalesce and divide the colonies. Thus, there are two series of important structural characteristics, which necessarily change in consonance with, or are dependent upon the gradual change of the parchment-like ectocyst of Fredericella, to the gelatinous, transient excretion of Cristatella.

This gelatinous condition of the ectocyst, as has been shown, is only a rare individual characteristic in Fredericella, becoming peculiar to some species in Plumatella, and, finally, essential to the organization of Pectinatella, Cristatella, and perhaps Lophopus. I have succeeded in producing the transparent, gelatinous ectocyst in Fredericella, by simply allowing a colony to grow in water free from all sediment; and I have not yet found a transparent variety or species except in clear water. The transparent ectocyst is also common in the young of all the brown varieties of Fredericella and Plumatella, and these are much longer lived than the transparent species, such as Plumatella vitrea, the Pectinatellæ or Cristatellæ. Whether the ectocysts of P. vitrea would become brown and tougher if they lived longer, it is impossible to say; but certainly such would appear to be the most likely result, since the ectocyst of all the brown Fredericellæ and Plumatellæ, which live longer than they do, are trans-

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parent in the young, and acquire the pergameneous character only by age. I do not here allude to the color acquired simply by the gathering on the surface of minute particles of sediment, but the deep brown color due not only to these particles, but to the horny condition of the ectocyst produced by age. The increase in the gelatinous character of the ectocyst in Plumatella may be safely said to be in part due to the shorter lives of those varieties, and species that are habitually transparent; but the change in Cristatella cannot be accounted for in any such way.

In order to see how this happens, it is necessary to notice another series of characteristics. These are the horizontality of the cœncœcium in Pectinatella, due to the withdrawal of the support of the ectocyst, and its concentration below the cœnœcium, which last is probably caused by the same changes in the outer membrane, that enlarge the size of the cells. The increase in the size of the minute cells, composing the tissue, are the only ostensible changes noticeable in the membrane secreting the ectocyst, to which their sudden cessation of the excretory powers on the upper side might be referred.

In Cristatella the ectocyst still continues to be excreted only from the lower side, and the introduction of its power of locomotion enabling it to secrete a new ectocyst as it goes, always maintains the latter new and soft. Pectinatella has no locomotive muscles, and, therefore, the ectocyst accumulating under it is tougher than in Cristatella, though it remains gelatinous in consequence of its great thickness.

The modifications of the variable character of the lophoric region, as has been said, are dependent upon the increment in the length of the arms.

The variable characteristics of the entire group of Phylactolæmata, as may be conceived from the preceding, are dependent for their modifications or changes upon (1) the increase in the number of buds developing from the original cell, (2) the increase in the number of individuals having the gelatinous ectocyst, (3) the changes or agencies that remove it from the upper side of the cœnœcium, (4) the bending inwards of the third and fourth

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muscular, and fifth membranous layers to form the reticulated walls, (5) the increasing growth of the arms.

These are the fundamental characteristics, and yet it cannot be denied that they may first make their appearance as a variable characteristic of different branches of the same colony become common to the varieties of other species, and eventually of generic value. Thus, as before described, a single branch of P. vesicularis assumed the aspect which afterwards distinguished variety *c* of P. vitrea, and approximated to the generic characteristic of Lophopus. The obliteration of the cell-walls in this branch and in the colonies of variety *c* of P. vitrea were traced to the increase in the number of buds growing up side by side from the same cell, just as in Pectinatella and Cristatella the generic form of the colony was traced to the number of buds developing simultaneousiy from the parent cell.

The second, also, as has been stated, appears as a rare variety in Fredericella regina and Walcotti, an ordinary character in F. pulcherrima, and among the Plumatellæ ending with becoming of specific value in P. vitrea, perhaps on account of the short time which that species lives, and is finally common to all the species of the remaining genera of the group. It is evidently a local characteristic, due partly to age and partly to physical causes in these two genera; but in Lophopus, Pectinatella, and Cristatella, it is an *essential* peculiarity of the generic structure, apparently *not affected by physical causes*, since wherever these genera have been found the ectocyst is gelatinous.

With regard to the third, it is possible that the enlargement of the cells in Pectinatella indicates a loss of the execretory power, and consequently causes the removal of the ectocyst. As previously stated, this change is begun in variety *c* of Plumatella vitrea, where the action of alcohol creates a gap between the ectocyst and endocyst.

The fourth is even more inexplicable than the third; the walls are there, and are evidently necessary to keep the cœnœcium firm and shapely, but they are apparently without precedent. They do not begin, like other char-

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acteristics, in a few individuals or species, gradually becoming of generic value and general application as the complication increases, but start into life and functional activity without even a whispered warning of the coming change in the organization of any preceding genus or species.

The fifth is characteristic in different degrees of the individuals in Plumatella (the length of the arms always varying with the number of tentacles, and these are different in nearly every individual), and becomes much more constant, if not invarjable, in Cristatella. Four of these five fundamental characters, therefore, are incremental. These begin in a few individuals and become of more general value and characterize more and more extended divisions and more complicated animals. Thus the second is an individual variety in the first genus, obtains a more general application and finally a specific value in the the second, and at last is sufficiently constant in the two species of Cristatella already known, to be considered at least of generic value.

The increased value, or constancy and applicability, therefore, of these incremental characteristics is due enentirely to the increase in the number of the individuals characterized by them in each succeeding and more complicated division, with regard to the number of the individuals that remain unchanged in the same division. For example, in P. arethusa the majority are brownish, wherever found; in P. vesicularis there are few brown individuals in proportion to the transparent; in P. vitrea all yet found are transparent; and in the succeeding genera every individual is transparent.

The fourth character must be considered an exception to this rule, unless indeed new discoveries should disclose an intermediate form between Cristatella and Pectinatella, or a lower form of the same genus that will give us the clue to the abrupt introduction of the reticulated walls.

It is surprising that when viewed with regard to their own young, the condition of the cœncecial and lophophoric regions in Cristatella, although more complicated, is nev-

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ertheless more embryonic in some respects than the evaginatory regionin the same genus, or in Plumatella.

Nothing can be more opposed to the fully evaginated state of the adult Cristatella than the embryonic aspect of the lophophore, and it will be readily perceived, from the homology suggested between the original cell of the colony, and the sack-like cœnœcium, that the latter has a more embryonic aspect than the branching cœnœcium of Plumatella. This is the only point in which the lophophoric and cœnœcial regions agree; in all others they are at variance.

Such would be inferred to be their most appropriate relationship, from the fact, that all the modifications of the evaginatory tube were found to be due to the more fundamental changes of the cœnœcium; whereas, those of the lophophore were not dependent upon any of the changes in the other two. Thus the lophophoric adds its greatest increment of complication, the "fully developed" arms, in the second genus of the sub-order, whereas the cœnœcial more gradually progresses and acquires its greatest anatomical increment, the reticulated walls, only in the last genus. Both are most complicated in Cristatella, but both arrive at the highest degree of complication by different methods.

The evaginatory region does not agree with either of these; the increment of complication is gradually and slowly added, and no new organs or sudden developments of particular parts take place. In all its relations with the regions above and below, this region occupies an intermediate place.

In fact, the mutual influence of the modifications in one region upon the organs of another is proportional to their positions in the body of the adult, and the times of the acquisition of the adult characters by such region during the development of the individual.

The modifications of the cœnœcial region, situated as it is at the anterior pole, bear directly on the next region, the evaginatory, changing its organs greatly, but it does not affect the lophophoric at the posterior pole of the body. The forces or organic momenta of the changes

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seem to be expended entirely upon the evaginatory system, and do not reach the lophophoric except in so far as they increase its distance from the anterior pole by increasing the evagination of the tube.

The cœnœcial is also invariably the first region to assume the full characteristics of the adult zoöid, the evaginatory next, and the lophophoric last. The bud, as previously observed, is developed from the wall of the cell, which last becomes well formed and distinct before the alimentary canal loses the peculiar shortness and breadth of the younger stages of growth, such as is figured in Pl. 8, fig. 2, and not until long after both regions have attained their full growth, do the tentacles on the ends of the arms acquire the adult length.

The three regions are equally well marked among the Polyzoa of simpler organization than the Phylactolæmata, with the exception of the genera Urnatella and Pedicellina. The two latter have all three regions consolidated in one, and there may be said to be but two systems in their structure, the cœnœcial and lophophoric, the evaginatory having entirely disappeared, and the alimentary canal and reproductive organs occupying the cœnœcial region together.

The exceeding simplicity of the alimentary canal, the approximation of the mouth and anus, especially in Urnatella, where, according to the unpublished plates of Dr. Leidy (Pl. 15, fig. 5), they are so close together, that they are separated only by their own membranes which are continuous with each other, so that the intestine and œsophagus in the young seem to have but one common aperture through the disk (Pl. 15, fig. 6); the absence of the gastric cœcum of the Phylactolæmata, of the pointed œsophagal valve, and of the evaginable tube are all characteristics, that not only separate these two genera from the Phylactolæmata, but show them to be the very lowest of the Polyzoa.

The lophophore is withdrawn within the cell, and the invaginated fold forms in both genera a net between the tentacles, resembling the calyx of the Phylactolæmata, to which the lower part of the tentacles are soldered on its

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inner side, and its upper free border forms the true aperture of the cœnœcial cell. This is shown by the position of the sphincter muscle and its action in closing the cell, by drawing together the upper edge of the calyx-like fold and including the free ends of the tentacles which have been previously bent inwards and doubled upon themselves.* Thus not only does the so-called calyx homologize in position with the invaginated fold of the higher Polyzoa, but it closely resembles that organ in function, with the exception, however, of performing the office of a sheath for the invaginated tentacles in the absence of any evaginable tube. Both Urnatella and Pedicellina are invaginated zoöids, and as such cannot be associated with those forms of Polyzoa which have the three regions of the body fully differentiated. The lophophore is permanently held attached to the inferior edge of the evaginated fold, and cannot be extruded from the cell, the superior portions of the tentacles being the only parts freely evaginated. I am aware that Pedicellina is said to possess an epistome and two arms by Prof. Allman, but these characters will hardly weigh against the absence of the tubular endocyst, which is common to all the Polyzoa from the Cheilostomata to the Phylactolæmata, the absence of a funiculus, and the simple character of the whole organization. Their appearance, also, is more suggestive of the Radiata than other Polyzoa, especially Urnatella, and the peculiarity of permanent invagination is shared equally with the young of the Phylactolæmata, whose lophophores at an early age are permanently invaginated and joined with the parietes of the cell, and are unfurnished with œsophagal valves. Embryology, therefore, as well as their general structure, justifies the position assigned to them, as the lowest types of the Polyzoa.

The concentration of the three regions is towards the anterior end of the Polyzoön, and if I am right in my estimation, this is a low feature. The evagination of the Perigastric and neural systems among the Cheilostomata,

* This is most clearly shown by several of Dr. Leidy's figures in which the tentacles are withdrawn as described.

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and Cyclostomata and the Phylactolæmata, show that throughout all the modifications of succeeding and more complicated genera, the class as a whole retains the neural system at the posterior pole.

Although cephalization, as shown by Mr. Morse, is the tendency of the Saccata as a whole, still it must be admitted, that it is not the tendency of the lowest class, but, on the contrary, this class betrays throughout an anti-cephalic character.

From the intensely cephalized Urnatella and Pedicellina we have no cephalized forms until we reach Pedicellina. This, with its two invaginated folds, is a more cephalized type than Fredericella, which in its turn is more invaginated, and therefore more cephalized than the higher forms of Plumatella, such as P. vitrea. Lophopus and Pectinatella lead us gradually to Cristatella, which is as completely evaginated as any of the Ctenostomata or Cyclostomata. Thus, it is clearly shown that the differentiation of the three regions of the body by the elevation of the neural region to the posterior pole is the governing tendency of the organic changes of the class.

DESCRIPTION OF SPECIES.

The measurements were computed by a micrometer set in Tolles' B orthoscopic eye-piece with a 2 inch objective, and are given in decimal parts of a "millimètre," and also in equal numbers. The equal numbers roughly computed are each equivalent to $\frac{1}{30}$ m. m. or $\frac{1}{769}$ inch, according as they are measured upon the French scale, or an English steel ruler. The statoblasts are drawn upon the enlarged scale of $\frac{1}{30}$ m. m. or $\frac{1}{769}$ inch to $\frac{1}{16}$ of an inch, and consequently the figures give the relative sizes. The annuli were measured on either side, and the results are contrasted by placing the widths on the upper and lower side of a dividing line. The figures of the statoblasts being drawn upon the same scale, the different varieties of the same

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species, as well as in the different species and genera, may be seen by comparing them. Those figured in the plates are not sufficiently accurate.

FREDERICELLIDÆ.

Cœnœcium attached, dendritic. Lophophore oval. Statoblasts bare and smooth.

FREDERICELLA.

Cœnœcium composed of elongated cells covered by a thin ectocyst. Invaginated fold broad, with numerous rows of posterior retentor muscles. Posterior attachment of œsophageal retractors solid.

Fredericella Walcottii Hyatt.

This species differs from all others of the same genus in its peculiar mode of growth. The main branches are closely attached to the surface, and the free parts of the cells or branches rise abruptly from them. The former are long single stems, growing at acute angles, and often crossing each other.

There are two well-marked varieties, *a* and *b*.

All the branches of variety *a* were single and closely attached throughout, the only free parts were the upper portions of the cells. These might be of extreme length or quite short, the attached part varying between 12 m. m. and 5 m. m. the free portions between 6 m. m. and 1 m. m. The constant attachment and rarity of the branches, together with the length of the attached part, gives them the aspect of true stolons, the free portions of the cells appearing like individual zoöids (Pl. 15, fig. 2). The branches of variety *b* still have the stolon-like aspect of variety *a*, but the deep channels in the surface of the wood prevent them from crossing each other to any great extent. The free portions of the cells also frequently branch, and the growth is then more dense than in variety *a*. Statoblasts were not observed.

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Locality, Georgetown, Mass.

Remarks. The cœnœcia cover large areas, differing in this respect from all the other Fredericellæ, whose colonies when upon a flat surface are never very diffuse.

The more open growth, or variety *a*, was found in a shallower and more rapid part of the stream than variety *b*. Their peculiarities fit them for these different situations. Variety *a* exposes only its single cell to the action of the swift current, the remainder being firmly fastened, while variety *b*, not being in danger from the current, indulges in a freer and more dendritic growth.

I have taken the liberty of dedicating this species to Miss Elizabeth Walcott, of Salem, in whose agreeable society I had the pleasure of discovering it, during a field meeting of the Essex Institute.

Fredericella pulcherrima Hyatt.

Cœnœcia radiating more distinctly than in any other species, resembling in this respect Plumatella. Branches colorless, generally attached throughout; the free portions of the cells occasionally subdividing into free branches. Polypides do not differ sensibly from those of Fredericella regina. Statoblasts measure about .5 m. m. long, by about .16 m. m. broad (Pl. 15, fig. 3).

Remarks. The only locality is White's Bridge, at the outlet of Lake Sebago, Maine. The colonies upon the bark of branches near the shore were young, and had not yet attained their growth, but it is probable that the adults upon such surfaces are never so symmetrical as those upon the stems of the water-lilies.

Fredericella regina Leidy, Mss.

The cœnœcia are scarcely describable in general terms, since they display almost all kinds of growth; but there are three principal varieties.

Variety a, Pl. 7, fig. 1. The colonies are not very large, but the branches are numerous. The attached parts of the cells are very long, but the free portions mere

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nubs thickly strewn upon the branches. This variety occurs only where the surfaces are sufficiently large and smooth. Found only at Gorham, Maine.

Variety b, Pl. 7, figs. 2 and 3. The main branches are not necessarily attached, but grow in clumps, the colony often being attached by only a portion of the branch, and the free portions of the cells long. This occurs only on wide surfaces.

Variety c, Pl. 15, fig. 4, is an extremely dense growth, the branches are so crowded that in some instances they become adherent. The refuse matter in the current is deposited between them, and the whole appear to be adherent, resembling the Alcyonelloid variety of Plumatella so closely, that at first sight they might be mistaken for the same. This variety is found only upon limited surfaces or small twigs.

The polypide has from 18 to 22 tentacles. The intestine in some specimens has a faint, pinkish color. The statoblasts range all the way from .166 m. m. in breadth by .366 m. m. in length, to an almost orbicular outline which is .299 m. m. in breadth by .316 m. m. in length. In equal numbers they range as follows, from 5 by 11 to 5 by 12, from 6 by 11 to 6 by 14, from 7 by 10 to 7 by 13; and, finally, one specimen was 9 by 9½. Thus, there is a gradual increase in the proportional breadth from 5 to 7, while the length fluctuates between 10 and 14 without regard to the breadth.

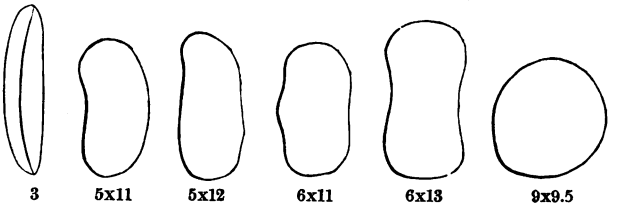

FIG. 13, statoblasts are all, with one exception, taken from one spot in a branch of a colony from Fresh Pond, Mass. The figures underneath give the proportions of the breadth to the length, except under the side view where they give only the breadth. This side view is taken from a specimen found in Mystic Pond, and is the longest I have seen, measuring .466 m. m.

Remarks. The extensive distribution of this species from Norway, Me., to Baltimore, Md., would prepare us

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to meet with extraordinary power of adapting its organization to the different circumstances under which it might be placed, and it does afford a happy illustration of this principle. The colonies inhabiting a small brook near Gorham, Me. (Young's Brook), has all three varieties. The upper part of this stream where it is comparatively narrow and deep and where the supports for the colonies are generally rounded twigs, contains almost exclusively variety *c*, and occasionally variety *a*, wherever the surface is sufficiently extensive. Farther on, as the stream broadens and the current is less swift, variety *b* makes its appearance, and is the preponderating form. The other waters in which this species has been observed, namely, Pennissewassee Pond, Norway, Me.; Fresh Pond, Cambridge, Mass.; Schuylkill River at Philadelphia; and Gwinn's Falls, Baltimore, Md., are comparatively still, and contained but one variety, variety *b*, the same that occurs in the more sheltered spots of Young's Brook.

The colonies of variety *b* rarely attain any considerable size, while in variety *c* they sometimes form thick clusters one or two inches in depth by three or four in length. Besides these three varieties, there is another probably belonging to this species, found in the outlet of Great Pond. The colonies are small, consisting only of a very few polypides. The brook formerly emptied a large fresh-water pond; but this has been drained, and now at high tide the water becomes quite brackish, which probably accounts for the diminutive size of the colonies.

PLUMATELLIDÆ.

Cœnœcium attached, branching. Lophopus with two arms, standing out like the arms of a horse-shoe. Statoblasts annulated and spiney, the spines passing through the annulus.

PLUMATELLA.

Cœnœcium, with shorter cells than in Fredericella, covered by the thin ectocyst. Invaginated fold broad,

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with numerous rows of posterior retentor muscles. Statoblasts with plain annulus, and rounded extremities.

PLUMATELLA DIFFUSA Leidy.

I found this species abundant in the ponds and brooks near Cambridge and Baltimore. Those which inhabited the brooks differed greatly from the pond varieties. The first, or variety *a*, has distinct cells, with tough, brown ectocyst, and the branches diffuse, and rarely adherent (Pl. 8, figs. 11, 12, 13). The pond varieties, or variety *b*, were much denser growths; the branches generally adherent, the ectocyst colorless, and, in several specimens from Mystic Pond (living in brackish water, associated with Cordylophora), the branches were so closely packed that the colonies formed thin, gelatinous sheets of considerable extent, in which no branches could be traced from above. The cells also had the hexagonal outline usually ascribed to Alcyonella, and their lower portions were more or less merged in the branch.

The brook variety, or variety *a*, was generally keeled and channelled, but this was an exceedingly variable character. Polypide was not examined.

Statoblasts vary from .199 m. m. in breadth by .333 in length, to .249 in breadth by .349 in length. In equal numbers they vary from 6 by 10 to 6 by 12, 6.5 by 11.5, and 7.5 by 10.5.

Here, again, as in other species, the transverse diameter is increased steadily, while the longitudinal fluctuates between 10 and 12. Annulus varies between $\frac{3}{5}$ and $\frac{2.5}{4}$ at the ends, and between $\frac{1.5}{2.5}$ and $\frac{1.5}{1.5}$ at the sides.

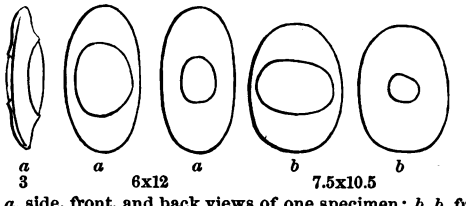

FIG. 14, *a*, *a*, *a*, side, front, and back views of one specimen; *b*, *b*, front and back views of another, all from Mystic Pond, Mass.

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Plumatella Arethusa Hyatt.

The cœncecia have the usual range of variation. Variety *a* has distinct cells and radiating branches. The ectocyst may be either brown or colorless, and the cells vary greatly in size (Pl. 8, figs. 1, 2).

Variety *b* has the branches and cells adherent, forming thick encrustations upon the surfaces of branches or logs; the cells, however, appear to be distinct, the lower portion not being obliterated to so great an extent as in variety *c* of P. vesicularis and variety *b* of P. diffusa. Variety *a* has generally a brownish ectocyst, but the younger colonies or branches are colorless. Orifices are channelled in the brown colonies, and entire in the colorless ones. The posterior retentors consist of from 7 to 13 rows, and the anterior retentors have about 10 bands. Tentacles from 40 to 60 in number. Statoblasts vary from .199 m. m. in breadth by .266 m. m. in length, to .266 in breadth by .399 m. m. in length. In equal numbers the statoblasts measure 6 by 8, 6¼ by 9, 6½ by 10, 7 by 9 to 7 by 11½, 8 by 11 to 8 by 12.

There is, therefore, as in the preceding species, a gradual increase in the breadth, and also a gradual increase in length among the full-grown statoblasts.

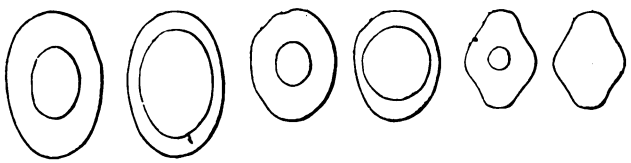

Fig. 15, three varieties of the statoblast; *a*, *a*, back and front view of one specimen; *b*, *b*, back and front view of one specimen; *c*, *c*, back and front view of one specimen. In this specimen the annulus covers the whole side of the statoblasts on one side.

Localities. Pennissewassee Pond at Norway, Gorham, Great Falls, the outlet of Great Pond on Cape Elizabeth, Presumpscot River, all in Maine; Fresh Pond and Mystic Pond at Cambridge, and Green River at Greenfield, all in Massachusetts.

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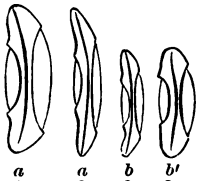
Remarks. I have collected variety *a* generally upon broad surfaces in moderate currents or still water; but small colonies may occur upon twigs and roots. In Tommy's Brook, variety *b* is associated with variety *c* of F. regina; while farther down the brook, variety *a* is found in company with variety *b* of that species. It is evident here that the Alcyonelloid varieties of both species are due to the action of the limited areas of growth and extraordinary development of the reproductive powers.



a *a* *b* *b'*
4 2 2 3

FIG. 16, four varieties of the statoblast seen from the side. The outlines correspond to those with similar letters in fig. 15, but their thickness is represented by the numbers below. In both figures *a*, *a*, are from Mystic Pond; *b*, *b*, *c*, from Fresh Pond; *b'* from Pennissewassee Pond.

The specimens found in the brackish water of the outlet of Great Pond are small colonies agreeing in general character with the small-sized Fredericellæ, also found there. Those in Mystic Pond belonged to variety *b*, agreeing in all respects with the specimen of P. vesicularis, diffusa, and vitrea, found together near the outlet of the lower pond. Those from Fresh Pond belonged to variety *a*, and were associated with variety *a*, F. regina, variety *b*, P. vitrea, and variety *a*, P. vesicularis. The general character assumed by the different species leads at once to the supposition, as the only reasonable inference, that these varieties are the results of the association of the different species under the action of similar physical causes.

PLUMATELLA VITREA Hyatt.

The cœncecia of this species are covered by colorless gelatinous ectocysts, rather thicker than in any other of the Plumatellæ, except the Alcyonelloid variety of P. diffusa.

Variety *a* has radiatory branches, and the cells are more distinct than in variety *b*; but the lower portions are merged in the common branch more than in the diffuse form of P. vesicularis or diffusa. When contracted, the cells are quite distinct and prominent. It is common

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upon small sticks and twigs in the fresh water of Mystic Pond.*

Variety *b* grows in long lines—rarely branching—upon the surfaces of boards, and invariably solitary; the polypides arranged sometimes in one row, but oftener in clumps of from two to twenty heads, of all sizes (Pl. 9, figs. 1, 2). The lower portions of the cells are merged in the main branch, the breadth of the invaginated fold, when the polypide is fully expanded, is less, and the polypide can be more fully evaginated than in any other species (vide Pl. 9, fig. 3.) When contracted, the cells project but slightly above the branch. Viewed from above, a branch is very like the variety of P. vesicularis depicted in figure 18. It has been found only in Fresh Pond.

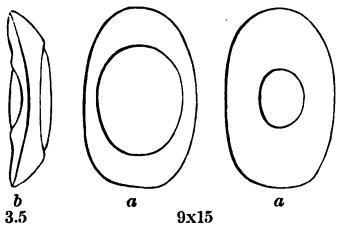

FIG. 17, *a*, *a*, front and back views of same specimen from Mystic Pond; *b*, side view of another individual from Fresh Pond.

Variety *c* occurs upon flat pieces of tin and other broad surfaces in the brackish waters of Mystic Pond. The colonies differ from those of variety *b* in their diffuse and closely crowded branches, forming a dense gelatinous carpet. The statoblasts measured between .266 m. m. by .366 m. m., and .383 by .566 m. m. In equal parts from 8 by 11 to 9 by 15, and 10 by 16 to 11 by 15, 11 by 16 to 11½ by 16, and 11½ by 17. The annulus from $\frac{4}{5}$ at the ends and $\frac{2}{3}$ at the sides, to $\frac{3}{5}$ at the ends and $\frac{1}{2.5}$ at the sides. Found only in Mystic and Fresh Ponds, Cambridge, Mass.

PLUMATELLA VESICULARIS Leidy.†

This species, previously described from the neighbor-

* This Pond is divided by a dam so that the upper portion is wholly filled with fresh water, while the salt tide enters the lower part, rendering it quite brackish.

† Proceedings Philadelphia Academy Natural Sciences, vol. 7, p. 192.

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hood of Philadelphia by Dr. Leidy, is found also near Cambridge, Mass., and in Sebago Lake, Maine.

The colonies differ considerably. Variety *a*, found upon smooth boards in Spy Pond near Cambridge, is very large when full grown, the branches often crowded, but never adherent, the cells distinct. The branches, however, of variety *b*, upon rougher boards, where the decaying surface was deeply grooved, grew in these channels, and were neither so radiatory or closely crowded. These are only accidental varieties, which do not differ essentially in structure; but at White's Bridge, Sebago Lake, Maine, I found upon the same colony an interesting structural variation from the usual mode of building out the branches. The tip of a branch (Fig. 18), either in consequence of some impediment upon the surface, or from a sudden and excessive development of the vital energies, began to produce three buds at a time instead of one, thus giving to the branch a lobiform aspect corresponding with the characters of variety *b* of Plumatella vitrea.

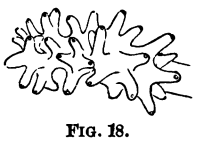

FIG. 18.

This species may therefore be assumed to be capable of two important variations, one in which the cells are distinct, and one (variety *c*) in which they are partly merged in the branch. The ectocyst is not constantly colorless, but may be brown in some localities.

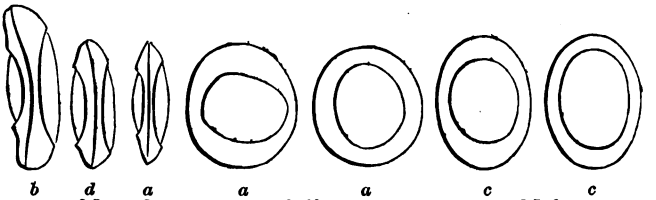

FIG. 19, *a*, *a*, *a*, front, back, and side views of one statoblast; *c*, *c*, front and back views of another specimen, both from Beaver Pond, near Cambridge, Mass.; *d*, from Spy Pond, near same place; *b*, from Sebago Lake, Maine, is inaccurate, should be but little longer than *d*, and about the same thickness.

The anal extremity of the intestine is rather lower than in P. Arethusa, and the gastric cœcum is very blunt. Posterior retentors are about eight rows, and the anterior retentors about ten or twelve bands; tentacles, fifty to

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sixty. The statoblasts vary between .199 m. m. in breadth by .333 m. m. in length; .233 m. m. in breadth by .349 m. m. in length. The proportions are in equal parts from 6 by 10 to 6 by 12, $6\frac{1}{2}$ by $11\frac{1}{2}$, and $7\frac{1}{2}$ by $10\frac{1}{2}$; annulus varies from $\frac{2}{4}$ at the sides to $\frac{2}{2}$ at the sides and $\frac{3}{5}$ at the ends.

PECTINATELLA.

Cœnœcium without cells, the branches being large lobes with the polypides on the upper side; naked above, with the ectocyst gathered below into a thick common base for the colonies. Invaginated fold almost obsolete. Statoblasts with spinous annuli, extremities rounded.

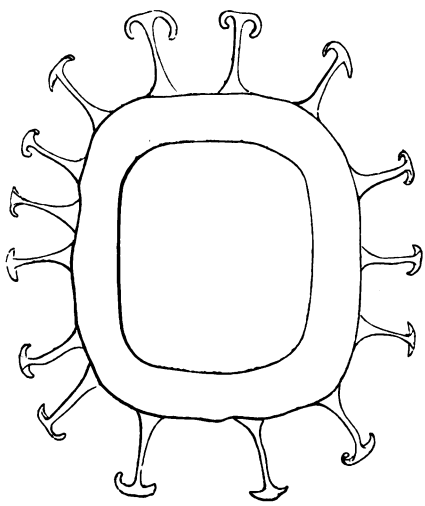
PECTINATELLA MAGNIFICA.

The polypides are arranged on the lobes; sometimes in single, but generally in double rows, placed alternately.

The ectocyst is of great thickness at the centre, and may be from four to eight inches in depth; arms about as long as the evaginable tube of the polypide.

Tentacles number from sixty to eighty-four. Lower part of these and the mouth parts are crimson.

Statoblasts vary from .8 m. m. in breadth to .9 m. m. in length. The proportions in equal numbers are as follows: 24 by 27, or 26 by 27, 27 by 28, 28 by 29, 29 by 30, 30 by 30.



· 24x27

FIG. 20, from Mystic Pond, near Cambridge, Mass. Although usually the annulus on the lower side presents a broader surface, as in Pl. 10, Figs. 3 and 4; this is often so narrow that when measured from above there is no appreciable difference. [The lateral view of the statoblast in Pl. 10 is correct, and therefore not given here.]

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Annulus varies from $\frac{3}{3}$ to $\frac{4}{5}$ at the sides, and from $\frac{3}{3}$ to $\frac{4}{4}$ at the ends. The spines are about .233 in length, measuring from the exterior of the annulus outward.

The specimens found in Fresh Pond, Mass., and those occurring in Pennissewassee Pond, Maine, differ in the number of tentacles and spines. The former have from sixty to seventy-five tentacles, and the statoblasts from twelve to seventeen spines, while the latter have from seventy-two to eighty-four tentacles, and from twenty to twenty-two spines. The varieties of form in the masses are due wholly to the contour of the surfaces upon which they grow. If these be flat the mass becomes sub-conical; if around a twig, spindle-shaped; on the end of a short projecting stump of a branch, a rotund mass, as in Pl. 9, fig. 4.

When the ectocyst decays, as previously remarked, in old age, most of the colonies either dying or floating off becomes attached and live for some time isolated, but do not increase in size; some, however, continue to live more or less widely separated upon the remains of the ectocyst, but in consequence of the removal of the lateral pressure from surrounding colonies, lose their sub-angular hexagonal form

The polypides are found only upon the outer portions of the lobes in the colonies, the inner surface being left bare, spotted however with yellowish and opaque white blotches, the remains of the tentacles and gemmæ of dead polypides in different stages of absorption.

In this process of absorption of dead polypides the stomachs disappear first, the tentacles next, the gemmæ last. The persistence of the latter is interesting, because they vanish in the living Plumatellæ and Fredericellæ soon after the breeding season of early spring is passed. The large size of the albuminous envelope of the winter buds, very seriously incommodes freedom of motion, in the muscles of living polypides, and presses the stomachs out of place. The statoblasts are largest and most crowded near the centre, where the polypides first die out. These circumstances would imply that the growth of the gelatinous covering was not only a matrix for the hooklets, but served—in part at least—to accomplish the death of

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the inner lines of polypides. This is probably not the case, however, for colonies which have but few statoblasts show as many dead polypides internally as the others. It seems to depend wholly upon the age of the polypides.

Specimens may be very roughly handled before the polypides will retract, even lifting them out of the water has no lasting effect, they expand almost as soon as they are replaced. After being kept in confinement some weeks they become more fearful, and when alarmed will remain longer retracted, but even then seem to find it necessary to spread out the tentacles for air very soon after the annoyance ceases, although an hour will sometimes elapse before the rest is expanded.

CRISTATELLIDÆ.

Cœnœcium locomotive, entire, divided internally by muscular walls. The ectocyst a transient excretion from the endocyst. Invaginated fold obsolete. Statoblasts annulated and spinous, the spines passing outside of the annulus.

CRISTATELLA.

The generic characters not ascertained.

Cristatella ophidioidea.

Cœnœcium round in the young, but in the adult colonies is frequently about eight inches long by one-fourth of an inch broad; a specimen of this length always follows a sinuous course; the smaller cœnœcia sometimes proceed in straight lines, and one about an inch long crawling in this way, will progress its own length in twenty-four hours.

Adult polypides are in two rows, the tentacles of the third row are not fully developed on the extremities of the arms, and from the latter outwards, all stages of growth are represented in the lines of buds and young polypides, varying from two to five.

The lophophore is as long as the perigastric tube when fully expanded, and bears about ninety tentacles.

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The statoblasts are orbicular and fringed with from twenty to twenty-two short, and thirty-two to thirty-seven long hooklets with forked points, making from one to six points to each hooklet. Diameters vary from .8 m. m. to .83. In equal parts from 24 to 25. Annulus varies from $\frac{1}{2}$ to $\frac{1}{4}$.

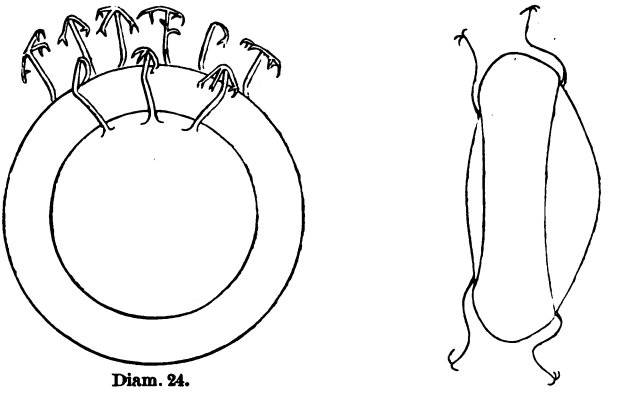

FIG. 21, statoblast from Pennissewassee Pond, Maine. The spines are drawn from various specimens to show the range of variation.

Remarks. This species was found upon the under side of snags or flat-boards in settlements, underlaid by the common ectocyst as in Pectinatella. This is an even sheet, perhaps in large settlements one-eighth of an inch in thickness.

The statoblasts are few in number and differ materially from those figured by Professor Allman of C. mucedo. The outer edge of the annulus is entire and not scolloped as in the last named, and the brown sheath of the statoblast is smooth and not covered by minute bosses as in C. mucedo; the outline of the statoblast in our species, when seen from the side, is also much less symmetrical.

Cristatella Idæ, described by Dr. Leidy, is only about one and three-fourths of an inch in length, and has only seventy-two tentacles, and a statoblast with about seventy spines.

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EXPLANATION OF SIGNS USED IN THE PLATES.

A Cœnœcium.
A′ Cœnœcial Trunk.
A″ Cœnœcial Branches, lobes or tubes.
A‴ Cœnœcial Cells.
A⁗ Cœnœcial Orifice.
B Invaginated Fold.
C Polypide.
C′ Dead Polypide.
D Ectocyst.
E Endocyst.
E′ First layer of the Endocyst.
E″ Second layer of the Endocyst.
E‴ Third " " "
E⁗ Fourth " " "
F Brachial Collar.
F′ Neural Partition or diaphragm
G Calyx.
H Tentacles.
H′ Tubular interior of the Tentacles.
H″ Cilia.
I Lophophore.
I′ Epistome.
I″ Mouth.
J′ First layer of the Alimentary Canal.
J″ Second layer of the Alimentary Canal.
J‴ Third layer of the Alimentary Canal.
J⁗ Fourth layer of the Alimentary Canal.
J̄ Hepatic Folds.
K Œsophagus.
K′ Stomach.
K″ Intestine.
K‴ Œsophageal Valve.
K⁗ Intestinal "
K̄ Anus.
L Sphincter Muscle.
L′ Brachial Contractors.
M Gastric Retractors.
M′ Œsophageal Retractors.
M″ Bracial Retractors.
M⁺ Common trunk of the Retractors.
M Lophophoric Flexor.
N Anterior Retentors.
N′ Posterior "
O Outer Tentacular Bands.
O′ Inner " "
P Median muscle of the Epistome.
P′ Lateral muscle of the Epistome.
Q Cœnœcial walls of Cristatella.
R Parietal fibres (probably abnormal).
S Nerve-mass.
S′ Lateral ganglions.
T Lophophoric nerve-trunks.
T′ Epistomic " "
T″ Brachial " "
T‴ Polypidal " "
T⁗ Œsophageal " "
T̄ Gastric " "
T⁺ Intestinal " "
U Lophophoric " branches.
U′ Tentacular " "
V Funiculus.
W Free Statoblasts.
W′ Horny Casing, or brown sheath.
W″ Annular Sheath.
W‴ Spines.
W⁗ Gelatinous Envelope.
X Fixed Statoblasts.
Y Buds.
Y′ Young Polypides.
Z̄ Clear spaces below the bases of the Tentacles.

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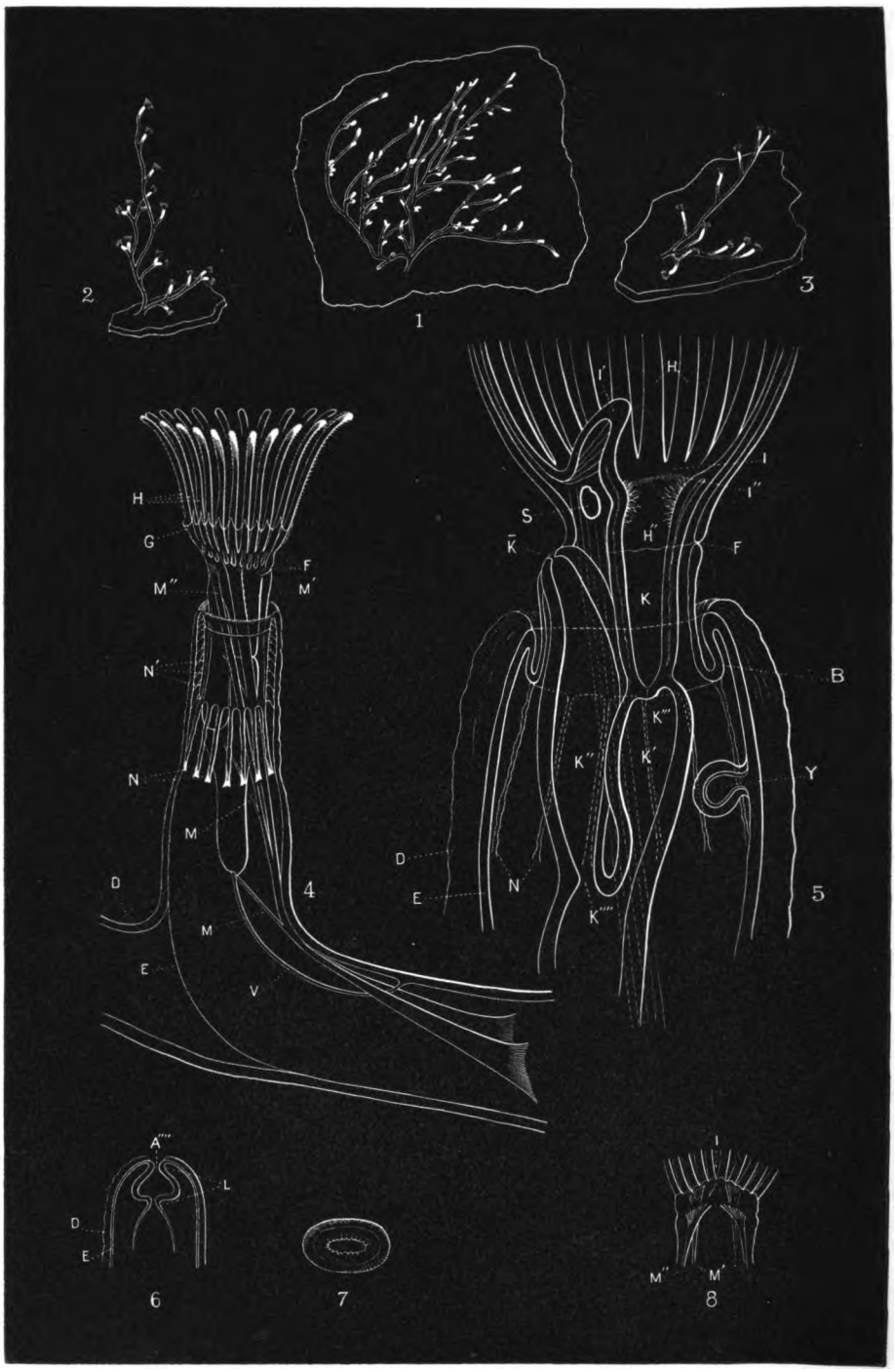

Prof. H. J. Clark, E. S. Morse, and A. Hyatt, from Nat. E. S. Morse, on Wood. J. F. Richardson, Portland, Eng.
A. Holland, Boston, Printer.

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PLATE 7.

FREDERICELLA REGINA Leidy, Mss.

Fig. 1.* One colony, life size, with all the branches attached. (Gorham, Me.)

Fig. 2. Two branches of one colony: one attached and one free. (Cambridge, Mass.)

Fig. 3. Attached branch of one colony. (Gorham, Me.)

Fig. 4. Magnified view of one adult zoöid. (Norway, Me.) D, ectocyst; E, endocyst; V, funiculus; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors; N′, posterior retentors; F, brachial collar; G, calyx; H, tentacles.

Fig. 5.† Section of a young specimen, showing the internal structure and the limited extent of the invaginated fold. (Cambridge, Mass.) D, ectocyst; E, endocyst; B, invaginated fold; Y, bud; N, anterior retentors; K, œsophagus; H″, cilia; K‴, œsophagal valve; K′, stomach; K⁗, position of intestinal valve; K″, intestine; K̄, anus; I, lophophore; I′, epistome; I″, mouth; H, tentacles; F, brachial collar; S, nerve mass.

Fig. 6.‡ Lateral view of an invaginated specimen, showing the shape of the cœnœcial orifice. A⁗, orifice; L, region of the sphincter; D, ectocyst; E, endocyst.

Fig. 7. View of the same from above.

Fig. 8. Front view of a zoöid, showing the incipient arms and the relative positions of the muscles. M′, lophophoric retractors; M″, brachial retractors; I′, epistome.

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*This figure was drawn and presented to me by Mr. Mcrse.

†This figure is part of a study drawing made by Prof. H. J. Clark, and obligingly placed at my disposal by him.

‡All figures with no locality mentioned must be referred to the habitat last named; thus in Pl. 7, Figs. 6, 7 and 8 are all from the same locality as Fig. 5.

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PLATE 8.

PLUMATELLA ARETHUSA Hyatt.

Fig. 1. General view of one colony, life size, with most of the polypides retracted. (Norway, Me.) Three apertures in the ectocyst of the main trunk indicate the former positions of as many living polypides, and show this colony to have been a branch of a much larger colony, from which it has been separated by the death and disappearance of the original stock.

Fig. 2. One polypide evaginated, with a younger polypide from the same cell invaginated. D, ectocyst, E, endocyst; Y, bud; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; M̃, trunks of the retractors. F, brachial collar; V, funiculus; W, statoblasts; W‴, gelatinous envelope; N, anterior retentors; N′, posterior retentors; A‴, cœnœcial orifice; L, region of the sphincter.

Fig. 4. View of the cœnœcial orifice of fig. 2, from above, showing the four broad plications of the invaginated fold. The crenulations on the border are produced by the contraction of the sphincter, and do not indicate cellular structure.

Fig. 5. Special view, showing the arrangement of the retentor muscles around the invaginated fold of the evaginated zoöid in fig. 2. The five anterior rows of the posterior retentors are contracted, and have drawn the external wall into five slightly crenulated folds. N, anterior retentors; N′, posterior retentors; L, region of the sphincter.

Fig. 6. View of the partial division between the cell of fig. 2 and the preceding polypides, formed by an infolding and thickening of the endocyst. D, ectocyst; E, endocyst.

Figs. 7, 8, 9. Upper and lower sides and profile view of the statoblast. W′, horny sheath; W″, annular sheath; W‴, gelatinous envelope.

Fig. 10. View of a dead and half decayed specimen, showing the peculiar constrictions of the cell occasioned by annular muscular bands. D, ectocyst; E, endocyst; H, tentacles; I″, mouth; L, region of the sphincter; K′, stomach; M̃, trunk of the retractors.

PLUMATELLA DIFFUSA Leidy.

Fig. 11. An old colony of life size, with but few living polypides. (Cambridge, Mass.)

Fig. 12. Enlarged lateral view of a branch from a younger colony, showing different degrees of invagination. First cell on the left has even the upper pliable part of the ectocyst drawn in; second cell is vacant, the polypide and softer parts having entirely decayed; third, fourth and sixth cells show different degrees of invagination.

Fig. 13. Enlarged view of another variety of this species with all the polypides retracted.

Fig. 14. Enlarged ventral view of the expanded crest of a polypide from fig. 13. M′, lophophoric retractor; M″, brachial retractors.

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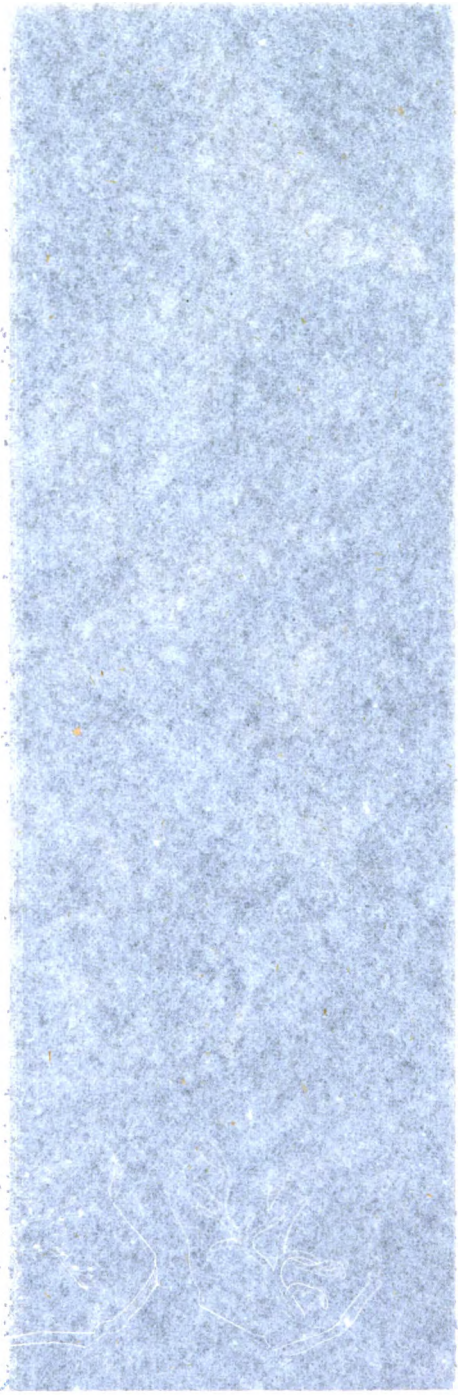

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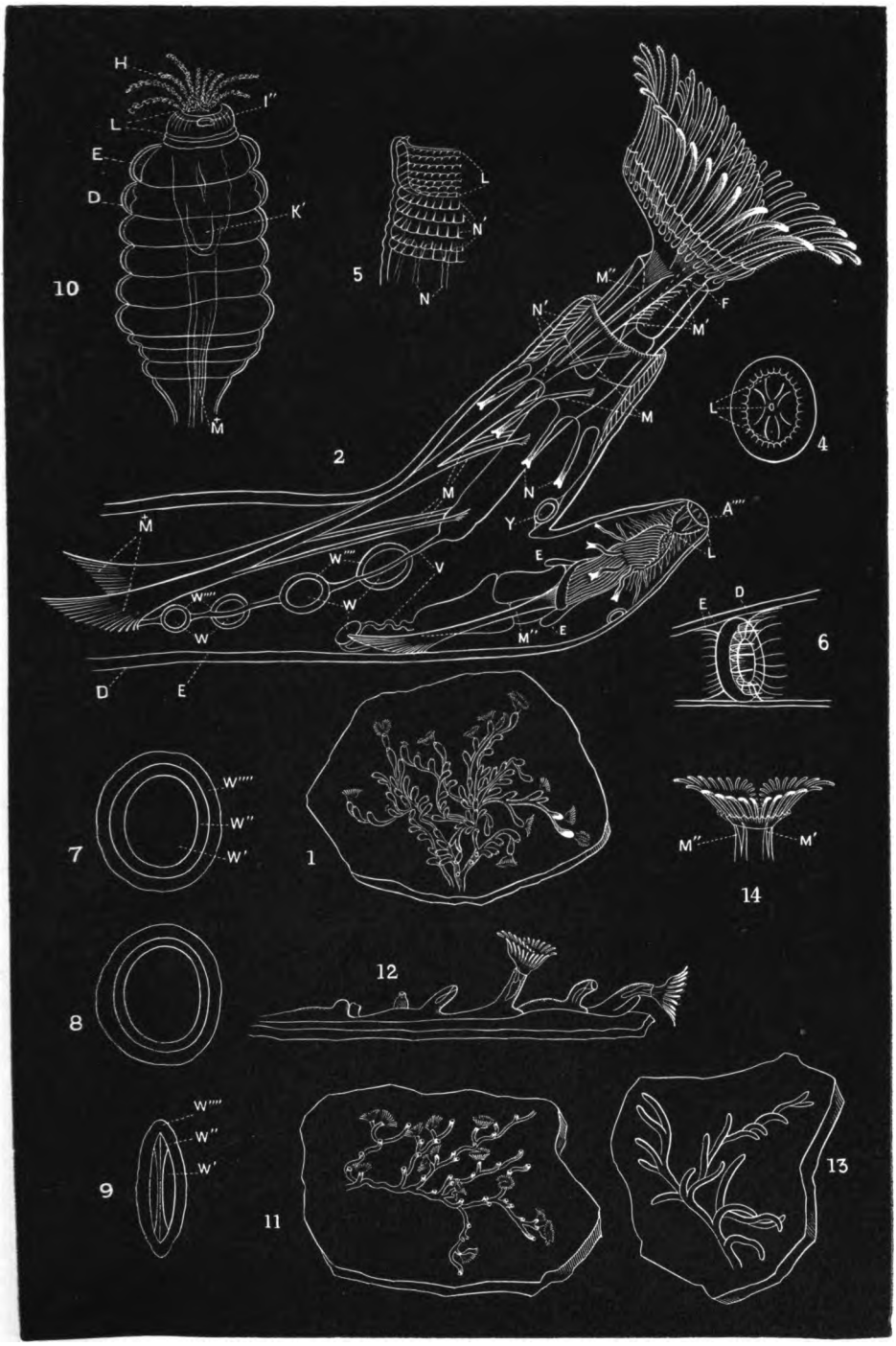

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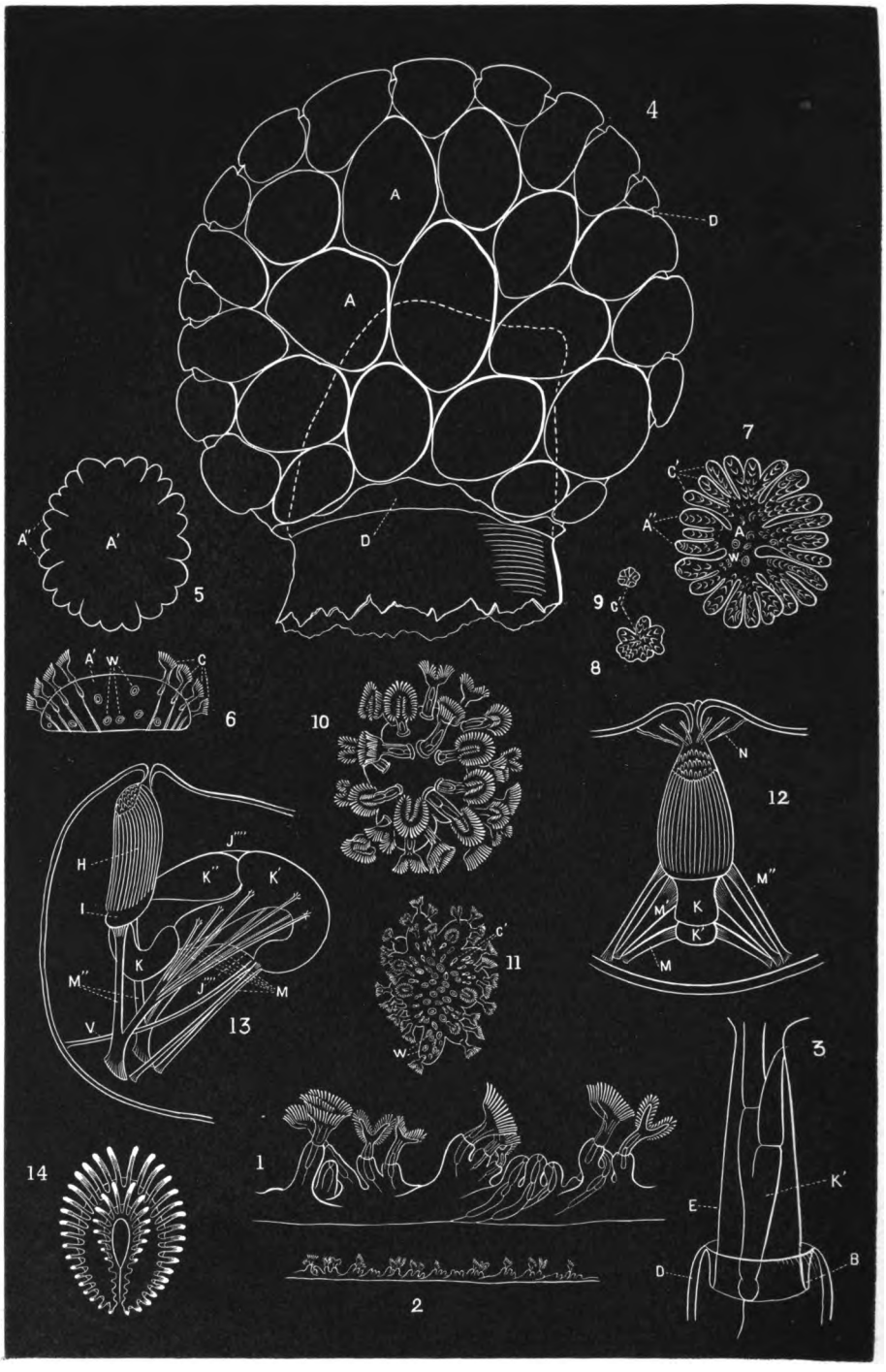

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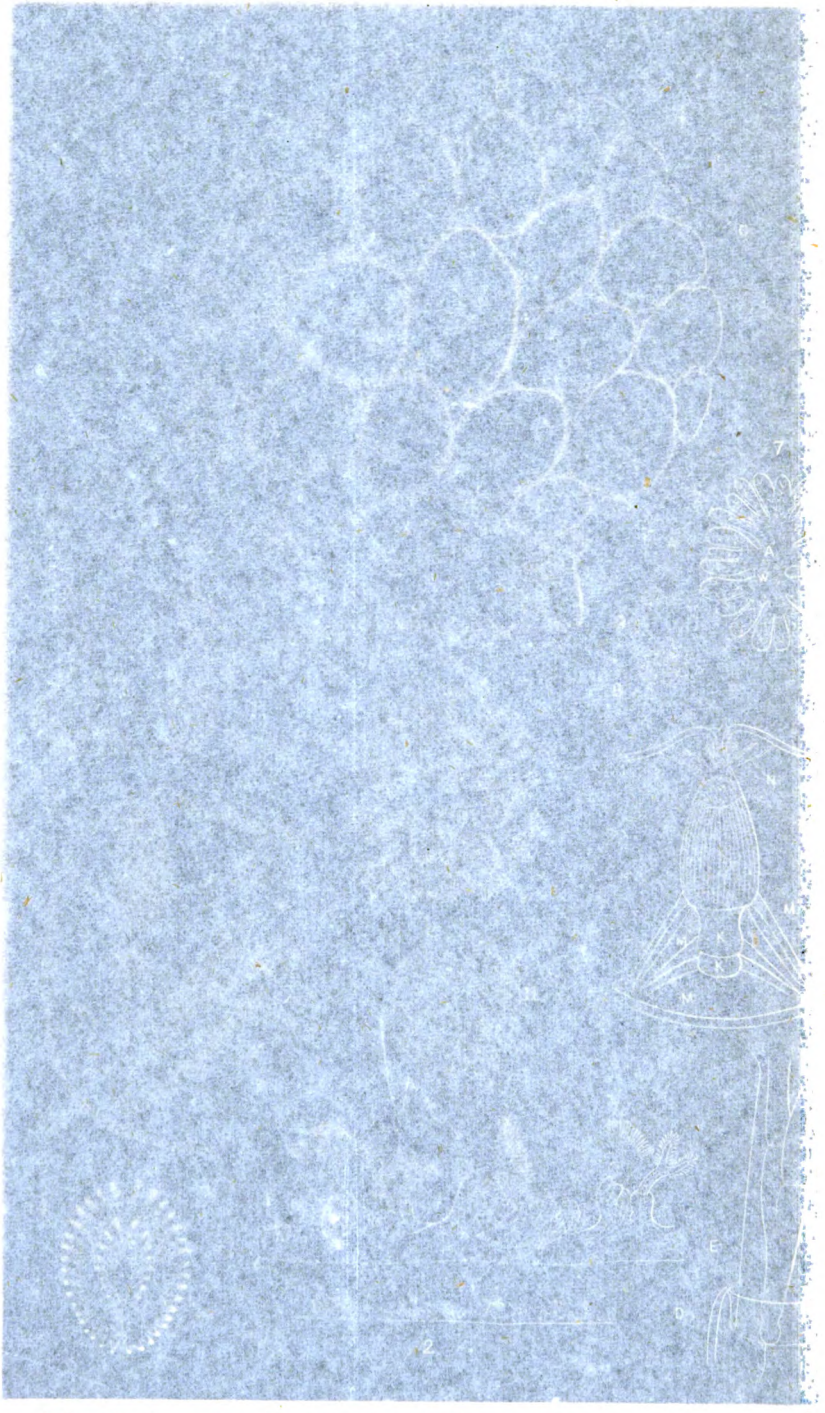

PLATE 9.

PLUMATELLA VITREA Hyatt.

Fig. 1. Enlarged view of five groups on one branch, corresponding to the first five on the left of the branch below, fig. 2. (Cambridge, Mass.)

Fig. 2. View of one branch, natural size.

Fig. 3. Shows the great extent to which the polypide is often evaginated. D, ectocyst; E, endocyst; B, invaginated fold; K′, stomach.

PECTINATELLA MAGNIFICA Leidy.

Fig. 4. Outline of a mass gathered on the stump of a dead branch. (Norway, Me.) The outline of the branch where it is covered by the mass, is indicated by a dotted line. This figure shows the general aspect of the mass, the great thickness of the ectocyst, and the general arrangement of the colonies. A, outlines of cœnœcia; D, ectocyst.

Fig. 5. The outline of a colony, natural size, from a large mass, showing the radiating and tripartite character of the lobes. A′, cœnœcial trunk; A″, cœnœcial lobes, divided into three minor lobes.

Fig. 6. Ideal transverse section of the same, with the polypides expanded. W, statoblasts; A′, cœnœcial trunk; C, polypide.

Fig. 7. The colony represented in the outline of fig. 5, after being treated with alcohol. C′, dead and retracted polypides; A′, cœnœcial trunk; A″, cœnœcial lobes; W, statoblasts.

Fig. 8. Younger colony, showing the central polypide.

Fig. 9. Young colony, showing the genesis of five polypides, the progenitors of an equal number of branches, from the central polypide.

Fig. 10. A young colony enlarged, showing the arrangement of the polypides. (Cambridge, Mass.)

Fig. 11. A very old colony; the cœnœcial trunk occupied by numerous statoblasts, and the half absorbed remains of dead polypides. W, statoblasts; C′, dead polypides.

Fig. 12. Ventral view of a closely retracted polypide, showing the positions and relations of the three pairs of retractors. (Norway, Me.) K′, bottom of the stomach; K, part of the œsophagus; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors.

Fig. 13. Lateral view of a retracted polypide, showing the aspect of the fourth membrane and of the retractors during the process of invagination. J″″, fourth membrane of the alimentary canal; M, gastric retractors; M″, brachial retractors; V, funiculus; K, œsophagus; K′, stomach; K″, intestine; I, lophophore; H, tentacles.

CRISTATELLA OPHIDIOIDEA Hyatt.

Fig. 14. View from above of the lophophore of an immature polypide. The arms are still joined near the extremities, and the tentacles and calyx along the line of the juncture remain undeveloped. (Norway, Me.)

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PLATE 10.

PECTINATELLA MAGNIFICA Leidy.

Fig. 1. Enlarged view of one polypide situated at the end of a lobe. (Norway, Me.) The full adult growth of the terminal tentacles is not yet attained. They become about one-third longer in the adult. A″, cavity of the cœnœcial lobe; D, common ectocyst; E, endocyst of the cœnœcium and polypide; J̄, hepatic folds; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors; N′ posterior retentors.

Figs. 2, 3, 4. The upper and lower side, and profile of the statoblast. W′, horny sheath; W″, annular sheath; W‴, spines.

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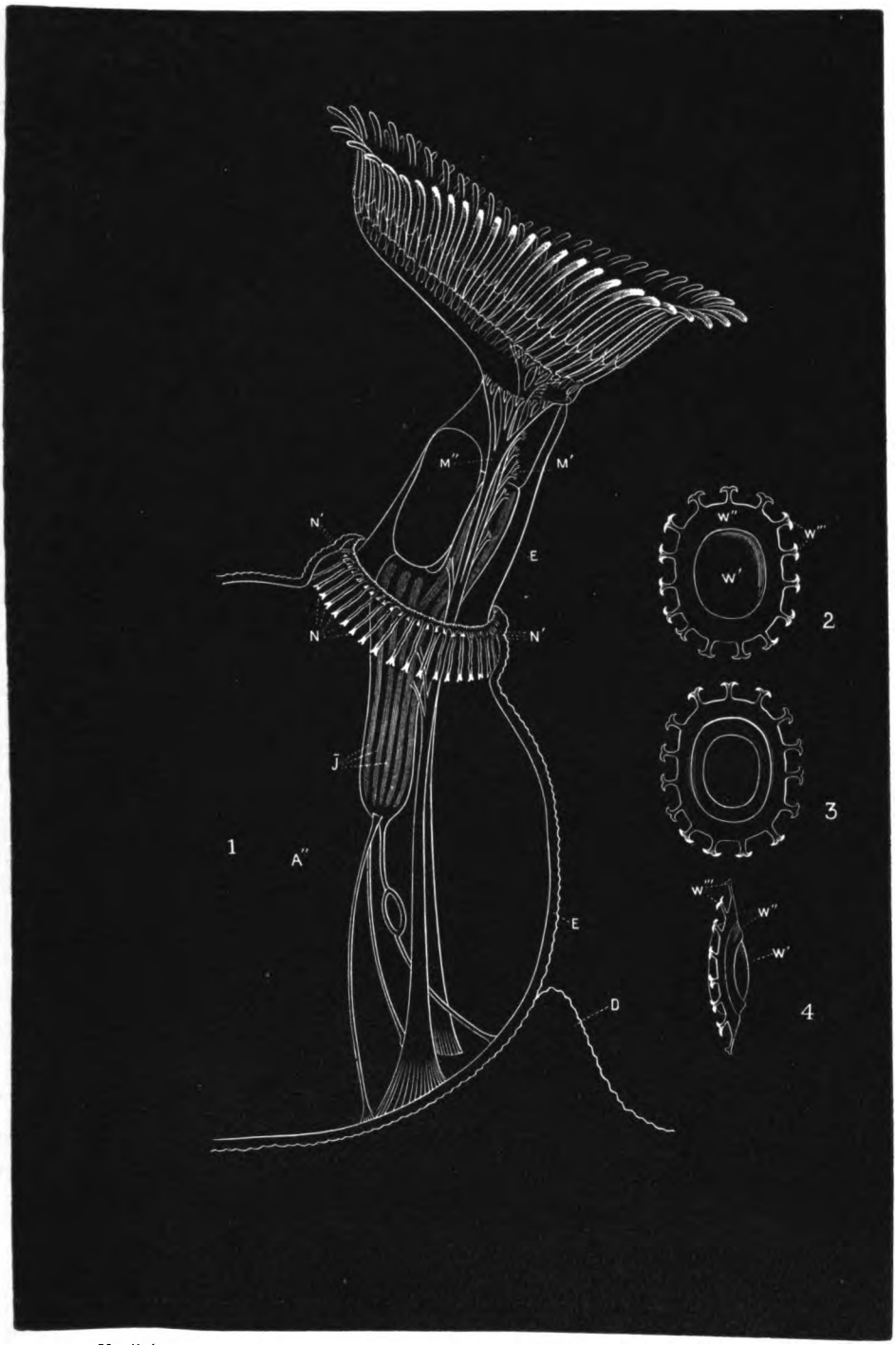

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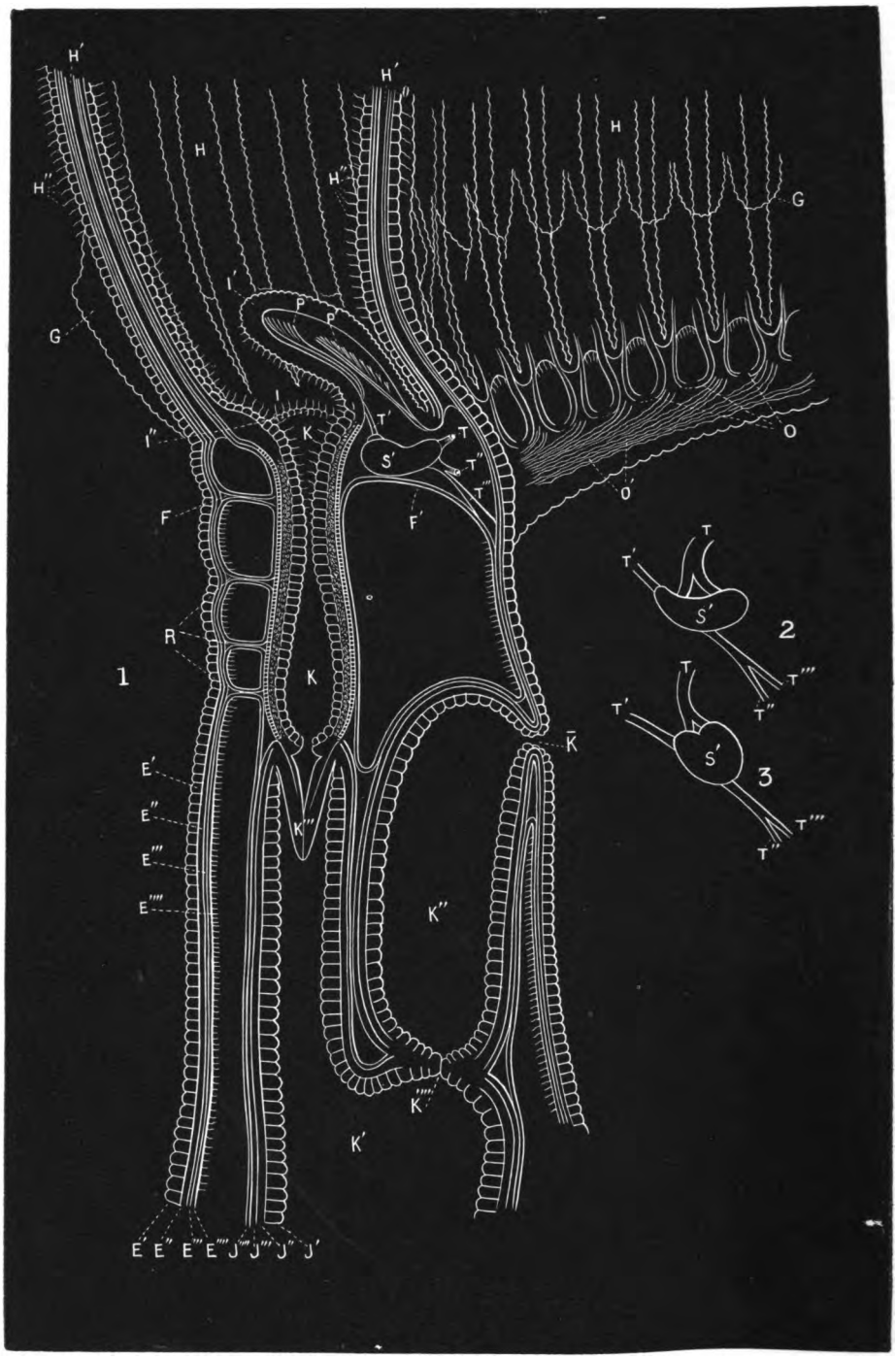

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PLATE 11.

PECTINATELLA MAGNIFICA Leidy.

Fig. 1.* Enlarged longitudinal section exhibiting a portion of the left arm and the left side of the body, of a polypide. The ganglion, however, is from the right side of the body, towards the observer, and is supposed to be pressed inwards, and away from the observer, in order to show its relation to the neural partition and the polypidal nerve. (Norway, Me.) H, tentacles; H′, tubular interior of the tentacles; G, calyx; H″, cilia; O, bases of the outer tentacular bands; O′, fibres of the inner tentacular bands, seen from the outside; I′, epistome; P, one-half of the median muscle of the epistome; P′, left lateral muscle of the epistome; R, parietal fibres, probably abnormal, enveloped by the fourth membrane; I, lophophore; I″, mouth; E′ the first, E″, the second, E‴, the third, and E⁗, the fourth membrane of the endocyst; F, brachial collar; F′ neural partition; K, œsophagus; K′, stomach; K″, intestine; K‴, œsophagal valve; K⁗, intestinal valve; K̃, anus; J′, the first, J″, the second, J‴, the third, and J⁗, the fourth membrane of the alimentary canal; S′, right ganglion; T, right lophophoric nerve trunk severed near the base; T′, right epistomical nerve trunk; T″, right brachial nerve trunk severed near the base; T‴, right polypidal nerve trunk.

Fig. 2. Enlarged ganglion of another specimen from the same colony as fig. 1, showing the extreme variability of the ganglia and nerve trunks. T, right lophophoric nerve trunk; T′, right epistomical nerve trunk; T″, right brachial nerve trunk; T‴, right polypidal nerve trunk.

Fig. 3. Shows the same ganglion contracted, the nerve trunks indicated by the same letters.

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*This figure is composed from numerous drawings of different individuals. The number of the membranes in the tentacles, as has been explained in the text, was inferred but not observed.

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PLATE 12.

PECTINATELLA MAGNIFICA Leidy.

Fig. 1.* Front view of a polypide much enlarged, with the arms removed, showing the under side of the lophophore. (Norway, Me.) E, endocyst; B, invaginated fold; H′, tubular base of the tentacles; $\bar{Z}$, clear spaces in the endocyst; L′, brachial contractors; $\bar{M}$, position of the lophophoric flexor; I′, outline of the epistome; S, nerve mass; T, lophophoric nerve trunks; T″, brachial nerve trunks; T‴, polypidal nerve trunks; K, œsophagus; K‴, œsophagal valve; K′, stomach; K⁗, intestinal valve; K″, intestine; $\bar{K}$, anus; M′, lophophoric retractor; M″, brachial retractors; F, brachial collar; N, anterior retentors; N′, posterior retentors.

Fig. 2. Lateral view of a portion of the inside of one of the arms, showing the fibres of the inner and outer tentacular bands. H, bases of the tentacles; $\bar{Z}$, clear spaces in the endocyst; I, lophophore; E′, the first, E″, the second, E‴, the third, and E⁗, the fourth membrane of the endocyst; O, bases of the outer tentacular bands; O′, fibres of the inner tentacular bands. The third membrane, E‴, is lifted from the second, E″, by the action of the lower fibres of the brachial contractor, which also form the knee-like ridge at L′.

* This figure is composed from numerous drawings of different individuals.

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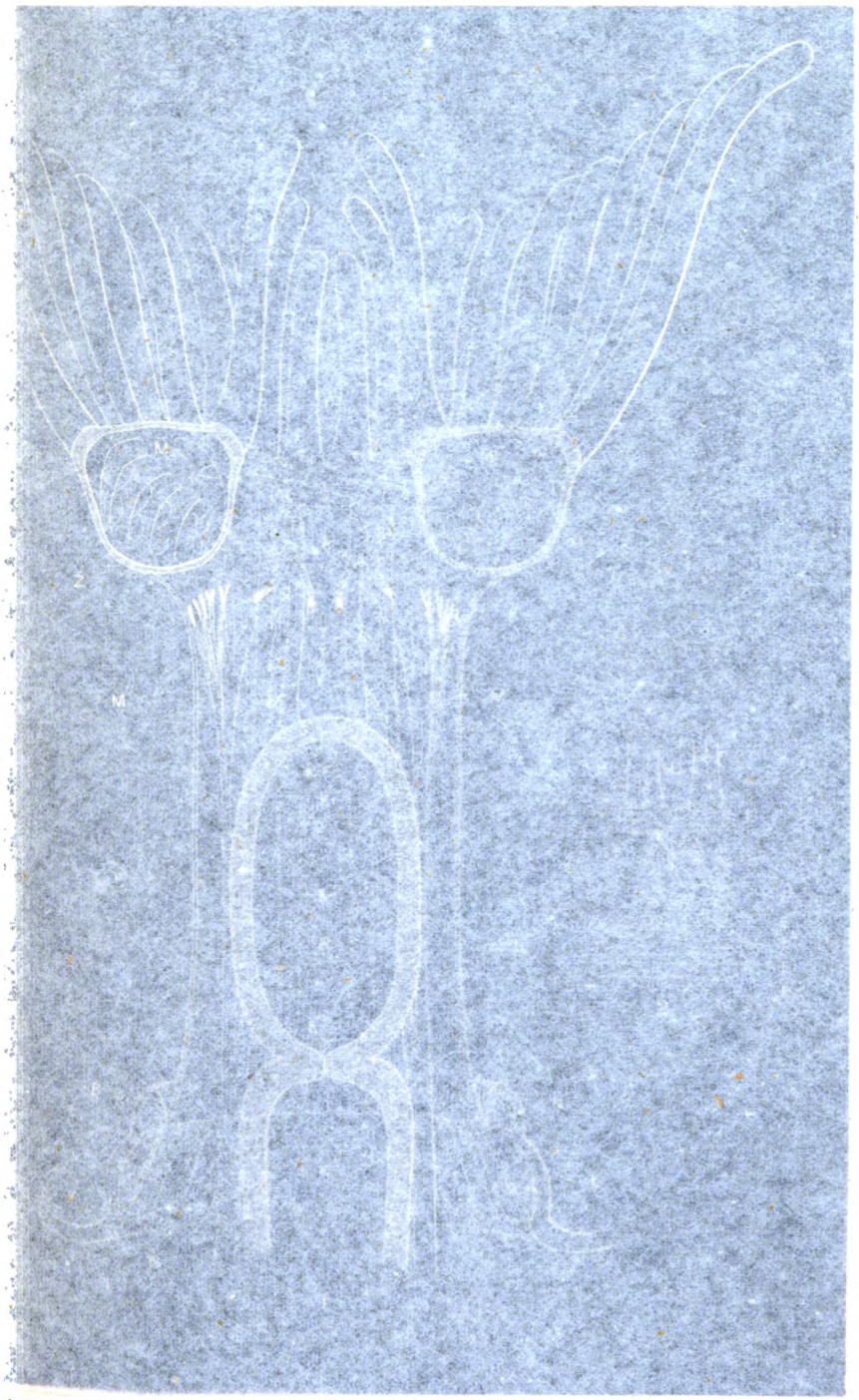

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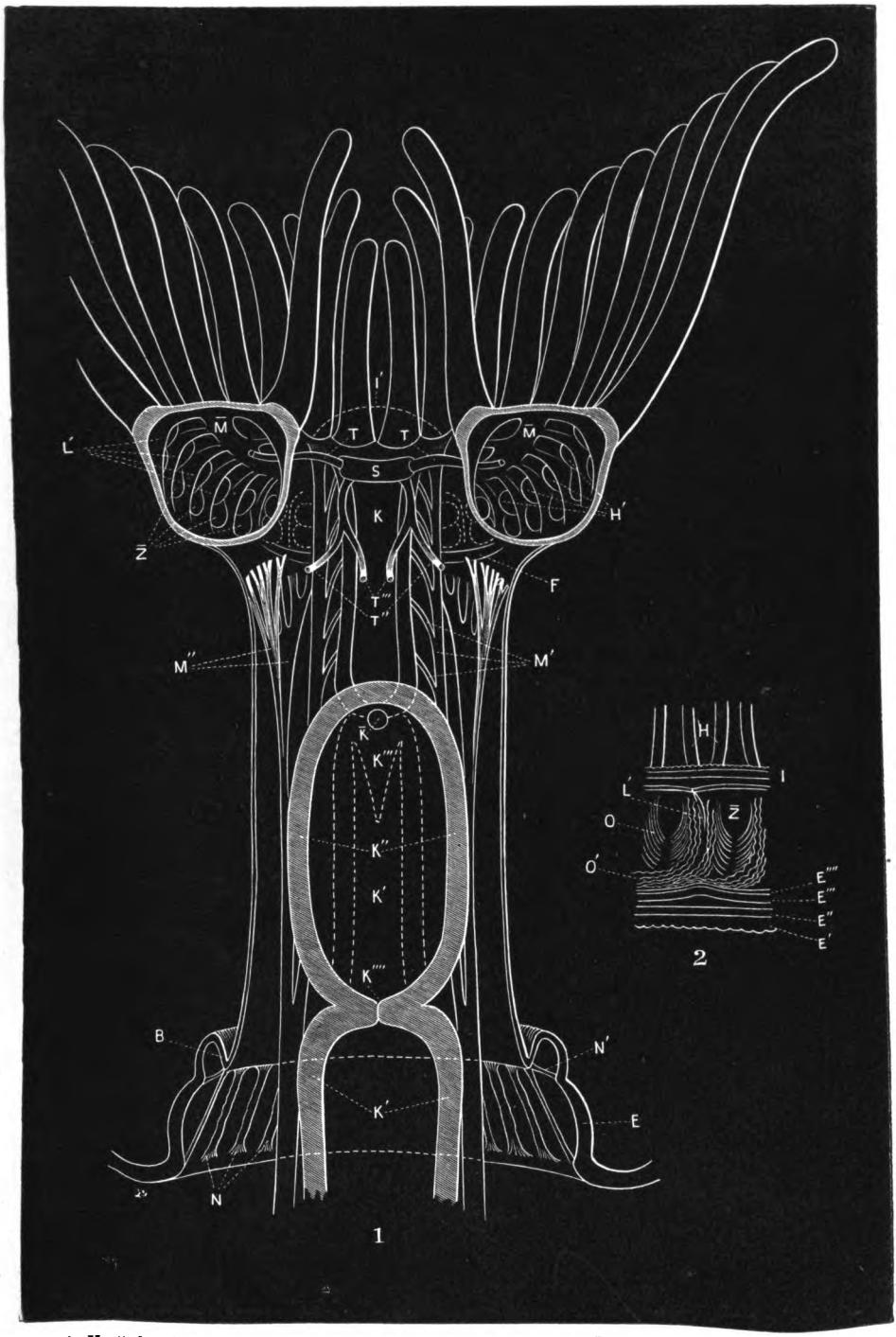

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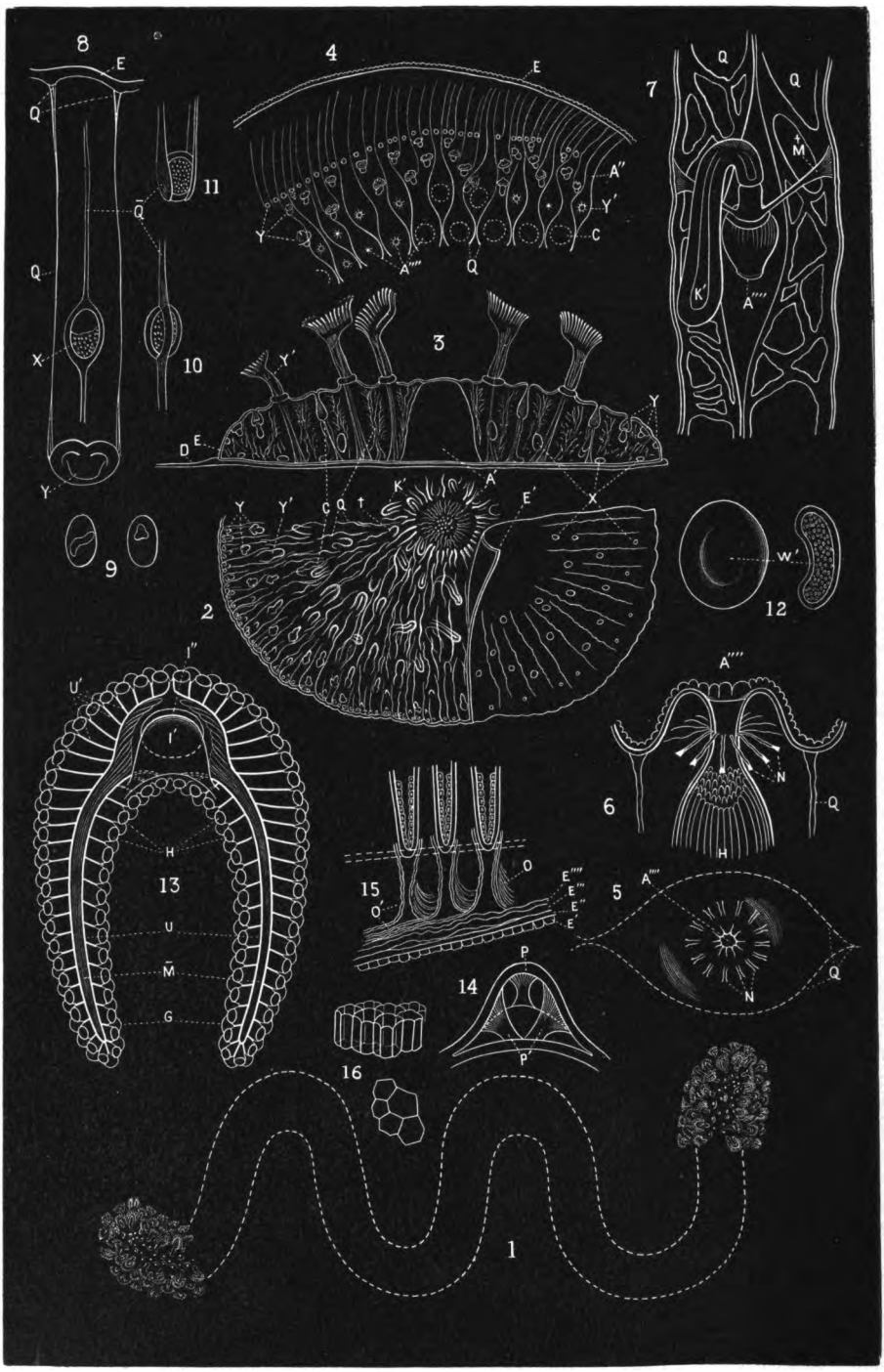

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PLATE 13.

CRISTATELLA OPHIDIOIDEA Hyatt.

Fig. 1. A colony of natural size in its natural position. The polypides are figured at the ends only, the outline of the colony between them being indicated by dotted lines. (Norway, Me.)

Fig. 2. Enlarged view of the underside of one-half of a young colony with the ectocyst and endocyst removed from a portion of the base, disclosing the stomachs of the polypides and the bases of the muscular walls. On the border are the buds attached to the upper side of the endocyst, and in the centre is the inverted cone formed by the interior edges of the muscular walls. On the left, the uncovered portion, the white lines show the positions of the muscular walls, but on the right, the covered portion, they show only the temporary external folds of the endocyst caused by the contraction of the cœnœcium. The relations and positions of all these parts are best explained by reference to the ideal section of this colony, as depicted in fig. 3, the lettering being the same in both; with the exception of K′, stomachs of adult polypides partially retracted, and †, stomach of an evaginated polypide in fig. 2; and D, ectocyst in fig. 3.

Fig. 3.* E, endocyst; C, stomach of polypides wholly retracted; Q, muscular walls; Y, buds; Y′, immature polypides, capable of evagination;† X, fixed statoblasts; A′, cœnœcial trunk.

Fig. 4. View from above of a portion of the border of the same colony when expanded to about twice the vertical height of fig. 3. Lettering same as in preceding figures, with the exception of A″, cœnœcial tubes, and A‴, cœnœcial orifices. Some of the latter are closed, and some, indicated by dotted lines, are open; the polypides, however, are omitted from the latter, in order to give a better view of the cœnœcium.

Fig. 5. Enlarged cœnœcial cell of the first row, the orifice closed over the invaginated polypide. A‴, cœnœcial orifice; Q, attachments of the muscular walls of the cell; N, anterior retentors.

Fig. 6. Transverse section of the same, viewed from the ventral side. A‴, cœnœcial orifice; Q, muscular walls; N, anterior retentors; H, tentacles.

Fig. 7. View of a fully invaginated polypide of the first row, from below, with the endocyst removed from that side. The gastric and part of the lophophoric retractors, have been entirely omitted. A‴, cœnœcial orifice; Q, muscular walls; M, trunk of retractor muscles; K′, stomach.

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* When this figure was drawn, I had, as I supposed, observed three rows of full grown polypides on the cœnœcium as in fig. 2. This, however, is probably erroneous, and I doubt whether at any time of the life of the colony, there are more than two living rows of fully grown polypides and one row of immature polypides. In this section, therefore, the innermost rows should have been represented in a retracted condition, the polypides dead and partly absorbed.

† For a magnified view of crest from above, see Pl. 9, fig. 14.

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Fig. 8. A tube isolated and viewed from the lower side. Y, bud attached to the upper endocyst; X, young, fixed statoblast attached to the lower endocyst; Q, cœnœcial walls; $\bar{Q}$, base of membranous ridge; E, endocyst.

Fig. 9. Two figures of the same statoblast, showing the variations in the form and position of the vacant spot in the statoblast of fig. 8.

Fig. 10. View of the same from the upper side, showing the membranous ridge crossing the statoblast and apparently connecting with the endocyst on the upper side.

Fig. 11. An older specimen, in which the ridge has formed a tube.

Fig. 12. A still older specimen, from the interior of the cœnœcium, showing the elliptical depression in the horny sheath.

Fig. 13. View of the lophophore from above, with the tentacles and calyx removed, showing the distribution of the nerves. H, bases of the tentacles; G, calyx; $\bar{M}$, lophophoric flexor; U, lophophoric nerve branches; U′, tentacular nerve branches; I′, epistome; I″, mouth.

Fig. 14. Epistome isolated and viewed from above, showing the muscles. P, median muscle; P′, lateral muscles.

Fig. 15. Lateral view of a portion of the interior of one arm with the lophophore removed, showing the outer and inner tentacular bands, and the membranes of the endocyst in an alcoholic specimen. O, outer tentacular bands; O′, inner tentacular bands.

Fig. 16. Direct and profile views of a group of cells from the first membrane of the cœnœcial endocyst of fig. 2.

PLATE 14.

CRISTATELLA OPHIDIOIDEA Hyatt.

Fig. 1. Magnified view of an adult polypide in its cell. E, endocyst; Q, muscular walls of the cell; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors; $\bar{Z}$, clear spaces in the endocyst between the bases of the outer tentacular bands; O, bases of outer tentacular bands.

Figs. 2, 3, 4. Upper and lower side, and profile view of statoblast. W′, horny sheath; W″, annular sheath; W‴, spines. Of the last, there are in nature twenty-two short, and thirty-two long ones.

Fig. 5. View of the anus, showing its oblate form, and also the great breadth of the intestine, when compared with the œsophagus and the upper part of the stomach in the back ground; K, œsophagus; K′, stomach; K″, intestine; $\bar{K}$, anus.

Fig. 6. Section of stomach, showing the hepatic folds. $\bar{J}$, hepatic folds.

Fig. 7. Oblique view of the tip of a tentacle, showing the fan-shaped attachments of the tentacular bands.

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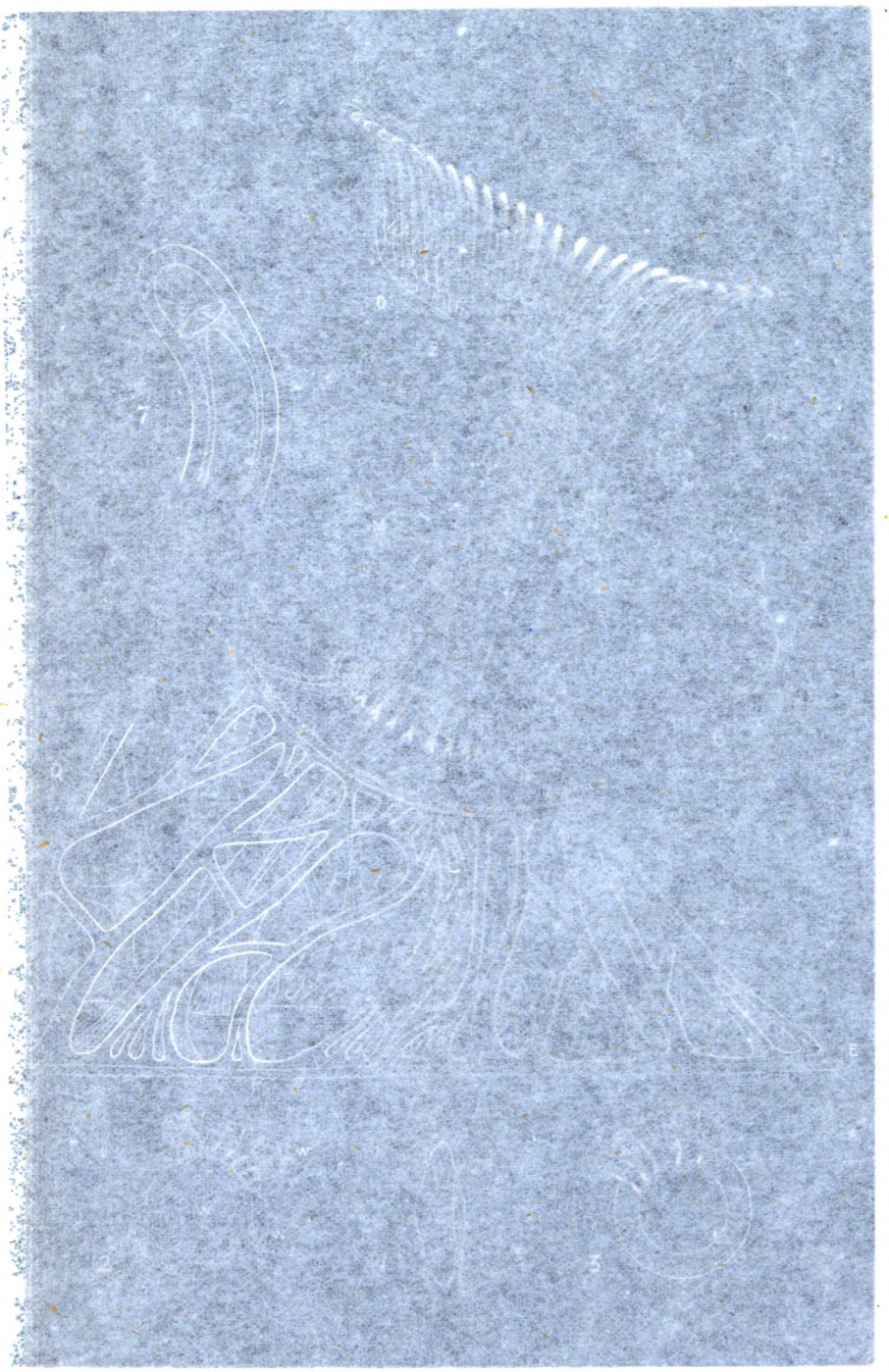

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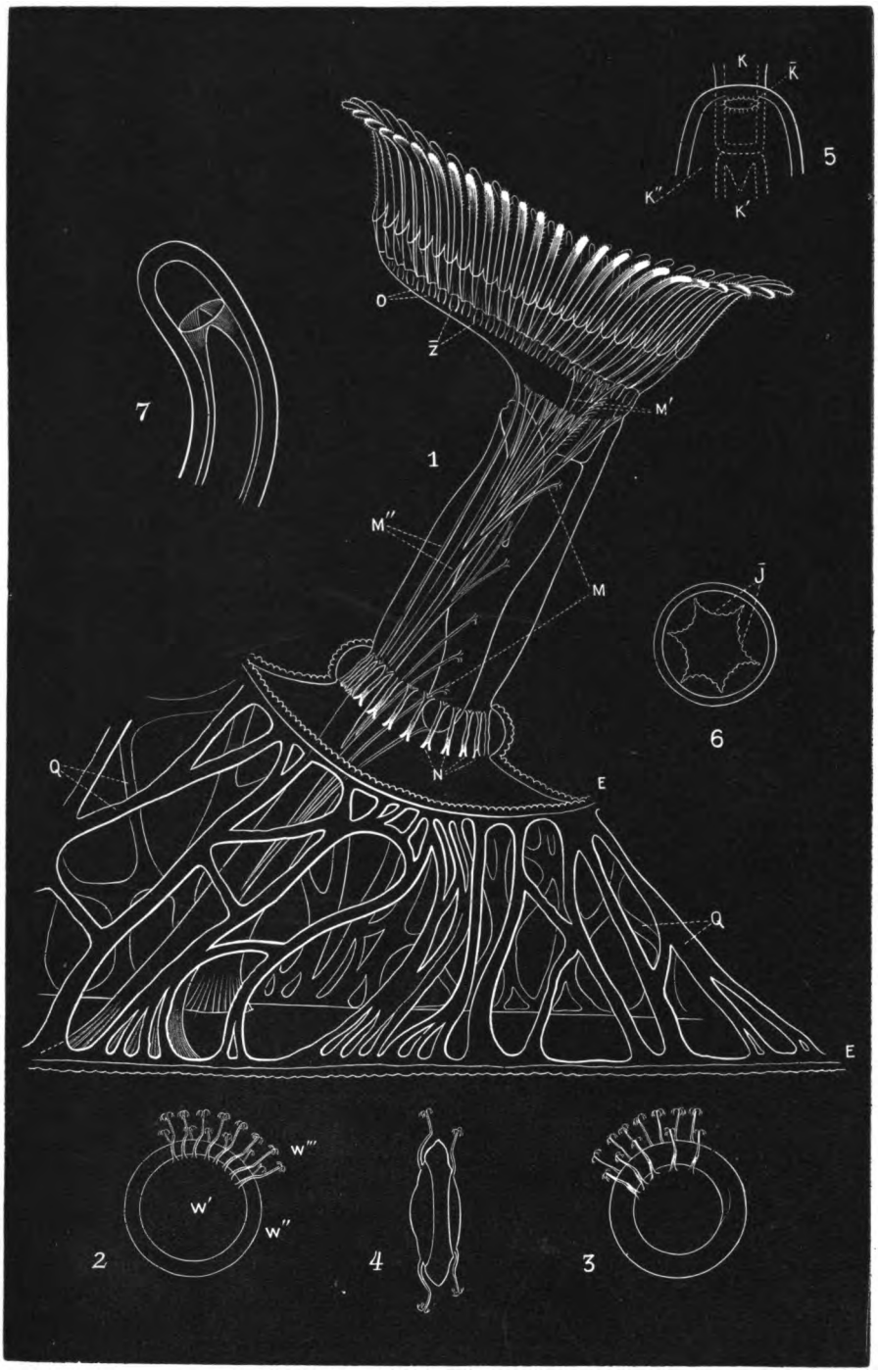

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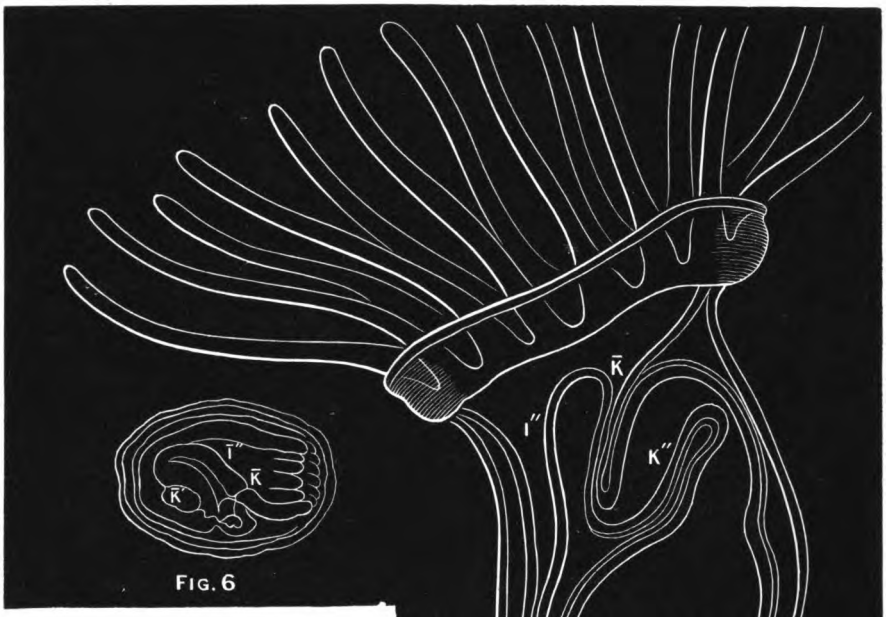

FIG. 6

FIG. 5

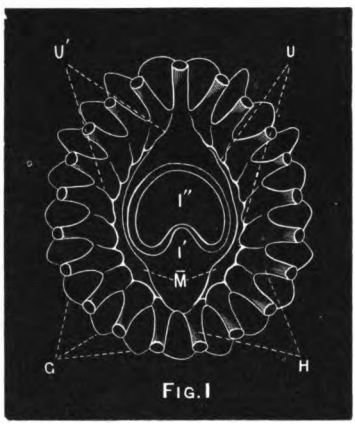

FIG. 1

FIG. 3

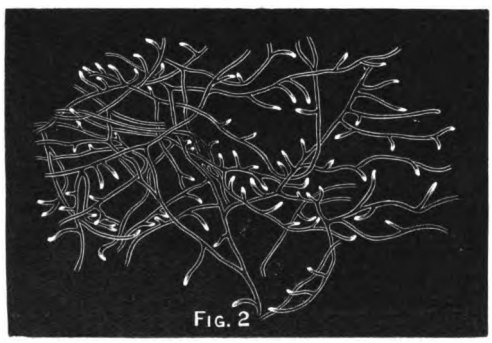

FIG. 2

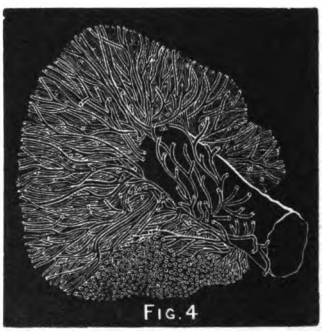

FIG. 4

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PLATE 15.

FREDERICELLA REGINA Leidy.

Fig. 1. View of lophophore from above with the tentacles removed, showing the nerves. G, calyx; H. tentacles; I′, epistome; I″, mouth; M′, lophophoric flexor; U, lophophoric nerve-branches; U′ tentacular nerve-branches.

Fig. 4. Alcyonelloid variety from Tommy's Brook, Gorham, Maine. The appearance of the surface of the colony is shown on the left of the figure, the branches having been all removed in front in order to exhibit the arrangement of the branches and their connection with the wooden stem around which they grew.

FREDERICELLA WALCOTTII Hyatt.

Fig. 2. Variety *a*, Georgetown, Massachusetts.

FREDERICELLA PULCHERRIMA Hyatt.

Fig. 3. Sebago Lake, Maine.

URNATELLA GRACILIS Leidy.

Figs. 5, 6. Diagrams of figures from one of Dr. Leidy's unpublished lithographic plates, showing the approximation of the mouth and anus. I″, mouth; K′, stomach; K″, intestine; $\overline{K}$, anus. Fig. 6 is a bud and exhibits the relation of these parts in the young.

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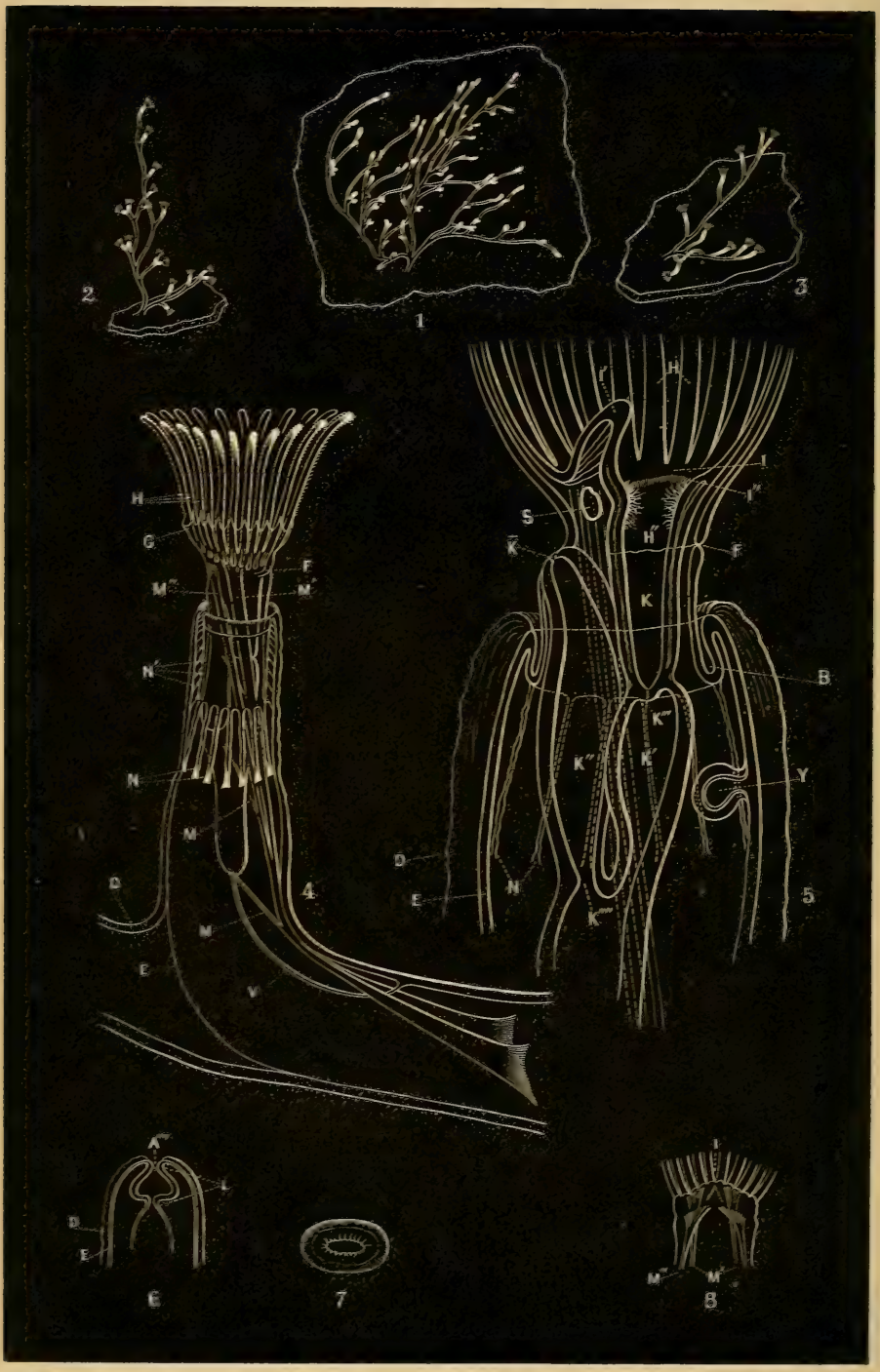

Prof. H. J. Clark, E. S. Morse, and A. Hyatt, from Nat. E. S. Morse, on Wood. J. F. Richardson, Portland, Eng.
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PLATE 7.

FREDERICELLA REGINA Leidy, Mss.

Fig. 1.* One colony, life size, with all the branches attached. (Gorham, Me.)

Fig. 2. Two branches of one colony: one attached and one free. (Cambridge, Mass.)

Fig. 3. Attached branch of one colony. (Gorham, Me.)

Fig. 4. Magnified view of one adult zoöid. (Norway, Me.) D, ectocyst; E, endocyst; V, funiculus; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors; N′, posterior retentors; F, brachial collar; G, calyx; H, tentacles.

Fig. 5.† Section of a young specimen, showing the internal structure and the limited extent of the invaginated fold. (Cambridge, Mass.) D, ectocyst; E, endocyst; B, invaginated fold; Y, bud; N, anterior retentors; K, œsophagus; H″, cilia; K‴, œsophagal valve; K′, stomach; K⁗, position of intestinal valve; K″, intestine; K̄, anus; I, lophophore; I′, epistome; I″, mouth; H, tentacles; F, brachial collar; S, nerve mass.

Fig. 6.‡ Lateral view of an invaginated specimen, showing the shape of the cœnœcial orifice. A⁗, orifice; L, region of the sphincter; D, ectocyst; E, endocyst.

Fig. 7. View of the same from above.

Fig. 8. Front view of a zoöid, showing the incipient arms and the relative positions of the muscles. M′, lophophoric retractors; M″, brachial retractors; I′, epistome.

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*This figure was drawn and presented to me by Mr. Morse.

†This figure is part of a study drawing made by Prof. H. J. Clark, and obligingly placed at my disposal by him.

‡All figures with no locality mentioned must be referred to the habitat last named; thus in Pl. 7, Figs. 6, 7 and 8 are all from the same locality as Fig. 5.

PLATE 8.

PLUMATELLA ARETHUSA Hyatt.

Fig. 1. General view of one colony, life size, with most of the polypides retracted. (Norway, Me.) Three apertures in the ectocyst of the main trunk indicate the former positions of as many living polypides, and show this colony to have been a branch of a much larger colony, from which it has been separated by the death and disappearance of the original stock.

Fig. 2. One polypide evaginated, with a younger polypide from the same cell invaginated. D, ectocyst, E, endocyst; Y, bud; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; M̊, trunks of the retractors. F, brachial collar; V, funiculus; W, statoblasts; W‴, gelatinous envelope; N, anterior retentors; N′, posterior retentors; A‴, cœnœcial orifice; L, region of the sphincter.

Fig. 4. View of the cœnœcial orifice of fig. 2, from above, showing the four broad plications of the invaginated fold. The crenulations on the border are produced by the contraction of the sphincter, and do not indicate cellular structure.

Fig. 5. Special view, showing the arrangement of the retentor muscles around the invaginated fold of the evaginated zoöid in fig. 2. The five anterior rows of the posterior retentors are contracted, and have drawn the external wall into five slightly crenulated folds. N, anterior retentors; N′, posterior retentors; L, region of the sphincter.

Fig. 6. View of the partial division between the cell of fig. 2 and the preceding polypides, formed by an infolding and thickening of the endocyst. D, ectocyst; E, endocyst.

Figs. 7, 8, 9. Upper and lower sides and profile view of the statoblast. W′, horny sheath; W″, annular sheath; W‴, gelatinous envelope.

Fig. 10. View of a dead and half decayed specimen, showing the peculiar constrictions of the cell occasioned by annular muscular bands. D, ectocyst; E, endocyst; H, tentacles; I″, mouth; L, region of the sphincter; K′, stomach; M̊, trunk of the retractors.

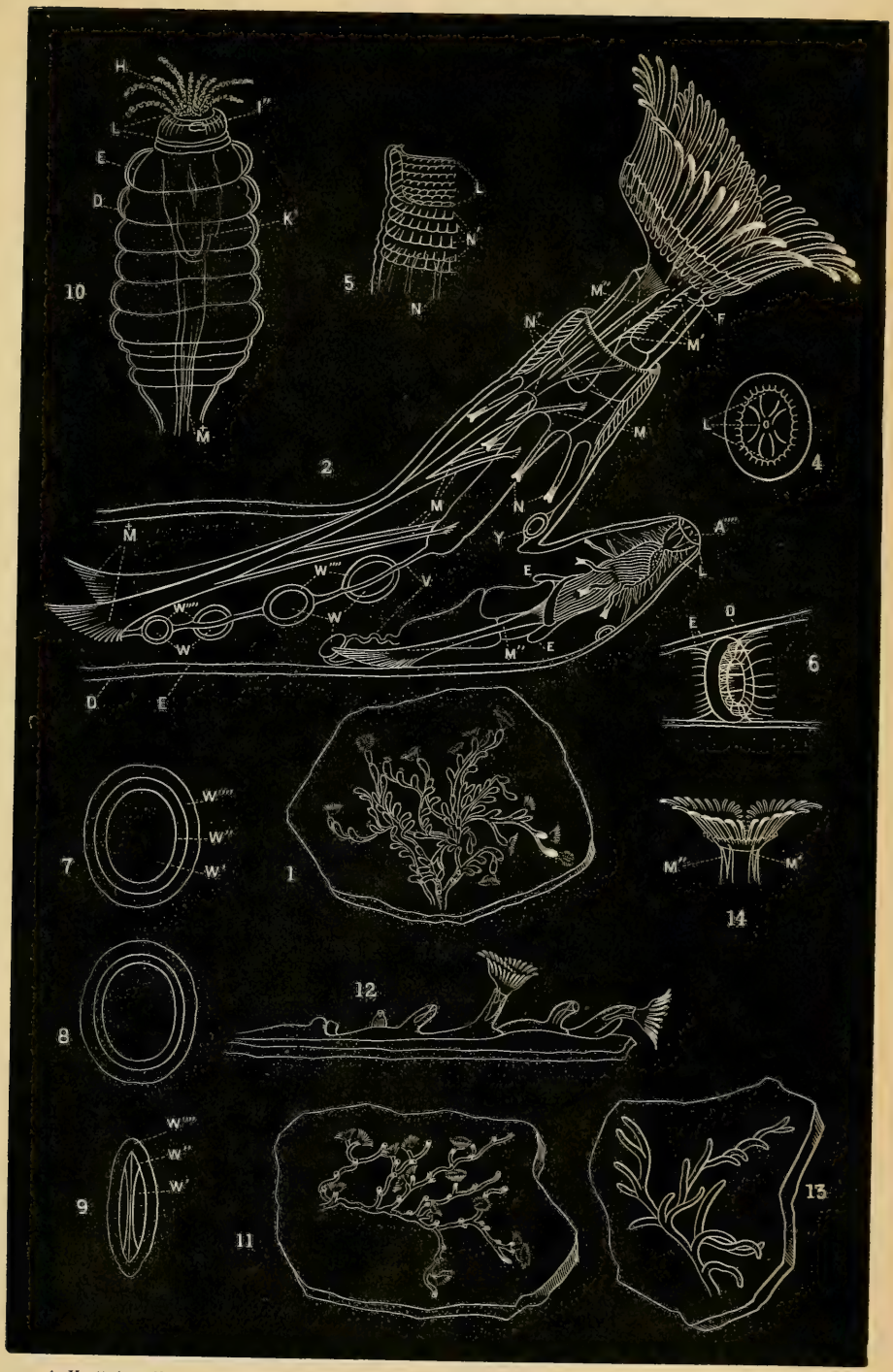
PLUMATELLA DIFFUSA Leidy.

Fig. 11. An old colony of life size, with but few living polypides. (Cambridge, Mass.)

Fig. 12. Enlarged lateral view of a branch from a younger colony, showing different degrees of invagination. First cell on the left has even the upper pliable part of the ectocyst drawn in; second cell is vacant, the polypide and softer parts having entirely decayed; third, fourth and sixth cells show different degrees of invagination.

Fig. 13. Enlarged view of another variety of this species with all the polypides retracted.

Fig. 14. Enlarged ventral view of the expanded crest of a polypide from fig. 13. M′, lophophoric retractor; M″, brachial retractors.



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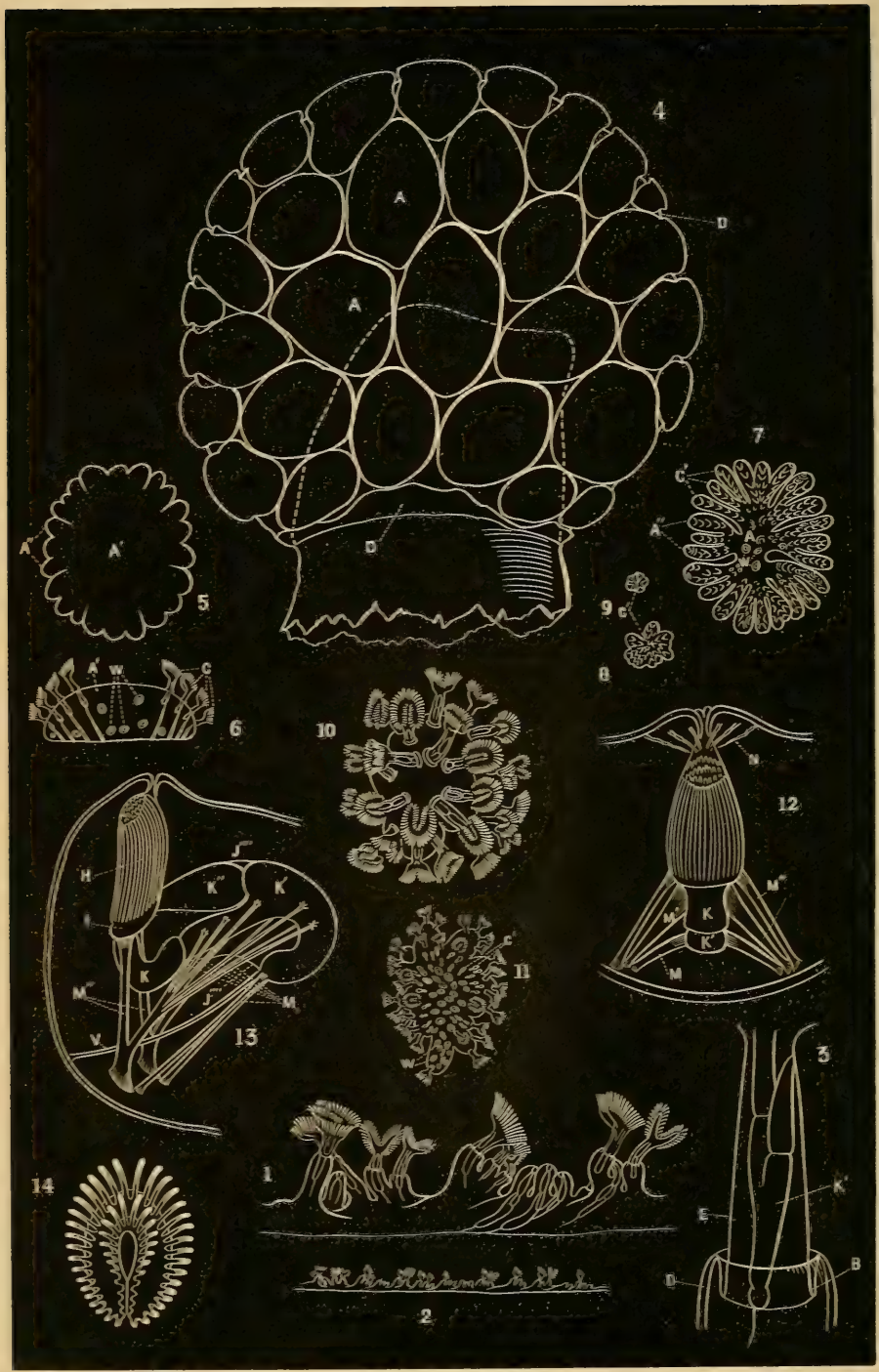

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PLATE 9.

Plumatella vitrea Hyatt.

Fig. 1. Enlarged view of five groups on one branch, corresponding to the first five on the left of the branch below, fig. 2. (Cambridge, Mass.)

Fig. 2. View of one branch, natural size.

Fig. 3. Shows the great extent to which the polypide is often evaginated. D, ectocyst; E, endocyst; B, invaginated fold; K′, stomach.

Pectinatella magnifica Leidy.

Fig. 4. Outline of a mass gathered on the stump of a dead branch. (Norway, Me.) The outline of the branch where it is covered by the mass, is indicated by a dotted line. This figure shows the general aspect of the mass, the great thickness of the ectocyst, and the general arrangement of the colonies. A, outlines of cœnœcia; D, ectocyst.

Fig. 5. The outline of a colony, natural size, from a large mass, showing the radiating and tripartite character of the lobes. A′, cœnœcial trunk; A″, cœnœcial lobes, divided into three minor lobes.

Fig. 6. Ideal transverse section of the same, with the polypides expanded. W, statoblasts; A′, cœnœcial trunk; C, polypide.

Fig. 7. The colony represented in the outline of fig. 5, after being treated with alcohol. C′, dead and retracted polypides; A′, cœnœcial trunk; A″, cœnœcial lobes; W, statoblasts.

Fig. 8. Younger colony, showing the central polypide.

Fig. 9. Young colony, showing the genesis of five polypides, the progenitors of an equal number of branches, from the central polypide.

Fig. 10. A young colony enlarged, showing the arrangement of the polypides. (Cambridge, Mass.)

Fig. 11. A very old colony; the cœnœcial trunk occupied by numerous statoblasts, and the half absorbed remains of dead polypides. W, statoblasts; C′, dead polypides.

Fig. 12. Ventral view of a closely retracted polypide, showing the positions and relations of the three pairs of retractors. (Norway, Me.) K′, bottom of the stomach; K, part of the œsophagus; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors.

Fig. 13. Lateral view of a retracted polypide, showing the aspect of the fourth membrane and of the retractors during the process of invagination. J″″, fourth membrane of the alimentary canal; M, gastric retractors; M″, brachial retractors; V, funiculus; K, œsophagus; K′, stomach; K″, intestine; I, lophophore; H, tentacles.

Cristatella ophidioidea Hyatt.

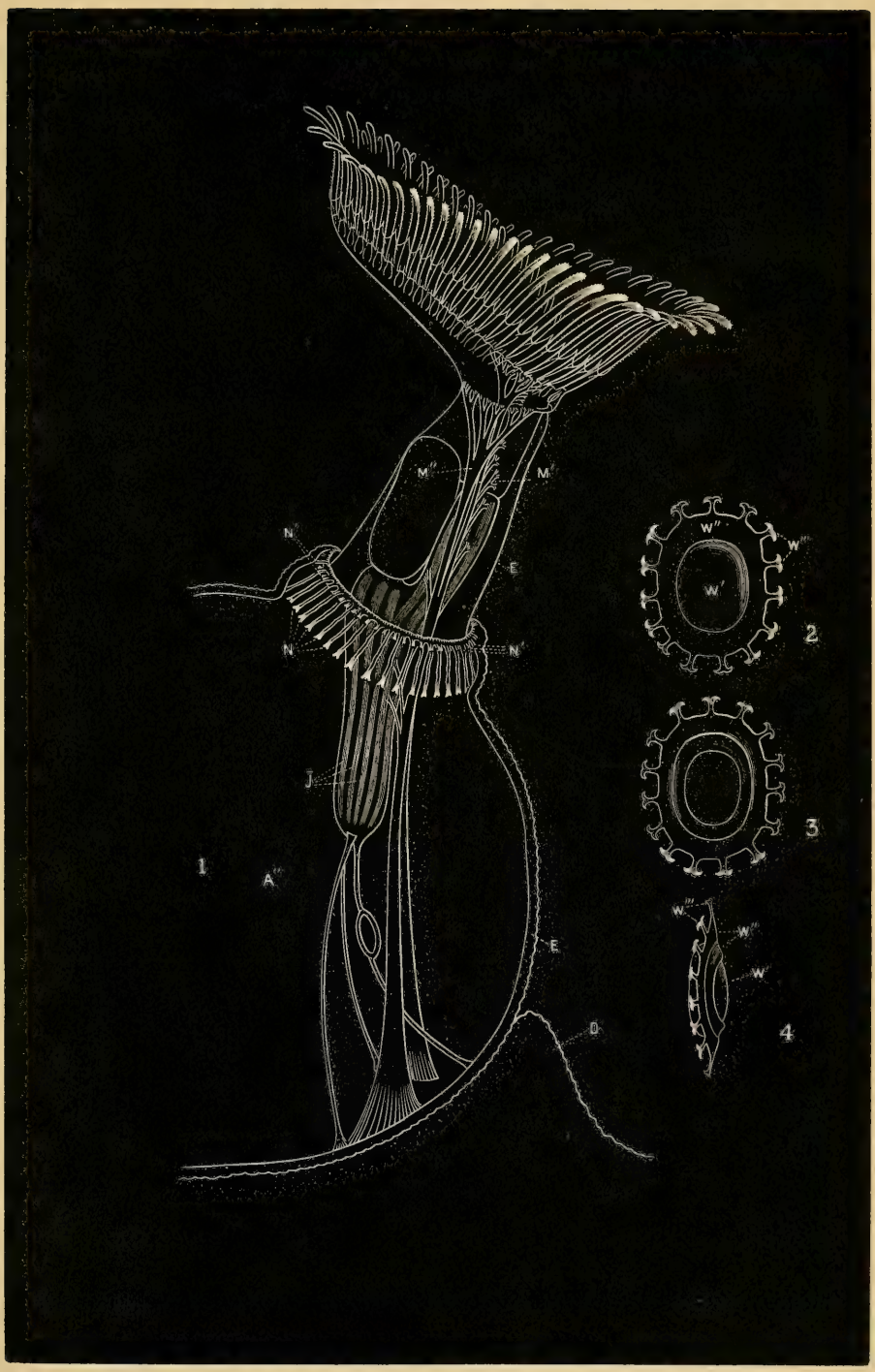
Fig. 14. View from above of the lophophore of an immature polypide. The arms are still joined near the extremities, and the tentacles and calyx along the line of the juncture remain undeveloped. (Norway, Me.)

PLATE 10.

Pectinatella magnifica Leidy.

Fig. 1. Enlarged view of one polypide situated at the end of a lobe. (Norway, Me.) The full adult growth of the terminal tentacles is not yet attained. They become about one-third longer in the adult. A″, cavity of the cœnœcial lobe; D, common ectocyst; E, endocyst of the cœnœcium and polypide; J, hepatic folds; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors; N′ posterior retentors.

Figs. 2, 3, 4. The upper and lower side, and profile of the statoblast. W′, horny sheath; W″, annular sheath; W‴, spines.



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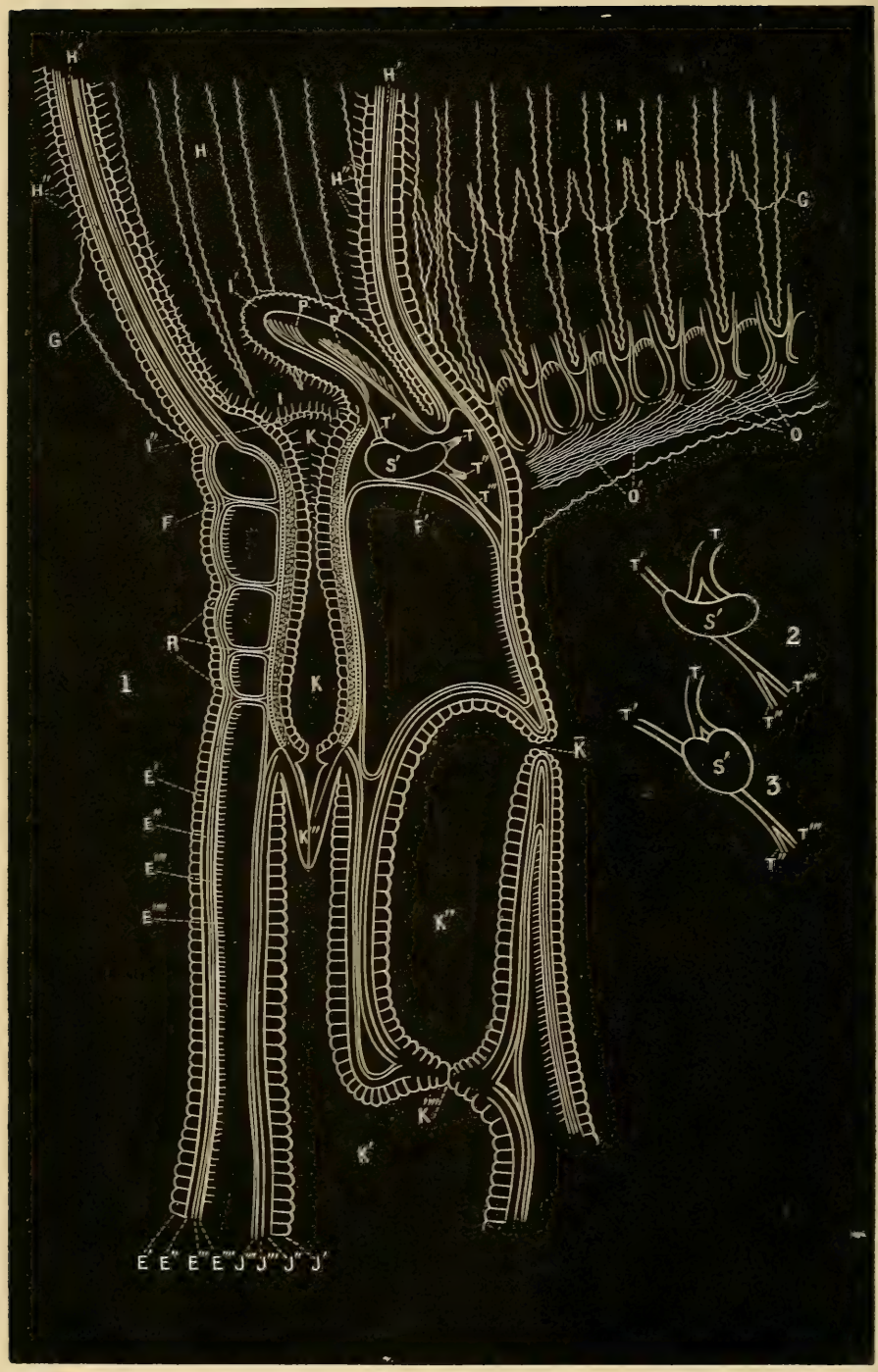

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PLATE 11.

Pectinatella magnifica Leidy.

Fig. 1.* Enlarged longitudinal section exhibiting a portion of the left arm and the left side of the body, of a polypide. The ganglion, however, is from the right side of the body, towards the observer, and is supposed to be pressed inwards, and away from the observer, in order to show its relation to the neural partition and the polypidal nerve. (Norway, Me.) H, tentacles; H′, tubular interior of the tentacles; G, calyx; H″, cilia; O, bases of the outer tentacular bands; O′, fibres of the inner tentacular bands, seen from the outside; I′, epistome; P, one-half of the median muscle of the epistome; P′, left lateral muscle of the epistome; R, parietal fibres, probably abnormal, enveloped by the fourth membrane; I, lophophore; I″, mouth; E′ the first, E″, the second, E‴, the third, and E⁗, the fourth membrane of the endocyst; F, brachial collar; F′ neural partition; K, œsophagus; K′, stomach; K″, intestine; K‴, œsophagal valve; K⁗, intestinal valve; K̄, anus; J′, the first, J″, the second, J‴, the third, and J⁗, the fourth membrane of the alimentary canal; S′, right ganglion; T, right lophophoric nerve trunk severed near the base; T′, right epistomical nerve trunk; T″, right brachial nerve trunk severed near the base; T‴, right polypidal nerve trunk.

Fig. 2. Enlarged ganglion of another specimen from the same colony as fig. 1, showing the extreme variability of the ganglia and nerve trunks. T, right lophophoric nerve trunk; T′, right epistomical nerve trunk; T″, right brachial nerve trunk; T‴, right polypidal nerve trunk.

Fig. 3. Shows the same ganglion contracted, the nerve trunks indicated by the same letters.

*This figure is composed from numerous drawings of different individuals. The number of the membranes in the tentacles, as has been explained in the text, was inferred but not observed.

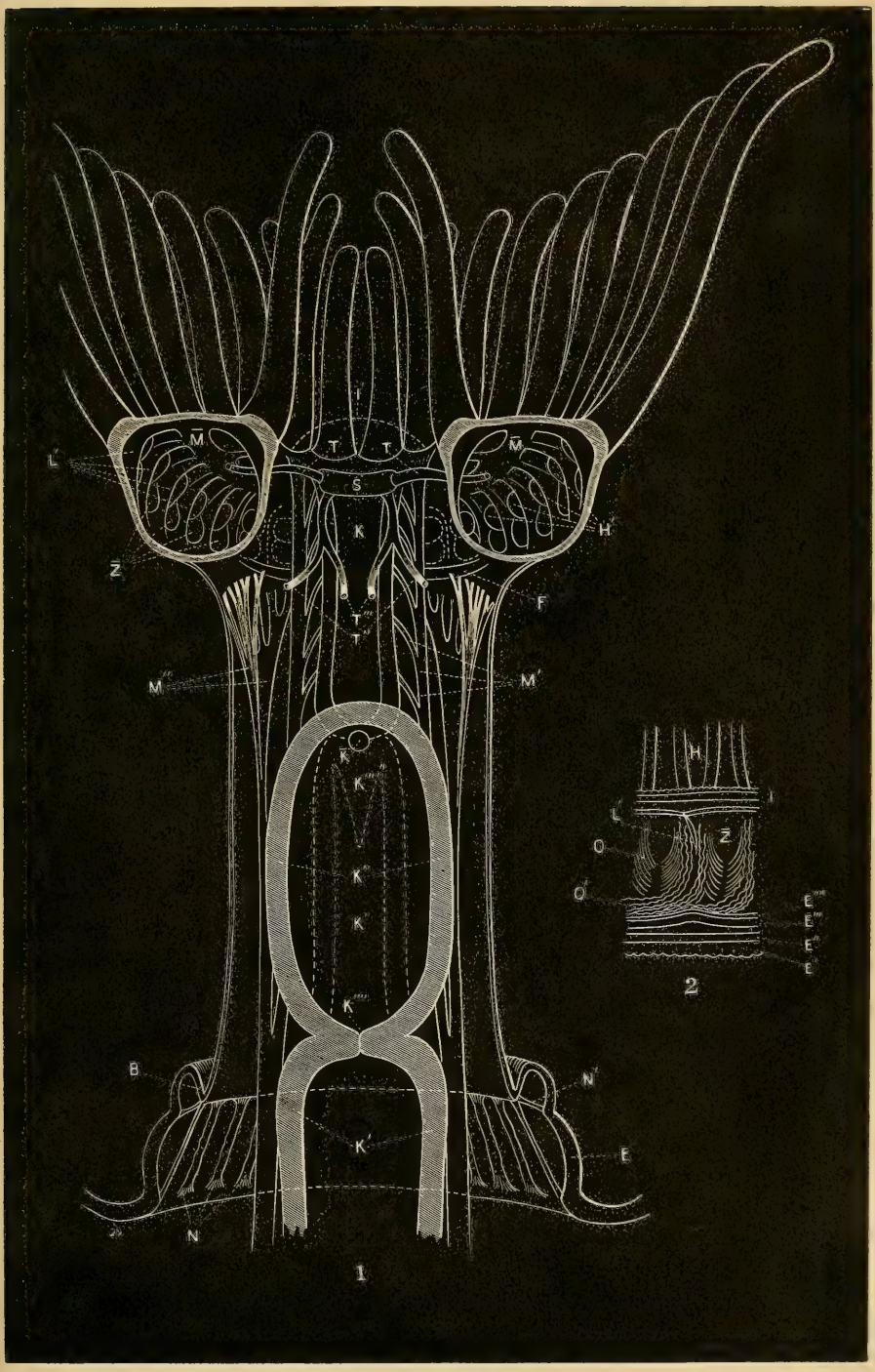
PLATE 12.

Pectinatella magnifica Leidy.

Fig. 1.* Front view of a polypide much enlarged, with the arms removed, showing the under side of the lophophore. (Norway, Me.) E, endocyst; B, invaginated fold; H′, tubular base of the tentacles; $\bar{Z}$, clear spaces in the endocyst; L′, brachial contractors; $\bar{M}$, position of the lophophoric flexor; I′, outline of the epistome; S, nerve mass; T, lophophoric nerve trunks; T″, brachial nerve trunks; T‴, polypidal nerve trunks; K, œsophagus; K‴, œsophagal valve; K′, stomach; K⁗, intestinal valve; K″, intestine; $\bar{K}$, anus; M′, lophophoric retractor; M″, brachial retractors; F, brachial collar; N, anterior retentors; N′, posterior retentors.

Fig. 2. Lateral view of a portion of the inside of one of the arms, showing the fibres of the inner and outer tentacular bands. H, bases of the tentacles; $\bar{Z}$, clear spaces in the endocyst; I, lophophore; E′, the first, E″, the second, E‴, the third, and E⁗, the fourth membrane of the endocyst; O, bases of the outer tentacular bands; O′, fibres of the inner tentacular bands. The third membrane, E‴, is lifted from the second, E″, by the action of the lower fibres of the brachial contractor, which also form the knee-like ridge at L′.

* This figure is composed from numerous drawings of different individuals.



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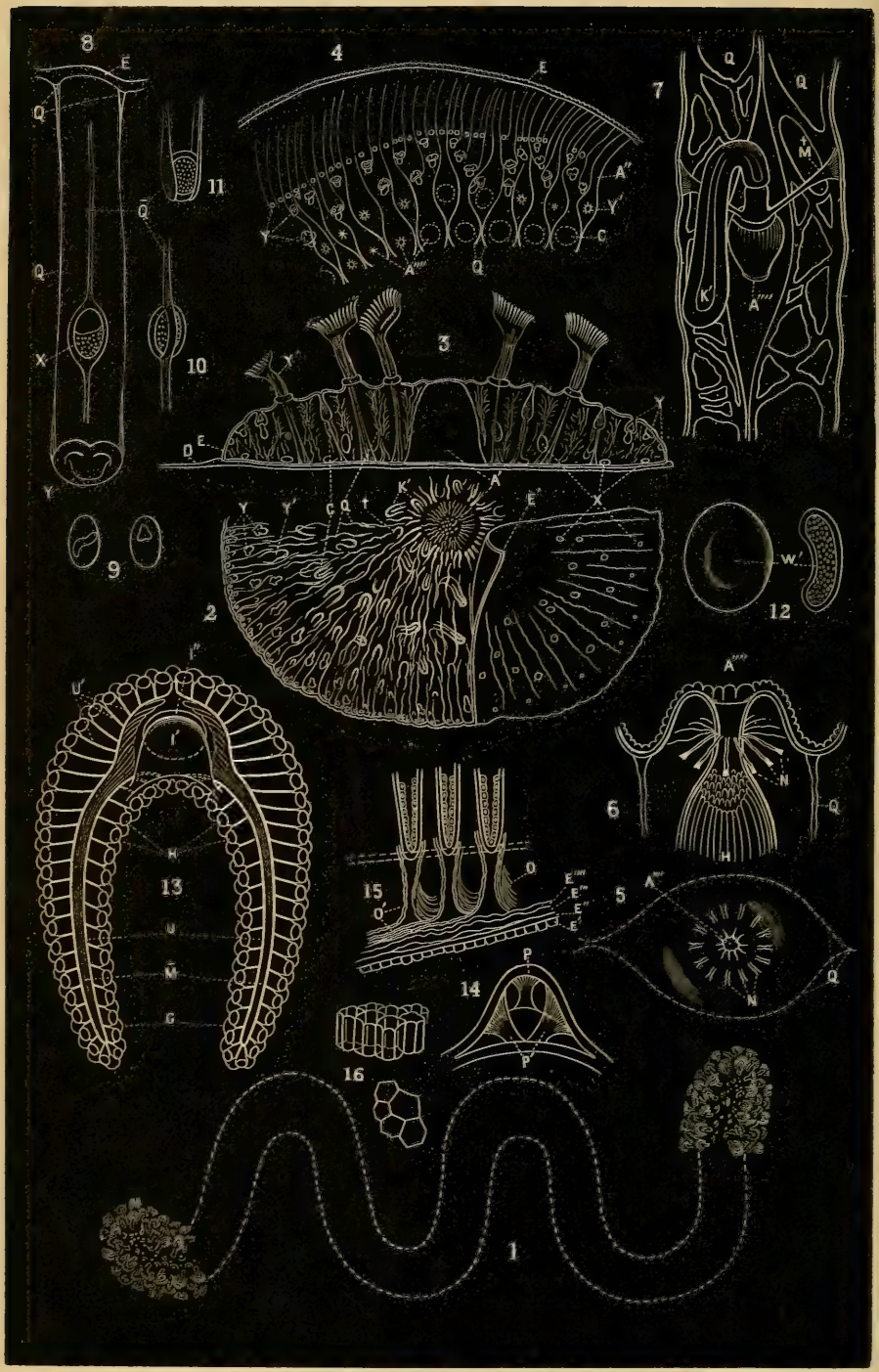

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PLATE 13.

CRISTATELLA OPHIDIOIDEA Hyatt.

Fig. 1. A colony of natural size in its natural position. The polypides are figured at the ends only, the outline of the colony between them being indicated by dotted lines. (Norway, Me.)

Fig. 2. Enlarged view of the underside of one-half of a young colony with the ectocyst and endocyst removed from a portion of the base, disclosing the stomachs of the polypides and the bases of the muscular walls. On the border are the buds attached to the upper side of the endocyst, and in the centre is the inverted cone formed by the interior edges of the muscular walls. On the left, the uncovered portion, the white lines show the positions of the muscular walls, but on the right, the covered portion, they show only the temporary external folds of the endocyst caused by the contraction of the cœnœcium. The relations and positions of all these parts are best explained by reference to the ideal section of this colony, as depicted in fig. 3, the lettering being the same in both; with the exception of K′, stomachs of adult polypides partially retracted, and †, stomach of an evaginated polypide in fig. 2; and D, ectocyst in fig. 3.

Fig. 3.* E, endocyst; C, stomach of polypides wholly retracted; Q, muscular walls; Y, buds; Y′, immature polypides, capable of evagination;† X, fixed statoblasts; A′, cœnœcial trunk.

Fig. 4. View from above of a portion of the border of the same colony when expanded to about twice the vertical height of fig. 3. Lettering same as in preceding figures, with the exception of A″, cœnœcial tubes, and A‴, cœnœcial orifices. Some of the latter are closed, and some, indicated by dotted lines, are open; the polypides, however, are omitted from the latter, in order to give a better view of the cœnœcium.

Fig. 5. Enlarged cœnœcial cell of the first row, the orifice closed over the invaginated polypide. A‴, cœnœcial orifice; Q, attachments of the muscular walls of the cell; N, anterior retentors.

Fig. 6. Transverse section of the same, viewed from the ventral side. A‴, cœnœcial orifice; Q, muscular walls; N, anterior retentors; H, tentacles.

Fig. 7. View of a fully invaginated polypide of the first row, from below, with the endocyst removed from that side. The gastric and part of the lophophoric retractors, have been entirely omitted. A‴, cœnœcial orifice; Q, muscular walls; M, trunk of retractor muscles; K′, stomach.

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*When this figure was drawn, I had, as I supposed, observed three rows of full grown polypides on the cœnœcium as in fig. 2. This, however, is probably erroneous, and I doubt whether at any time of the life of the colony, there are more than two living rows of fully grown polypides and one row of immature polypides. In this section, therefore, the innermost rows should have been represented in a retracted condition, the polypides dead and partly absorbed.

† For a magnified view of crest from above, see Pl. 9, fig. 14.

Fig. 8. A tube isolated and viewed from the lower side. Y, bud attached to the upper endocyst; X, young, fixed statoblast attached to the lower endocyst; Q, cœnœcial walls; $\tilde{Q}$, base of membranous ridge; E, endocyst.

Fig. 9. Two figures of the same statoblast, showing the variations in the form and position of the vacant spot in the statoblast of fig. 8.

Fig. 10. View of the same from the upper side, showing the membranous ridge crossing the statoblast and apparently connecting with the endocyst on the upper side.

Fig. 11. An older specimen, in which the ridge has formed a tube.

Fig. 12. A still older specimen, from the interior of the cœnœcium, showing the elliptical depression in the horny sheath.

Fig. 13. View of the lophophore from above, with the tentacles and calyx removed, showing the distribution of the nerves. H, bases of the tentacles; G, calyx; $\tilde{M}$, lophophoric flexor; U, lophophoric nerve branches; U′, tentacular nerve branches; I′, epistome; I″, mouth.

Fig. 14. Epistome isolated and viewed from above, showing the muscles. P, median muscle; P′, lateral muscles.

Fig. 15. Lateral view of a portion of the interior of one arm with the lophophore removed, showing the outer and inner tentacular bands, and the membranes of the endocyst in an alcoholic specimen. O, outer tentacular bands; O′, inner tentacular bands.

Fig. 16. Direct and profile views of a group of cells from the first membrane of the cœnœcial endocyst of fig. 2.

PLATE 14.

Cristatella ophidioidea Hyatt.

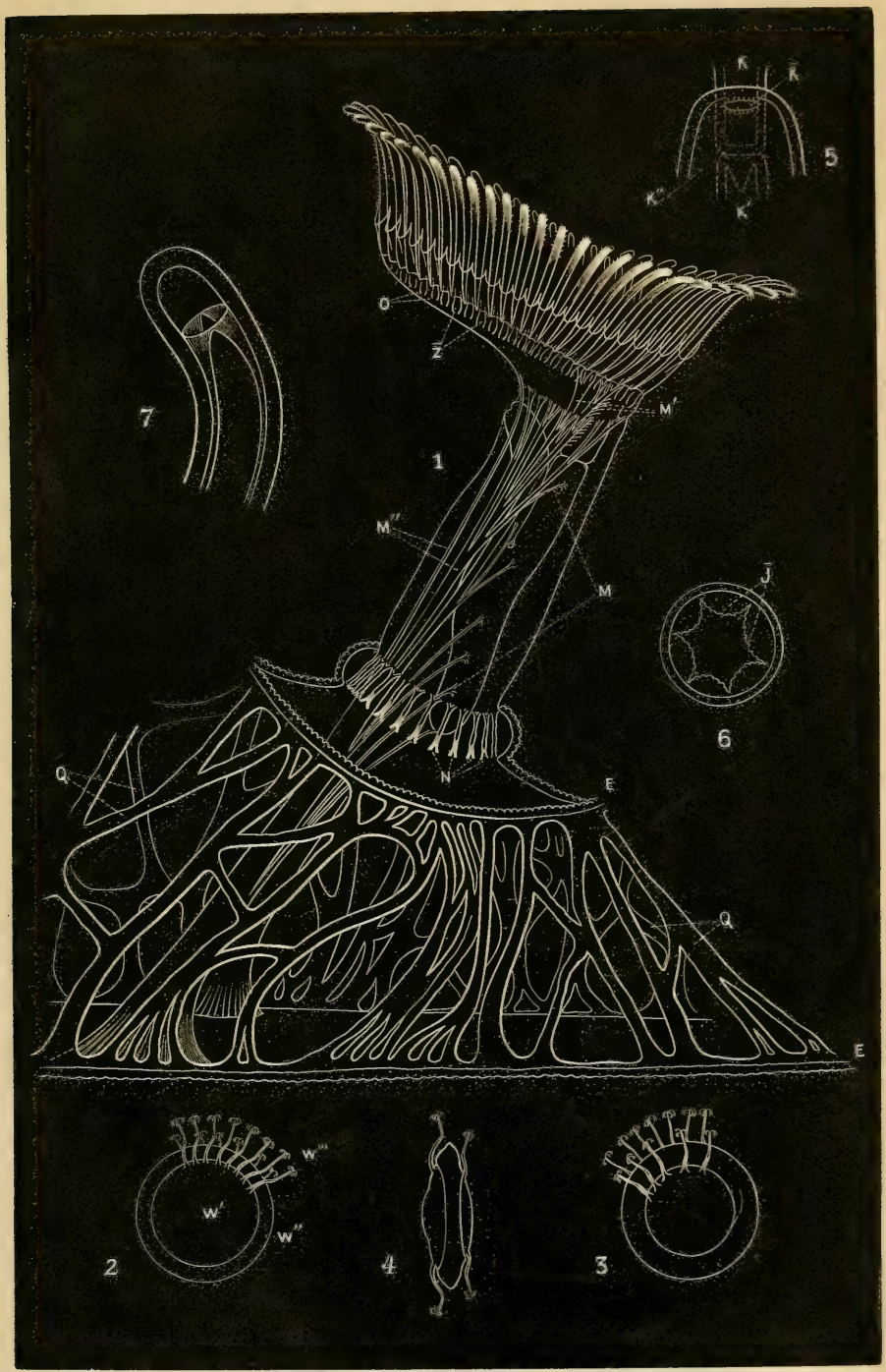
Fig. 1. Magnified view of an adult polypide in its cell. E, endocyst; Q, muscular walls of the cell; M, gastric retractors; M′, lophophoric retractors; M″, brachial retractors; N, anterior retentors; $\tilde{Z}$, clear spaces in the endocyst between the bases of the outer tentacular bands; O, bases of outer tentacular bands.

Figs. 2, 3, 4. Upper and lower side, and profile view of statoblast. W′, horny sheath; W″, annular sheath; W‴, spines. Of the last, there are in nature twenty-two short, and thirty-two long ones.

Fig. 5. View of the anus, showing its oblate form, and also the great breadth of the intestine, when compared with the œsophagus and the upper part of the stomach in the back ground; K, œsophagus; K′, stomach; K″, intestine; $\tilde{K}$, anus.

Fig. 6. Section of stomach, showing the hepatic folds. $\tilde{J}$, hepatic folds.

Fig. 7. Oblique view of the tip of a tentacle, showing the fan-shaped attachments of the tentacular bands.



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