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with the kind regards of
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OBSERVATIONS ON LIVING BRACHIOPODA.

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8. OBSERVATIONS ON LIVING BRACHIOPODA.

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INTRODUCTION.

THE following observations on living Brachiopoda were made many years ago. My work at the outset was more in the way of a reconnaissance of the group to sustain my contention that their affinities were with the chaetopod annelids and that their molluscan affinities were remote or entirely wanting. Before the observations on Glottidia, Hemithyris and Terebratulina were put in shape for publication, I visited Japan solely for the purpose of studying the Brachiopoda of the Japanese seas, and this step led to my accepting the chair of zoölogy in the Imperial University at Tokyo. Gradually I was drawn away from my zoölogical work, into archaeological investigations, by the alluring problem of the ethnic affinities of the Japanese race. The fascinating character of Japanese art led to a study, first of the prehistoric and early pottery of the Japanese, and then to the collection and study of the fictile art of Japan. Inexorable fate finally entangled me for twenty years in a minute study of Japanese pottery. The results of this work are embodied in the Catalogue of Japanese Pottery, lately published by the Museum of Fine Arts, Boston. With this work off my hands, I turned back with eagerness to my early studies of the Brachiopoda to find that my work on Lingula and alcoholic Discinisca had been in many details anticipated by the interesting work of Joubin and the incomparable memoirs of Blochmann. In looking over my notes and memoranda, however, I find that there are many points not touched upon by these zoölogists nor by those who have worked on the more complex Testicardines, notably the otocysts, the pharyngeal glands, the accessory hearts of Hancock, the strand-like spermaries, the external glands, the pallial circulation, the life attitudes of various forms and particularly the varied and graceful movements of the brachia, and certain other features. With the assurance that some of the points will be new and that the confirmation of others will be acceptable to those interested in this fascinating group of animals, I present the contribution without further apology. It is but fair to state that, since I began this work, the staining of tissues and section cutting have become dominant in the biological laboratory. I have neither the eyes nor the leisure to acquire these new methods, but realize in a thousand ways the imperative necessity of section cutting for the proper interpretation of certain parts in the anatomy of these creatures. In this connection, however, I cannot refrain from calling attention to the opening words of an introductory lecture by Professor J. R. Thomson, the newly appointed regius professor of natural history in the University of Aberdeen, wherein he gives utterance to a note of warning as to the direction in which our biological studies are tending. He says, "Amid the undoubted and surely legitimate fascination of dissection and osteology, of section cutting and histology, of physiological chemistry and physiological physics, of embryology and fossil hunting, and the like, do we not need to be reminded sometimes that the chief end of our study is a better understanding of living creatures in their natural surroundings?" He even goes so far as to say that it is difficult to see any reason for adding aimlessly to the already overwhelming mass of morphological and systematic detail, and that what we should rather aim at, is the understanding of the chief laws of organic architecture, of the certainties and possibilities of blood-relationship among living creatures, and a true conception of what is meant by the term organization. As has been pointed out elsewhere by Professor Alfred Newton, such a warning is undoubtedly needed at the present day, when there is far too great a tendency to regard the description of mere structure as the ultimate end of biological research. "It is as if some person to whom modern telegraphy were unknown were to describe in great detail the mechanics of the various instruments employed therein, without the vaguest conception of their practical use." (Nature: July 13, 1899.)

Had Hancock been able to avail himself of section cutting he would have got no light upon the action of the oblique muscles in Lingula, or the various attitudes of the brachia, or the extreme mobility of the brachial folds or the various behaviors of the setae, the convolutions of the elongated peduncle, and many other life features. On the other hand, his elaborate system of vascular circulation with the supposed functions of the "central and accessory hearts" might have been interpreted differently had he been familiar with this modern method. It is only fair to state that my only sections were cut with a razor, without staining or supporting substance, and most of the work was done with a Tolles' triplet.

I wish here to express my obligations to Dr. C. E. Beecher, Professor W. H. Dall, and Mr. Charles Schuchert, for many favors while preparing these pages. For providing the means to meet the considerable expense involved in reproducing the many plates in lithography, I am greatly indebted to the Bache fund of the National Academy of Sciences for a liberal grant, and to Dr. Alexander Agassiz and Mr. Augustus Hemenway. Acknowledgments are also due to Mr. Meisel for the care he has exercised in making the plates.

Note of explanation. I have used the terms Testicardines and Ecardines as they are in common use, and the forms they include are well known. They parallel Owen's divisions of Arthropomata and Lyopomata, as well as those of Huxley's Articulata and Inarticulata. The names proposed by King, Gill ('73), and others also include the same divisions. As Beecher ('92) says in referring to Huxley's definitions, "these names may be conveniently retained as two divisions or sub-classes, but they fail to express the true relationships of the various groups included in them," so the terms Testicardines and Ecardines are used simply as convenient names to designate certain well known forms. In justice to Beecher, I must say here that the classification proposed by this naturalist rests on such a profound and varied comparison of the fossil as well as the recent forms that it may well be accepted as the latest and best expression of the relationships of these animals. If he were compelled to bring his four groups into two divisions, however, he would certainly group Atremata and Neotremata together, which would give us the Inarticulata, or the Ecardines, and his Protremata and Telotremata, which would give us the Articulata or Testicardines. The works of Beecher and Schuchert are above all the most painstaking and philosophical studies of these fascinating animals yet given.

In referring to *Glottidia pyramidata* I have used the generic term only, to avoid the repetition of the long specific name. In every instance, then, the word Glottidia is used for the species *pyramidata*. Judging from the well marked characters of the shell of *Glottidia albida*, a Pacific coast form, I have no doubt that the internal structure will be found to be the same as in the Atlantic coast species.

For convenience of reference I have used the term coelomic cavity without asserting that it is the true coelom. In order to be explicit, I have at other times used the terms perigastric and perivisceral cavity. I have also used the word blood to indicate the only circulating fluid I have seen in living Brachiopoda. Perivisceral fluid, periënteric fluid, chylaqueous fluid, and other terms might be more exact or perhaps less committal, but when the term blood is used it will be understood to imply the fluid, charged with various corpuscles, which is seen circulating within the tissues.

References to the plates and figures are given by numbers only; thus **49**: 3 means plate 49, figure 3. In this way is avoided the repetition of the words plate and figure, or their abbreviations.

In all cases, unless otherwise explained, the figures are drawn with their dorsal region uppermost, if seen from the front or side; and if seen from the dorsal or ventral side, the anterior region is uppermost. With two exceptions, all the figures are exact copies of my original sketches; hence many of the drawings are incomplete, some of them being mere sketch memoranda.

HABITS.

The meagreness of observations on living Brachiopoda is somewhat surprising when one considers the ease with which abundant material of certain species in life may be obtained. Without a study of the living animal it is impossible to realize the activity of the lacunal circulation, the extreme mobility of various parts of the organism, the beautiful colors of the soft parts, and the varied and graceful attitudes of the brachia.

Many of these animals may easily be kept alive; indeed, with the Ecardine forms, the vitality manifested by them is almost beyond belief. I brought home in mid-summer, from North Carolina, a distance of nearly seven hundred miles, living specimens of Glottidia. These were kept in a small food bowl. They were afterwards carried to Eastport, Maine, and then to Troy, New York, yet none of them died until late in the fall, six months after. I also brought back from Japan a number of specimens of a small species of Lingula and not one of these died until late in the year. Joubin ('86) recounts a like vitality in Crania.[1] One cannot help associating this remarkable vitality in these genera with their persistence through geological horizons from the Cambrian to the present day almost unchanged in character. Living as they do in shallow seas, the gradual elevation or subsidence of the coast-line would in no way affect their condition. Temperature alone has probably caused their disappearance from the more northern regions, but otherwise, they have survived all the mutations of geological times unchanged, and with the persistence of this vitality, they may be the last forms of life to survive on the earth as they were among the earliest preserved. On the other hand, the Testicardine brachiopods do not possess this vitality, and this group has shown an infinite diversity of form since its first appearance in geological time.

Glottidia pyramidata.[2] This sound genus established by Dall, to which I shall add further generic distinctions, was found living in great numbers on Bird Shoals, Beaufort Harbor, North Carolina. The tides in this region are very small and these shoals are exposed at low tide. For collecting these animals, as well as many other sand burrowers, I devised a large hand-dredge in the form of a dust-pan with closely perforated bottom. With this device I scooped up the sand and sifted it at the same time, often securing, at one scoop, twenty or thirty individuals. The external appearance and behavior of these small diaphanous Lingulae are so alike that when I first began the study of *Lingula lepi-*

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[1] Joubin says "The Crania remained exposed, upon my table, to the sun, cold, heat, without being injured. Numerous algae had invaded my basins. I had left them entire months without changing their water which ought to have acquired a strong saltness. I have still the greater part of my Crania living seven months after their arrival in Roscoff and fourteen months after their gathering."

[2] I shall retain the specific name of *pyramidata* for this species until its anatomy is shown to be identical with that of *Glottidia antillarum*, which name it now bears.

dula in Japan, it was some time before I discovered that it was not even generically identical with the form now under consideration. Aside from the internal structure of the dorsal and ventral shell, the form of the protegulum, the presence of gill ampullae, the arrangement of the oblique muscles, and the more anterior position of the coelomic cavity, I found that in Glottidia the setal tubes were not formed, though the lateral setae assume a vertical position when partially buried in the sand, as in *L. lepidula*; the sand tube is much more complete and symmetrical and in alcohol is retained on the peduncle, while in *L. lepidula* the sand tube becomes detached. In general behavior, however, the two forms are almost precisely alike. Charles Schuchert ('97), in considering the enormous period in geological history occupied by the *Lingulidae*, says that the only change observable is that in the ancient forms the viscera occupy a little more and the brachia a somewhat less space than in the later forms. Glottidia by these characters is a more ancient type. This same feature in the relative space occupied by the two regions is seen in the adolescent state of Discinisca as compared with the mature state.

When an individual was placed on the sand it would slowly throw its peduncle into a series of irregular convolutions; directly the dorsal shell would be set in motion, oscillating from side to side in a peculiar rotary and sliding manner, and during this action the shells were rather close together but not entirely closed, the fringes of lateral setae were moving in a peculiar rhythm, not swinging back and forth simultaneously, but the impulse would start posteriorly and move forward; the posterior bunches of setae would swing widely back and forth; the setae, on account of their minute longitudinal markings, would appear a somewhat iridescent steel-blue. The sand by these efforts would be gathered in an irregular ridge and sometimes would adhere by the mucus which is freely emitted, so that when the animal was lifted from the water a narrow and irregular ribbon of sand would be found encircling the creature. In some cases, the posterior half of the body would be encased in a continuous sand sheath (**41**: 14). In one specimen, in which the peduncle was broken close to the body, the creature was observed to move sideways to the distance of an inch or more, piling up the sand in a ridge as it moved along (**41**: 12). It then began burying itself in the sand, going down head first, using the anterior portion of the shells in a shoveling motion and finally disappearing. The next day it was found affixed to the bottom of the bowl by the peduncular end, though not attached by the peduncle. It had made a sand case adhering to the bowl and this case enclosed the lower half of the body. Another individual traveled a distance of two inches on one side of its body, the setae plowing into the sand and forcing the body forward; other specimens penetrated the sand by means of the peduncle and, in a vermiform way, dragged the body out of sight. When at rest, the body would be half out of its burrow, the shells partially open and the lateral setae standing vertical and meeting at their tips. In no instance did I observe the fabrication of the setal tubes to be described in *L. lepidula.* The anterior margins of the pallium were thrown into folds and the anterior bundles of setae converged in a way to form rude channels for the water, which steadily flowed in and out in definite currents. The creature, though not very timid, would on certain alarms quickly jerk its body beneath the sand and out of sight. The extent of the oscillation of the dorsal shell is shown in **40**: 2. It will be seen that the right anterior corner of the dorsal shell is moved to the left so far as to cover the left anterior corner of the ventral shell. This movement is vigorous and quite rapid but not jerky. In this oscillation, the peduncular end of the shell also swings to the right and left, and the posterior adductor muscle is greatly stretched by this action. The dorsal shell oscillates from a centre near the middle of the coelomic cavity at a point about two-fifths the length of the shell, measured from the posterior end. When adhering to a plain surface, as at the bottom of a shallow dish, a wide, irregular sand tube is made, which in some cases covers the hinder part of the body (**41**: 13).

In studying Glottidia for the purpose of ascertaining its duration of life, it was observed that there was but little variation in the size of the specimens. The shells were equally fresh-looking, and there was in no instance any parasitic growth upon the shell. In an examination of a hundred individuals, no young were found. With the *Lingula lepidula* of Japan, I had precisely the same experience; the individuals appeared to be all full grown. A number of Glottidia were kept in confinement, and while showing the most remarkable vitality, as already alluded to, they all died in the fall and within a few days of one another, evidently of old age. *Lingula lepidula,* also, apparently lived its allotted span and perished in the same way. On dying, the body protrudes from its burrow and rests full length upon the sand; it gradually turns black as a result of decomposition and the slightest jar of the vessel holding it causes the body to separate from the buried peduncle and float away. An examination of the peduncle after a lapse of forty-eight hours shows the circulation of fluid within the peduncle as active as ever.

Lingula lepidula. A species of Lingula collected at Yenoshima, Japan, averaging half an inch in length, rarely exceeding this dimension, is rather doubtfully referred to *L. lepidula* of Adams. Davidson ('86–'88) supposed this form might be the young of some larger species. Adams's statement that the shell is yellowish, tinged with red (which is really the effect of the red coelomic fluid within), with the outline and dimensions given by him agrees more or less with the Yenoshima species, so for convenience of designation it will be considered as the *L. lepidula* of Adams.

The species was dredged in a few fathoms of water from a sandy bottom in a little cove on the western side of Yenoshima. The peduncle is from 2½ to 3 inches in length, the posterior third of which is encased in a sand tube of not so compact a nature as that of Glottidia, though, like Glottidia, it forms a globular ball of sand about the severed end, shorter and more bulbous, however. When the animal is placed on sand in a bowl with water, it disappears below the surface in from ten to fifteen minutes. This action is accomplished by oscillating the dorsal shell and raising and lowering the anterior margin of the shell in a kind of shoveling motion, the lateral setae in the meantime moving rhythmically back and forth, forcing the body forward and downward. If a number of individuals are placed in a bowl with sand, they soon work their peduncles to the bottom of the bowl where a number of loosely constructed burrows are made, which are firmly adherent to the bowl (**40**: 11). The individuals group themselves together in a closer cluster than do those of Glottidia. These tubes are often made in less than half a day, and in all cases the individuals had made their tubes within the space of three days. So firmly were these irregular tubes attached to the bottom of the bowl, that the sand and water could be flung out by inverting the vessel, yet they all remained dangling by their peduncles, anchored as they were by the sand tubes in which the peduncles were encased. In one experiment in which twenty-six individuals were flung upon the sand, only one attached itself with the ventral valve uppermost. In other words, those that had fallen upon the sand, ventral surface uppermost, righted themselves with this one exception. After burying its peduncle, the animal comes to the surface and projects its body a third of its length above the sand, sometimes lying nearly horizontal and at other times standing in a nearly vertical attitude. In these various positions the dorsal and ventral shells are separated anteriorly, while posteriorly the beaks of the shells are brought together as near as the peduncle will allow. The lateral setae now stand at right angles to the plane of the body, the tips of the setae meeting (**40**: 15). The setae thus form an effectual barrier against the ingress of sand in which the individual is partly buried. This barrier becomes strengthened by an accumulation of mucus upon the setae, which forms a closed partition. In the meantime the three groups of setae on the anterior margin align themselves in such a way as to form three flattened oval tubes which communicate with the pallial cavity, the central tube being slightly longest (**40**: 12, 13). The pallium is at the same time thrown into deep folds, one on each side of a median line above and below, the crests of these folds coming between the base of the tubes and in some cases almost meeting (**45**: 10). It is at precisely these points that the strong pigmentation is seen which will be referred to later as probably sensitive to light. The setae forming these tubes become coated with a film of mucus which appears to extend beyond the tips of the setae and this film is continuous with the lateral partitions just described. The function of these tubes is clearly shown when it is observed that a strong current is drawn into the lateral tubes, to be as vigorously forced out of the central tube. During this attitude the brachia have their lower surfaces turned toward the sides of the pallial chamber, while the cirri are directed inward and forward, their tips coming just at the junction of these tubes (**40**: 12). The cirri are strongly ciliated and their vigorous motions induce the currents above described.

The peculiar alignment of the lateral setae in Glottidia and *L. lepidula* will be understood when it is seen that the shells taper slightly from the posterior lateral bunches of setae, which are quite prominent toward the anterior end, while the lateral setae vary in length, being quite short posteriorly and becoming gradually longer anteriorly, so that when the dorsal and ventral shells are closed, or when the animal is in the act of crawling, it will be noticed that lines drawn along the tips of the lateral setae on each side would be parallel; now when the shells gape anteriorly and the setae meet across the gradually increasing space between the shells, the tips of the setae touch along the whole side (**40**: 15), the increasing length of the setae anteriorly balancing, so to speak, the gradual widening made by the parted shells.

On alarm, caused by the jarring of the vessel in which it is contained, or the interposing of a hand between it and the light, the animal snaps below the sand like a flash. The opening left in the sand is in shape like a transverse section of the body, with the sand piled up in a wide, shallow ridge around the opening (**40**: 10).

The animal, as might be supposed from an examination of the powerful oblique muscles, possesses considerable strength; this strength may be shown by placing upon it a heavy weight, such as the shell of a large Donax when in a short time this weight is flung off by the oscillations of the dorsal valve.

Lingula anatina. A large green Lingula, presumably *L. anatina,* was collected in numbers at the mouth of the Takahashi River, Higo, Japan, a river that empties into the Shimabara Gulf, the waters of which are so shoal that small steamers cannot approach within two miles of the shore at this point. The Lingulae were found in a gravelly and muddy deposit just beyond low tide. They were collected by drawing the fingers through the mud in rake-like fashion. The end of the peduncle was encased in a rough tube of mud an inch or more in length; in no instance was it attached to any solid substance. The blood was pinkish lake in color and, with the admixture of mucus, quite thick and dark, discoloring the water and staining the fingers in dissection. The auditory vesicles, to be described later, were plainly visible in the smaller specimens where the shells were not so opaque. The dorsal shell oscillates quite as freely and swings as far to the right and left as in *Glottidia pyramidata,* though moving less vigorously. The general behavior of the animal and the rich brown markings of the pallium and brachia were not unlike the smaller species with diaphanous shells; the ventral shell was rigidly fixed and held by the stout peduncle, which was quite firm and inelastic near the shell; the lateral setae swung back and forth, but not with that vigorous action seen in the smaller species.

SHELL.

The word shell is hardly appropriate except as a common term for all hard coverings, such as nut-shell, egg-shell, bomb-shell, and the like. The shell of the Brachiopoda in composition, structure, and relation to the soft parts has no relation whatever to the shell of the Acephala. The words scale, scutum, and elytron are equally used in widely different groups. For convenience of designation, however, the word shell will be used in reference to the outer hard parts of the Brachiopoda. It is desirable, however, that appropriate names should be given to the hardened integument of the different groups of animals supporting such coverings.

Unless the shell of Lingula be drawn from life, or from well preserved alcoholic specimens, it is, with some exceptions, impossible to get an outline of any specific value. These exceptions are the larger and heavier shells, such as those of *Lingula anatina*, wherein a heavy deposit of limy matter renders the shell more rigid, though even here a region of the shell extending in a median line from the peduncular end is generally represented a little more arched than in nature. In the diaphanous forms, such as Glottidia and the smaller species of Lingulae, the shells warp and twist quite out of shape. In one case the anterior half of the shell turned upward until the lateral edges touched in a median line. Outlines of the shell of *Lingula lepidula* drawn from life are presented at **42**: 5, while **42**: 6 represents the same shells removed from the body and allowed to dry slowly. A line below each set of figures shows the outline of the dorsal shell across the back transversely. The rounded ridge or carination, represented in the figures as running from the posterior end of the shell forward, has no existence in nature. In view of these facts it is no wonder that there is much confusion regarding the smaller and more diaphanous species of Lingula.

While the shells of *Lingulidae* collected at any one time vary but little in size, by comparing a number of specimens a series of broad and of narrow forms may be observed. These variations were so marked in *L. lepidula* that I thought the differences might be sexual. A further comparison showed that these variations blended and so the broad and narrow forms may be regarded as the extremes of variation. The extent of this variation is shown in **42**: 5. These differences were noted in *L. anatina*, *L. lepidula*, and *G. pyramidata*.

I have designated under setae, the long clusters of setae near the hinder third of the body, as the posterior cluster. The variation in the width of the shell is marked by a broadening of this region. In *L. anatina* the anterior margin is in some specimens pointed or beaked in the median line, in others it forms a rounded or flattened curve.

In examining a large number of the shells of *L. anatina* I found a certain proportion of them thickened, discolored, and eroded, forming a marked contrast to the other specimens equally large with clear green shells, thinner in texture and more perfect in condition. As all the specimens examined were collected at the same time in July, one might infer that the rougher, thicker shells belong to a last year's growth, and it is therefore possible that this species may live two or more years. In an individual of an undetermined species of Lingula, dredged in Nagasaki Bay, Japan, the dorsal shell was somewhat pointed, while the lower shell was evenly rounded in front and minutely notched in the median line (**46**: 8). This may be, however, only an individual variation.

The shell of *L. lepidula* is much more transparent than that of Glottidia and for this reason I was enabled to make out more of the internal structure, circulation, etc. In the smaller individuals the shell is steel-gray, or light bluish white; in the larger specimens a tinge of green is seen. In alcohol, these colors change to a uniform light yellowish.

In **42**: 3, a drawing is given of the peduncular end of *L. lepidula*. Here the peduncular opening is flaring and reminds one of the early brachiopods figured by Hall and others. A direct end view shows the straight, horizontal lines of accretion so often depicted in the Cambrian forms. The protegulum is oblong-ovate, the posterior margin being straight; the periphery of this stage is distinctly yellowish in color, and this is of interest as marking a distinct period in the shell growth. In the ventral shell the outlines of this early stage may often be detected in mature specimens. The dorsal shell is more pointed and shows a conspicuous, well-shouldered foramen. The successive increments of growth are seen in blunt, tumid beaks imposed one after another on the area covered by the protegulum (**42**: 3, 4, 7). In one specimen was observed a curious alation projecting on each side of the protegulum area, the result of some thickening due to the peduncular attachment (**42**: 8).

In Glottidia, the protegulum, while showing a straight posterior margin with a slight shoulder as it connects with the subsequent growth, is circular in outline; as in Discinisca, the periphery of this circular stage is minutely indented and radially striated (**42**: 2). Brooks ('78) has shown, in the free-swimming stage of this species, the same straight posterior margin with projecting points at either end. In a species of Lingula collected in Nagasaki the protegulum is ovate with the same straight posterior margin (**61**: 1). In all these instances, the peduncle is firmly adherent to the ventral shell, the beak of the dorsal shell standing free with an interspace between it and the peduncle.

In *Discinisca lamellosa*, the protegulum is elongate-ovate with anterior and posterior margins equally rounded. A perfectly circular nucleus is outlined in the posterior half of this stage (**42**: 12). This circular nucleus is made up of polygonal cells, and the irregular fracture of the edge shows that there have been no regular increments of growth. In this disk (**42**: 9), near the posterior margin, an irregular nucleus appears, surrounded by a few eccentric lines. It is an interesting fact that the successive stages of Discinisca begin with a nucleus eccentrically related to a perfectly circular stage; this circular stage, in turn, being eccentrically related to an oblong-ovate stage, which is the true protegulum; and this, in turn, being eccentrically related to an adult stage which is finally orbicular again.

The above description applies to the dorsal shell. I shall leave the relations of these stages to the early Cambrian forms to Dr. Beecher and Mr. Schuchert who have done so much to the elucidation of these interesting problems. The ventral shell does not show this circular disk, but a bi-circular outline arching inward on its posterior border. A thickened ridge runs through this stage in a median line to merge into a thickened anterior border (**42**: 13). The brachia, or rather the brachial cirri, start from the thickened, anterior border, as may be seen by referring to **61**: 9. The bi-circular outline of the ventral shell corresponds to the circular outline seen in the dorsal shell above described. A greatly magnified view of the ventral shell is shown in **42**: 10. A wide peduncular notch is formed by the rapid growth backward of the shell; on the sides of this wide notch, another growth appears with a new notch much narrower. In this figure, the beginning of the median septum appears, on each side of which a polygonal shell structure is seen. The anterior border shows three concentric outlines, and the rim is marked by irregular radiating lines. It will be seen that the long deciduous setae start from this primitive bi-circular outline (**42**: 11).

The shell of *D. stella* is quite different from that of *D. lamellosa*. When I first dredged this species at Nagasaki, I mistook it for a species of Crania. The dorsal shell is quite firm and very irregular in shape. The creature clung so closely to the rock, when first observed, that not until it erected itself on its peduncle did I become aware that it was a species of Discinisca. In *D. lamellosa* the peduncle issues very close to the posterior margin of the ventral shell, the shell substance behind the peduncle being membranous; in *D. stella* the peduncular opening is nearer the centre of the ventral shell, the dorsal shell is irregularly convex and laps considerably over the ventral shell, which is of extreme tenuity. It appears almost membranous and is so intimately blended with the ventral pallium that it must be considered an organic part of it. The shape of the ventral shell may be compared to a shallow pan with flaring rim and with the bottom pushed upwards. At **42**: 17 are shown the dorsal and ventral shells with peduncle in outline, while at 17*a* is shown the lower valve turned upside down; a series of radiating lines, some of which are branched, runs from the peduncular opening nearly to the periphery, turning up on the rim which meets the dorsal shell. These lines are somewhat irregular and clusters of fine striae occur at intervals along them (**42**: 15). The markings of the lower shell were quite unlike anything found in *D. lamellosa.* A narrow median line is seen, upon each side of which three eccentric lines spring from a nucleus, the larger curve of the eccentric being directed backward; in front of this a curved line crosses the median line and beyond this an indication of the continuation of the median line appears. This central line is the only feature seen in *D. lamellosa.*

Coecal Tubules.

A very marked characteristic of the Testicardine group is the presence, in the shell of many of them, of tubules with which the pallium has an organic connection; even the parts surrounding the peduncular foramen are supplied with them. Dr. Beecher ('92) shows that this statement is especially true with respect to the Telotremata, for in this order the deltidial covering, consisting of the deltidial plates, is secreted by the mantle border, and in punctate forms the deltidial plates are likewise punctate. On the contrary, the deltidial covering, or deltidium, in the Protremata (Thecidium, Strophomena, etc.) is primarily secreted by the peduncle and as such is always impunctate, even in the most highly punctate species, although the obliteration of the peduncle may result in a secondary punctate deposit secreted by the mantle within the delthyrium. Precisely what their functions are is still problematical. Various suppositions have been made by those who have studied these structures microscopically. It has been suggested that they might be respiratory, again it has been suggested that they were instrumental in conveying growth elements to the shell. Kowalevski ('74) is of this opinion; Schulgin ('84) is inclined to agree with him, but thinks they may have a respiratory function as well. From the glairy nature of the shells of the smaller *Lingulidae* one might suppose that in some way they functioned as mucous tubes, but in these forms only the barest traces of their existence have been detected, and in no brachiopod have these pores been seen to open externally, at least in the adult form. It was long ago established that coecal prolongations of the pallium project into these tubular perforations of the shell. In all cases, at least in the adult, a delicate periosteum covers the shell, and consequently the tubules do not communicate with the exterior. Briefly stated, these processes may be said to be aborted in the errantian forms and to be, with few exceptions, a marked characteristic of those forms which are attached by a peduncle, or of those forms in which the lower shell is welded to the substance upon which it rests. In Crania, which has no peduncle, and which is immovably attached by the lower shell, the tubules are numerously branched towards the exterior of the shell. Joubin ('86) finds that in Crania the tubules are branched in the dorsal shell only, and that they do not occur in the areas of muscular attachment. That the coecal tubules are sensory organs of some sort seems highly probable. Sollas ('86–'87) has figured a coecal tubule, in section, of *Waldheimia cranium* and shows a structure which he interprets as an organ sensitive to tactile impression. In my Embryology of Terebratulina ('73a), I compared these processes with what I regarded as an analogous structure in the test of Crustacea and considered them as organs of general sensibility. In this memoir I describe and figure in a very early stage of *T. septentrionalis*, veritable tenuous, hair-like processes, to the number of ten or more, radiating from the distal terminations of the first three tubules formed. Bemmelen ('83) suggests that I may have made a mistake in my observations of their displacement by a delicate brush. I can assure this accomplished naturalist that there was no mistake about the observation, though I agree with him that the hairs can have no relation to the radiating tubules described by King ('70). In my earlier memoir ('71) I figure and describe two short ramifications from the end of one tubule, which are probably comparable with the radiating tubules of King and probably with those of Carpenter ('56). In the early stage of Terebratulina, not only is the shell raised in a shallow collar about the external end of the tubule, but a yellowish glandular plug is seen from which radiate these delicate hairs. Claparède ('69) figures certain papillae on the elytra of Polynoë with cirri terminating in hairs, reminding one strongly of the features above described. In this connection it may be interesting to state that Davidson ('86–'88) describes a species of Crania from the Permian of England of which he says in the dorsal shell, "externally the entire surface is closely crowded by a multitude of minute, short, hollow, spinulose tubercles which produce a granulated aspect." The manner in which the ridges in Terebratulina coincide with the setae may explain the spinous character in certain forms of Productus and other fossil brachiopods; but in Crania there are no setae, and it would be an interesting inquiry as to the origin and function of these hollow, spinulose tubercles.

PEDUNCLE.

The peduncle is a characteristic feature of the Brachiopoda, though wanting in many Testicardine forms and in Crania. That the early stages of this interesting animal will show the presence of this structure, there can be no doubt. An examination of the shell of Crania shows no traces of a peduncular foramen, and it is probable that in the young stage the peduncle will be found projecting between the shells, as in the *Lingulidae*. It will be interesting to observe the attitude of the terminal end of the intestine in relation to the peduncle, for, in Crania alone, among the brachiopods, the intestine terminates posteriorly and not at the side, as in Lingula and Discinisca.

The variation in the size of the peduncle and the mobility of the body upon it, is correlated with the greater or less development of the setae. In those forms in which the peduncle is prominent, as in Lingula, or endowed with special muscles, as in Discinisca, indicating great freedom of movement, the setae are excessively developed. In *D. lamellosa*, the setae form a dense fringe about the pallium. As the peduncle becomes more aborted, the setae decrease in length and become less numerous, and finally, when we come to those forms which have no peduncle, and in which the lower shell is appressed or attached to its resting place, as in Crania, Cistella, and Thecidium, the setae are entirely absent. In the young stage of Terebratulina and Hemithyris, where the body has great freedom of movement on the peduncle, the setae are very long, often exceeding the length of the shell. As these forms become larger and have less freedom of motion, the setae become shorter and are less numerous. In forms like Terebratulina, Magellania, and others, where but slight movement of the body is possible, the setae are not crowded and have no power of motion, nor do we find any muscles to animate such movement as in the *Lingulidae*. The two extremes, then, are the Brachiopoda without peduncles, attached by their ventral shells, setae absent; and the errantian Brachiopoda, *e. g.* Lingula, peduncle exceeding by several times the length of the shell, capable of vermiform contortions, and setae forming a close fringe about the periphery of the pallium and differentiated into distinct groups, capable of swinging back and forth and having the most complex muscles to effect these movements, as so beautifully depicted by Blochmann (:01).

In Lingula and Glottidia, the peduncle is firmly attached to the ventral shell just within the beak, which, in alcoholic specimens, seems to be embedded in the peduncle. The peduncle issues from the shell as a slender stalk to enlarge immediately to three or four times its diameter at its point of attachment (**54**: 1). The dorsal shell is free, and capable of an extended oscillatory, as well as a fore and aft movement; the posterior occlusor muscle is stretched to right and left as the beak of the dorsal shell swings from side to side. It is difficult to realize the extreme and varied mobility of the peduncle until one has examined Lingulae freshly dug from their burrows. For this reason I feel justified in devoting an entire plate to illustrating the various attitudes assumed by the peduncle of Glottidia in life.

I have reproduced in **40**: 5, a sketch of *G. pyramidata* which appeared on the cover of my separate on the Systematic Position of the Brachiopoda. This drawing has been repeatedly copied until all the character of the original figure has disappeared. For this reason it is here presented. Under *Habits*, the formation and character of the peduncular sand tubes have been alluded to. The *Lingulidae* thus far examined agglutinate particles of sand about the posterior end of the peduncle. The perfection of the sand or mud tube varies in the different forms studied. The formation of these tubes, more or less firm, indicates the presence of mucous glands in the peduncle, for in no other way could these sand tubes be fabricated into symmetrical and somewhat durable sheaths such as we find in Glottidia. When the animal is living in the open sand in the sea, the tube has a certain compactness and symmetry; but when confined in a shallow bowl, the animal forms a loosely constructed burrow of sand which is made adherent to the bottom of the bowl and often encloses part of the shell beside.

When the peduncle is broken, the mutilated end contracts into a bulbous form and gathers about it a globular ball of sand whose walls are much thicker than those of the normal sand tube. An injury to the peduncle of *L. lepidula* makes plain its structure. There is first a thick outer tube having little structural character, a middle tube, or sheath, having strong transverse folds on the outside, which alternate with the irregular annulations of the outer tube, and, finally, an inner tube with delicate encircling and longitudinal muscular fibres. When the peduncle is broken, the inner tube bulges like a button beyond the severed end, and in this attitude it presents a curious ribbed and turbinated appearance caused by the contraction of these two sets of muscular fibres (**43**: 1, 2). The action of the longitudinal muscles contracting in the centre, with the contraction of the outer encircling fibres, gives this button-like end the peculiar ribbed appearance shown in the figures. When only a slight contraction of the fibres takes place, the button-like end is smooth (**43**: 3). Whether the undue enlargement of the outer sheath is caused by the unnatural contraction of the inner tube or the absorption of water, I do not know.

In Glottidia the peduncle has the same structure, though I have never observed the turbinated appearance of the end. Minute transverse striae mark the surface of the peduncle, and areas of minute dots are seen which may be mucous pores, and I may add here that in life the peduncles of Lingula and Glottidia are exceedingly mucous, the mucosity extending to the body as well. The peduncle consists of a thick outer wall irregularly annulated, though this appearance is not the result of a true vermian annulation. In certain states, the peduncle in Glottidia is so symmetrically and structurally annulated that when I first saw this condition I was almost inclined to look for setae. Within this thickened tube is a lining membrane and within this is a tubular sheath held to the lining membrane by delicate connective tissue. This is shown in **43**: 6, where the body has decayed and separated from the peduncle; the inner delicate tube is seen held in place, by threads of tissue. In this figure the current is indicated running down toward the end of the peduncle and back on both sides. In **43**: 7 there seems to be a ciliated rod, on each side of which the current courses in opposite directions. On the same plate, 4, 8, 9, the current is shown running down on one side and back on the other side. In **41**: 16 is shown the appearance of the inner tube as it is drawn away from the outer sheath. A transverse section of the peduncle in alcohol shows the outer tube made up of a series of concentric layers, next a thickened cellular lining, and then a thin membrane from which spring fine fibres of connective tissue (**43**: 11). Another transverse section (**43**: 12) from a preserved specimen shows a series of folds of the inner cavity. In **43**: 5, is presented the appearance of the peduncle of Glottidia in life, and a somewhat complex structure of the parts is indicated. Thus the outer sheath, which seems almost structureless, is, at times, thrown into distinct and regular annulations; the annulations of the inner tube alternate with those of the outer tube, and the crests of these inner annulations seem to send minute processes into the outer tube. This appearance is probably due to a wrinkling of the substance. In **43**: 10 is shown a columnar epithelium on the outer surface of the middle tube; **43**: 4 shows very clearly the retraction of the inner tube, leaving a distinct space between its end and the end of the peduncle, which is enlarged and irregularly folded. The mobility of the peduncle even at its thickest portion and the manner in which the beaks of the shells impinge on its substance are illustrated by **43**: 13. The peduncle of *L. anatina* is quite opaque and but little could be seen through its walls. In Glottidia and *L. lepidula* the peduncle is somewhat translucent and the circulation of the blood within gives it a rosy hue.

A figure of the peduncle of *D. lamellosa* is given in **43**: 14. The various muscles here shown certainly indicate great mobility of the body upon its stalk.

The peduncle of Terebratulina has been most exhaustively treated by Ekman ('96), and so, for comparison only, I have ventured to give one figure illustrating the peduncle from a small specimen of *T. septentrionalis* (**43**: 15). I have shown elsewhere that in the extreme young of Terebratulina, the peduncle is elongated, exceeding the length of the shell, and with the elongated shell gives it a very linguloid appearance. In later stages it becomes shorter and sends out a number of processes which have been fully figured and described by Ekman in the memoir above referred to.

SETAE.

A very characteristic feature of the Brachiopoda is the setae which fringe the borders of the pallium. These vermian hairs arise from true setigerous follicles which are immersed at various depths in the thickened borders of the pallium. In the errantian forms they are highly mobile and act, as in the annelids, as locomotive organs; in Discinisca, they are variously barbed and in the extreme young of all forms thus far examined, the setae are not only barbed but deciduous. The setae of brachiopods differ from those of most chaetopods in not being jointed. Among the chaetopod annelids, however, there are certain sedentary forms as well as a few errantian forms in which unjointed and barbed setae are found; in Sabelliformis, for example, the setae are unjointed, hair-like, and fringed with short setellae. Sphaerodorum is exceptional among the errantian annelids in having unjointed setae; in the *Capitellidae*, also, the setae are unjointed.

In the errantian Brachiopoda, Glottidia and Lingula, as we have already seen, the setae act as locomotive organs, swinging with the same rhythmic motions that characterize the chaetopods. The setae were primarily locomotor in function and persist through inheritance, a secondary function being acquired in the *Lingulidae* in forming the lateral barriers to protect the pallial cavity from the ingress of sand and mud. In other groups, a secondary acquisition has probably been established in furnishing a nidus for diatoms and other foreign growths which they sustain, often in rich abundance, for the benefit of the animal in furnishing, or attracting, a food supply. In all brachiopods, they undoubtedly act as a sensory apparatus for tactile impressions.

The setae in all brachiopods thus far observed are marked by transverse lines, or joints, which are shouldered and which indicate successive increments of growth. Even in the almost aborted setae of Dallina the transverse lines are easily detected. Fine parallel lines also mark these hairs, and their appearance has been happily compared to the stem of an Equisetum.

In examining the setae of different genera more in detail, we shall find that in the unattached group, *Lingulidae*, they are most highly developed. Furthermore, the setae are grouped in definite clusters. On the anterior median line of the animal is a group of setae in which the middle ones are the longest, the setae on each side diminishing rapidly in length. This may be called the median cluster. The setae on each side of this cluster increase gradually or abruptly in length according to the species, becoming longest at the round angle of the shell where the anterior and lateral borders of the shell meet. These stand out at an angle from the median line of the body, right and left, and may be called the anterior clusters. From these clusters on the side, the setae very slowly diminish in length till they reach that part of the shell where it begins to taper rapidly toward the peduncular end; at this point they immediately become much longer, forming a very sharply defined cluster. These groups may be called the right and left posterior clusters. The setae between the anterior and posterior clusters may be designated as the lateral setae (**40**: 1). These clusters, with the anterior clusters, are peculiarly active when the creature is crawling over the sand or burrowing into it head foremost. Behind the posterior clusters, the setae are less numerous, and toward the peduncular end become more filiform, and are often bent and broken. They appear to be functionless and are becoming rudimentary, presenting a condition not unlike that seen in certain Testicardine forms. The proportionate length of the setae, and the outline made by the median and anterior clusters vary in the different species. In *L. anatina*, the posterior clusters are not so prominent as in *L. lepidula* and Glottidia. The lateral setae are very short, while the setae of the anterior clusters are very long, the setae rapidly increasing in length from the outside, and ending on the inner side of the cluster with the longest setae. The middle setae of the median cluster are about half the length of the longest setae of the anterior cluster, the setae becoming shorter on each side in such proportion as to form a rounded outline for the cluster (**40**: 16). In *L. lepidula* (**40**: 6) the median cluster does not assume the rounded outline seen in that of *L. anatina*; it forms a pointed cluster and the cluster is as long as, if not longer than, the anterior cluster, and this difference may be related to the tube-forming function of the setae already described and figured (**40**: 12). The anterior clusters have their longest setae in the middle of the cluster and not on their inner sides as in *L. anatina*. The clusters in Glottidia are very much like those of *L. lepidula*, except that the median cluster is much shorter than the anterior clusters. These various clusters both in Glottidia and *L. lepidula* are very prominent and sharply defined.

In Glottidia, the minute longitudinal markings of the setae remind one of the ruled gratings for spectroscopic work, and it is this feature which causes the clear steel-gray appearance and at times an iridescence when the setae are swinging back and forth.

The transverse markings of an ordinary seta number 158, and these are separated from one another the width of the seta. In *L. lepidula*, the setae are colored a light brown within the pallium, and this color extends some distance beyond the edge of the shell, as shown in **44**: 1.

After watching Glottidia and *L. lepidula* in their activities, at one time crawling slowly over the sand with the setae swinging in rhythmical motion, or when half buried in the sand, with the lateral setae standing at right angles to the edge of the shell and forming the side partitions already described, and, in the case of *L. lepidula*, forming the setal tubes, one is prepared to understand the varied functions of the complex system of muscle fibres which endow the borders of the pallium as depicted by Blochmann (:01). In the young of *Discinisca stella* the anterior setae are nearly three times as long as the diameter of the shell; the length of the setae diminishes rapidly toward the posterior end where they are very short (**61**: 3). In the mature *D. stella*, the setae are quite short and crowded together, though they are slightly longer in front than those springing from the posterior border. The setae in *D. stella* vary greatly in character; some have a brush of minute hairs, others have setellae between the joints which are more widely separated than those of Lingula, and in others still the setellae are extremely minute (**44**: 3). The setae are densely covered with various forms of minute growth. On the setae of Lingula and Glottidia, no trace of foreign growth is seen, as their functional activity prevents any adhesion of this matter. In *D. lamellosa* a rich growth of organisms abounds, and even in young Terebratulina the inactivity of the setae permits this accumulation of foreign substances. In the mature *D. lamellosa* the setae are rich light brown in color; they are closely crowded together about the entire periphery of the pallium, though not so thickly massed on the posterior border and being in this region only $\frac{1}{24}$ the length of the shell, while on the anterior border they attain the length of the shell (**49**: 2). They are mostly barbed, rarely smooth (**44**: 7). In the young of *D. lamellosa*, the setae are much longer than the diameter of the shell, becoming shorter on the posterior border or quite absent (**61**: 5, 9, 11, 12). Some are furnished with short bristles on the sides of the setae, and these setae are thicker and are not so deeply buried in the pallium as the more delicate setae which are furnished with long hair-like setellae (**44**: 9) and in rare instances more delicate setellae branching from these (**44**: 6). The setellae are bent at their junction with the setae, and those nearest the border of the pallium are bent backward. Joubin ('86) figures the setellae before they have issued from the pallium, as pointing in the same direction as the growth of the setae. This attitude would be manifestly impossible unless a sheath, enclosing the whole seta with its branches, moved outward in its growth from the follicle. On the contrary, the setellae trail backward in the growth of the seta and, after issuing from the border of the pallium, preserve for some time the bent attitude they had while immersed in the pallium (**44**: 8). Blochmann has figured their appearance correctly.

In *T. septentrionalis*, the longitudinal ribbing of the shell corresponds to the number of setae; that is to say, at the marginal termination of every rib of the shell a seta projects; this is especially marked in the early stages of the animal. In *Terebratalia coreanica*, the border of the pallial membrane is light rose-color and the setae and follicles are light yellow (**39**: 11). The setae are very short, hardly extending beyond the margin of the shell, and are embedded at various depths in the pallium. They are somewhat apart from one another (**44**: 12). In *Terebratalia minor*, the setae are extremely short and are quite widely separated from one another (**44**: 13). In *Laqueus rubellus* the setae are very short and the transverse marks upon them are much farther apart than in the other forms studied (**44**: 14). In *Hemithyris psittacea*, the setae are very short, delicate, and very brittle; the setigerous follicles are only slightly enlarged at their base. Two and even three setae apparently spring from one follicle. Between the follicles are threads of binding tissue and what appear to be muscular fibres (**44**: 15).

In summing up this brief examination of the various forms of setae here studied, it may be stated, first, that in every instance the setae are longest on the anterior border of the pallium, diminishing gradually in length around the lateral border and being shortest around the posterior border where they are tenuous, brittle, and often bent and broken;

secondly, that when in the mature form, the setae are very short; in the young of all species observed they are very long, often exceeding in length the shell (**61**), notably in Terebratulina (**61**: 16) and Hemithyris (**61**: 17).

BRACHIA.

The brachia form one of the most complex structures of the animal and, in life, one of the most beautiful. In one division they are more or less rigidly held by the calcareous loops or crura; in the other division they have the greatest freedom of movement within the pallial cavity. No drawing can convey the grace and beauty of their various motions; in one attitude suggesting the lophophore of the phylactolaematous Polyzoa, at another time thrown into a position resembling that assumed by some sabelliform worm. The attitudes of the brachia are constrained to a symmetrical position on either side of a median line in those forms having crura; even the cirri seem to be controlled by this bi-symmetrical impulse, though individual cirri often move more independently. *Hemithyris psittacea* was observed to move one coiled brachium beyond the shell in advance of the other (**46**: 14). In the *Lingulidae*, the brachia have the greatest freedom of motion, yet, so far as observed in life, the various attitudes are strictly bi-symmetrical. The veil or collar at the base of the cirri is brown, being lighter or darker in different species; the brachia are pure white, and the cirri are variously colored with brown pigmentation. The various attitudes of the brachia in *G. pyramidata* are depicted on **45**. Under a low power they present attitudes of the most exquisite grace and beauty; the brachia coil and uncoil with the greatest freedom, and sometimes the cirri stretch quite to the anterior borders of the shell and even a little beyond (**45**: 13); again the coils are depressed like a flat helix and gradually change their position, assuming the attitude of a globular helix with high spire. The axis of this helix is often changed, sometimes standing nearly vertical and then taking a nearly horizontal position, these attitudes being duplicated with perfect symmetry by the two brachia. A characteristic and beautiful attitude of the brachia of Glottidia is figured on **45**: 6. This attitude is assumed when the animal is at rest, with the anterior part of the body slightly protruding from the sand. The entire width of the pallial chamber is occupied by the out-stretched cirri. In this figure the gill ampullae may be seen projecting from the pallium above and below. The double flexure of the anterior margins of the pallium is richly colored a dark brown, and later I shall suggest that these are sensory regions susceptible to light impressions. The drawing but faintly represents the surpassing grace and beauty of the extended arms; the faint brownish tinge of the cirri, the rich brown border of the brachia contrasting with the pure white color of the remaining surface, the nearly transparent ampullae tinted a delicate rose-color by the red blood coursing through them, the deep, rich brown markings of the pallium, and the fringes of iridescent setae, form a striking picture of the beauty of these remarkable creatures. In one observation (**45**: 3) the brachia were thrown widely apart with the coils depressed; in this attitude a few cirri were seen brown in color, and these were not aligned with the other cirri but were bending irregularly. Precisely from what part of the brachia they originated, or whether they had special functions or were abnormal, was not ascertained. Similar attitudes of the brachia are assumed by *L. lepidula*, but it would be simply duplicating the figures to represent them. The veil, or collar, at the base of the cirri is a much darker brown than in Glottidia (**45**: 15; **39**: 2). In **46**: 4, the brachia of *L. lepidula* are represented devoid of cirri, and again, in **53**: 8, one brachium is shown in this way. These outlines were drawn through the nearly transparent cirri. In *L. anatina* the brachia are the purest white, the border and collar a rich dark brown. In **40**: 16, 18, is shown a view of the brachia contracted, in which the color of the borders of the brachia is represented. In young *L. anatina*, the brachia were observed extended at right angles far beyond the borders of the shell (**40**: 17).

In all my collections of *Lingulidae*, I have never met with very young or small specimens. Individuals a few millimeters in length would doubtless show a much greater freedom in the movements of the brachia. Realizing the interesting features displayed by the young of Terebratulina and Discinisca, of which it is easy to obtain examples, an important addition to our knowledge of the life attitudes of these parts will be made when the young of Glottidia and Lingula are found. It is a rather curious fact that these young stages have never, to my knowledge, been collected, and with the exception of a brief description of an early stage by McCrady and the admirable memoir by Brooks ('79), who was the first to make an important study of the swimming stages of Glottidia, nothing is known either of the embryonic or adolescent condition of these animals. In a small and unknown species of Lingula, dredged in Nagasaki Bay, and upon which but a single observation was made, the underside of the brachia was dark brown, this color extending to the mouth with widely diverging lips as well as to the cirri (**46**: 7). In *Discinisca stella*, in a young stage, the brachia, head, and neck were a rich madder brown, the dorsal cirri were dark brown, while the ventral cirri were white.

The brachia in all alcoholic *Lingulidae* are contracted to the last degree, and it is in this condition that they are always figured in memoirs on the subject. In life such an attitude is never assumed unless the shells are torn violently apart. An interesting observation will be made when *Discinisca lamellosa* is studied in life. The brachia in the preserved specimens are far more expanded and stand out more freely on each side of the prominent head than in Lingula. They are more highly endowed with muscles, not only to move the several parts, but special muscles — the retractor brachia — are found which would seem to indicate a considerable movement of the structure as a whole. It is highly probable that the brachia have the power of uncoiling and even of partially projecting from the pallial chamber. The various muscles at the base of the cirri and of the collar indicate the same mobility of parts as is found in the *Lingulidae*. In **46**: 10, is represented a section of the brachium of *D. lamellosa* at a point indicated by A, B in **49**: 2. In the sinus at the base of the brachium, which is named the small brachial sinus by Blochmann, curious little round cells occur, held together by delicate threads; their function is not known, though they may be what Blochmann terms, in this region, gland cells. At **46**: 10*a* is a greatly enlarged view of the appearance of these bodies.

In *Terebratulina septentrionalis*, three millimeters long, the cirri project slightly beyond the borders of the shell (**46**: 12). Barrett ('55) has already observed the same in the adult form. In *Terebratalia coreanica* (**46**: 13), the cirri reach quite to the inner borders of the shell but were not observed to go beyond this edge. In all those forms with crura the brachia are constrained to a more or less rigid attitude, yet there must be some elasticity in the anterior portion of the brachia.

In *Hemithyris psittacea*, the brachium forms a coil of many turns. As I have shown elsewhere ('78), the brachia are at times protruded in a coiled condition (**46**: 14). In this figure it will be seen that one coil is projected farther than the other, indicating an independent motion of the brachia. In *Hemithyris albida*, dredged in Tsugaru straits, between Yeso and Japan, the brachia were observed protruding in the same way. One individual, with the coils protruded, was suddenly immersed in alcohol and the left brachium immediately uncoiled to nearly its full length, as shown in **46**: 15. In *H. psittacea* the brachia may be partly uncoiled within the pallial chamber as shown in **46**: 16, and it would not be surprising if, under certain conditions, the brachia might uncoil and be protruded as shown in the alcoholic specimens above mentioned. The free collar about the mouth is very mobile (**46**: 17, 17*a*), and just above the mouth a white, fibrous yoke is seen connecting the base of the brachia. A rounded area which appears on each side of this yoke indicates the great sinus connecting the brachia with the coelomic cavity.

The cirri, though apparently rigid, do move with great freedom. The general appearance, as they spring in double and alternating series from the brachium, is shown in **46**: 18. The margin from which they spring is scalloped, and the cirri rise from the crests of these scallops. Scattered muscle fibres are detected running to the scalloped margin, and parallel with this margin are other bands of muscle fibres.

CIRRI.

The cirri of the *Lingulidae* thus far observed are tubular to their tips and the blood circulates freely within this cavity, as shown in a cirrus of Glottidia (**46**: 2). The cirri are strongly ciliated and the ciliary movements must be vigorous to cause the rapid currents of water which steadily pass in and out of the pallial chamber (**40**: 12). The cirrus of Glottidia is marked by irregular transverse wrinkles which are repeated on the lining membrane of the cavity within, giving it the appearance of a rude sort of annulation. The walls of the cirrus are thick and the tubular cavity within has nearly the same diameter as the thickness of the wall. In *L. anatina*, the cirri are coarsely and densely ciliated.

In all Ecardine brachiopods the cirri are colored in various parts. In Glottidia, the tip of the cirrus has a light brown tinge (**39**: 7). In *L. lepidula*, it is brown on the outside from the base to a third of its length; near the tip a brown tint is seen on the inner surface (**39**: 2; **45**: 15; **46**: 5). In *L. anatina*, the sides of the cirrus are brown. The structure of the cirrus in Discinisca seems more complex than that of the *Lingulidae*. The cirri in the Testicardine group are usually white or yellowish, though Schulgin ('84) figures the cirri of *Cistella kowalevskii* as yellowish red, and these he represents as projecting slightly beyond the borders of the shell. He furthermore adds that he never saw a particle of blood enter them. The cirri of many Testicardine forms have already been figured and described, notably by Bemmelen ('83), who has, with infinite pains, given a most exhaustive series of drawings and descriptions illustrating the histology of a number of brachiopods.

At **46**: 18*a* is represented a portion of a cirrus much enlarged of *H. psittacea*. In dissection, it appears almost cartilaginous, so stiff and rigid does it seem. The ciliated epithelium is easily detached from the surface. A narrow inner tube is found in which the blood freely circulates; outside this tube is a sheath containing encircling muscle fibres, and outside of all is the firm cartilaginous-appearing substance which supports the loosely connected ciliated epithelium.

Schulgin, in the paper above referred to, described the cirrus of Cistella as having a somewhat firm exterior, which is elastic, and said that when the cirrus is bent by muscular contraction, the elasticity of this substance brings it back to position again. It has occurred to me that the cirrus of *H. psittacea* may act in the same way. There are no spiculae in the cirri, as in Terebratulina and allied forms, and though more complex in structure than the cirri of the *Lingulidae*, they bear a nearer relation to these than to those of the Testicardines. Hemithyris in other respects also approaches the Ecardine group.

Hancock ('59) states that in the brachium he found 4,000 cirri. Whether this number was based on a definite count or an estimate is not known. In the species studied in the St. Lawrence, and which has always been recognized as identical with the *H. psittacea* of Europe, I counted only 450 cirri on the brachium of a fully matured specimen. This leads me to believe that Hancock's figure is the result of a misprint and that the number should read 400 and not 4,000.

Muscles.

The muscles of many forms of Brachiopoda have been often figured and described, and a number of investigators have given their own interpretation of the functions of these muscles with a terminology of their own, differing, of course, from that of their predecessors. Hancock's names for the muscles of Lingula were vitiated because he argued from analogy that since the Testicardine forms had an interlocking device to prevent the lateral displacement of the shells, in Lingula, there being no such interlocking device in the shells, the muscles were so arranged as to accomplish the same purpose. He says, "Indeed the attachments of the various muscles [in Lingula] are so distributed around the margin of the perivisceral chamber that transverse, longitudinal and diagonal movements are alike guarded against. And perhaps their true functions are best understood when thus considered in co-operation; it is then seen that they form a complicated complementary system for the purpose of assisting in adducting the valves, their various points of attachment and different inclinations being so arranged, that, in whatever state of action they may happen to be, they will always keep the valves steadily and accurately opposed to each other." In commenting on the names given by previous investigators to the muscles of Lingula, Hancock says, "It is necessary to alter these later epithets as they imply what appears to be a false theory, namely: the sliding of the valves over each other." Owen ('35), to whose terminology he particularly refers and upon which he animadverts, in describing the various muscles of Lingula, says, "The arrangements of these powerful adductors are such as to effect the sliding movements of the valves on each other, beside closing the shell, and to compress and variously affect the interposed viscera and visceral lacunae with their contained sinuses," and I may add that no words could express more correctly the precise work accomplished by these muscles, for they cause not only the "transverse, longitudinal and diagonal movements" of the shell, and that in a more vigorous way than even Owen dreamed of, but they do compress and variously affect the interspersed viscera and the circulation, as will be seen farther on.

In a short paper in the American journal of science and arts in 1870, I first figured the appearance of the oscillatory and sliding movements of the dorsal valves in Glottidia, though Carl Semper ('62, '64) had described this feature eight years before. Blochmann, who has recognized this mobility of the dorsal shell, was prepared to understand the functions of the oblique muscles, and his nomenclature is so simple and so apt that I have adopted his names in this memoir. There is but little to add to what Blochmann has given of the musculature of *L. anatina*, and that is, that the anterior occlusor muscle should be recognized as containing two elements, at least, if not two distinct muscles, to which the names that he has applied to similar muscles in *Discinisca lamellosa* should be given, namely: occlusor anterior 1 and 2. He certainly shows the two elements in his figures, but calls them simply occlusor anterior. In *L. lepidula*, these two muscles vary in the appearance of the muscular bundles at their points of attachment and they vary in their color also (**47**: 6). I did not observe the separation of these muscles in Glottidia, on account of the opacity of the shell, but there is no doubt of their separation.

It remains for me to describe the muscles of Glottidia and of *L. lepidula* and to point out certain differences between them. In Glottidia, the oblique muscles are more delicate than in *L. lepidula*. The terminations of the muscles in Glottidia at their points of attachment vary slightly in color; the obliquus internus is greenish, the obliquus medius is white, while the obliquus externus is silvery in appearance. The obliquus medius has its dorsal attachment posterior to that of the obliquus internus, while in *L. lepidula*, it is anterior to that muscle. Furthermore, in Glottidia the obliquus medius passes inside of the obliquus internus, whereas in *L. lepidula* it passes outside that muscle (**48**: 1, Glottidia; 2, *L. lepidula*). The points of attachment to the ventral shell appear the same in both instances, except that in *L. lepidula* they are much nearer the posterior portion of the shell, as in *L. anatina*. In *L. lepidula*, the points of attachment of these muscles show different features in color and in the nature of the lobulated appearance, as shown in the figures (**48**: 6, 8). In *L. lepidula*, the dorsal attachment of the lateralis muscle presents features of such a character that at first I was inclined to believe that they slid back and forth to a limited extent. The dorsal terminations of these muscles present an appearance as if a thickened aponeurosis stood between them and that the muscles were attached to this and not to the dorsal shell. Vogt ('45) and Blochmann represent their appearance correctly. In Glottidia, however, they appeared to me to be attached to the shell. In *L. lepidula*, when the animal is in action, this region varies greatly, as may be seen by comparing **47**: 5 and 6. In a contracted attitude of the lateralis (**47**: 5), the oesophagus is drawn toward the stomach so as to be partly telescoped within it, and the anterior portion of the stomach appears like two horns, only a small portion of the oesophagus showing between the posterior face of the lateralis and the stomach, while the lateralis are turned sharply to the right and left respectively. The anterior occlusors are shortened in their longitudinal diameter. In **47**: 6, the lateralis muscles are drawn out, exposing a much longer section of the oesophagus and clearly exposing the pharyngeal glands, and the anterior portion of the stomach is no longer bifurcated, the anterior occlusors being also drawn out longitudinally. If these parts have a limited motion, these various appearances are accomplished mainly by a contraction of the obliquus externus, obliquus medius, and lateralis. In the contraction of the lateralis, the dorsal shell with its attachments is drawn backward, as the ventral shell is rigidly held by the peduncle, producing the appearance seen in **47**: 5, while the contraction of the obliquus externus and medius draws the dorsal shell forward, presenting the appearance shown in **47**: 6. From this description one may get an idea of the mobility of the dorsal shell.

There is but little to add to what has already been made known concerning the muscles of *D. lamellosa*. It seems strange, however, that Owen, Joubin, and others should not have seen the true character of the anterior occlusors. Blochmann is the first to give a correct figure of these muscles, in which he has shown that the occlusor muscle is really divided into two muscles, which he indicates as anterior occlusor 1 and 2. In my studies of these muscles I had intended naming them external and internal occlusors respectively, but to avoid increasing the already confusing nomenclature on the subject, I shall adopt the names given by Blochmann. In *L. lepidula*, the separation of the anterior occlusor into two elements has just been pointed out, and it would seem that they must be homologous with these muscles in *D. lamellosa*. The lateralis in Lingula and Discinisca is also found where it might be expected, considering that in Lingula the body is drawn out while in *D. lamellosa* it is concentrated. A further reference will be made to the musculature of Discinisca in a consideration of the early stages of the animal. The muscles of Terebratulina and allied forms have been thoroughly described by Hancock, and my observations are only confirmatory of what is already known. The interlocking shells of the Testicardine forms would seem to preclude any other function of the muscles save that of the opening and closing of the shells, and of causing the body to move on the peduncle. In Discinisca, the silvery and tendinous muscles connected with the peduncle imply much freedom of motion of the body. In the Testicardines the muscles have, without exception, broad bases of attachment tapering toward the middle of the muscle, while in the Ecardines, with the exception of the lateralis and the obliquus medius, the muscles have the same diameter throughout. In the young of *D. lamellosa* (**61**: 11), however, the muscles have broad bases of attachment. A very marked difference therefore is seen in the muscles of the Testicardine and Ecardine groups.

MESENTERIES AND PERIVISCERAL BANDS.

The various bands and mesenteries so characteristic of the Vermes are marked features of the Brachiopoda. These bands not only hold in place the various internal organs, but from them spring, as in many worms, the genital products. A transverse section of Glottidia, just back of the stomach, reveals a dorsal and a ventral mesentery and lateral bands springing from the intestine and attached to the various parietes. A dorsal view of the intestine of Glottidia (**50**: 8) shows the line of attachment of the dorsal mesentery running back for a short distance from the abrupt collar, which forms the posterior edge of the stomach, and then dividing to the right and left. The right line of attachment runs abruptly down the side of the intestine reaching the middle of the ventral surface (**50**: 7), and then back again and obliquely across the dorsal surface and on posteriorly. The left branch of attachment apparently continues along the left side of the intestine. These lines mark the attachment of the membrane known as the ilio-parietal band (**47**: 1). This membrane stretches across the coelomic cavity, its edges touching the oblique muscles and connecting also with the nephridia on each side and just back of the nephrostomes, sending bands to the lateral coelomic walls. It follows the upper inflection of the intestine and sends out a broad band to the posterior adductor muscle. Another sketch is given (**48**: 3), showing the appearance of the posterior bend of the intestine with a band running to the posterior adductor. A transverse section of the mid-gut presents the appearance of the ilio-parietal band, upon which may be seen delicate branches which are apparently vascular. The coelomic cavity seems to be ensheathed in a peritoneum which is attached to the dorsal parietes and seems to rest on the oesophagus and stomach and runs down on the right and left to the ventral region. A comparison with the oesophageal mesentery of Phoronis would be of interest in this connection. This membrane is quite vascular, and an injection from the peduncular cavity filled these vascular ramifications without entering the pallial sinuses or the coelomic cavity (**54**: 1, 2). Further remarks will be made on this matter under *Circulation*.

The gastro-parietal band in *L. lepidula* forms an almost complete wall between what might be called the gastric cavity and the perivisceral cavity. Its dorsal boundary is very conspicuous through the translucent shell and appears tendinous. On each side where this band joins the lateral coelomic walls, muscular fibres are seen. Blochmann observed these muscles in *L. anatina* and has called them gastro-parietal muscles (**48**: 6). In *D. lamellosa*, just back of the stomach and partially obscured by the stomachal glands, a band is attached on each side, which runs across the coelomic cavity to the right and left and terminates near the posterior dorsal face of the first anterior occlusor. This is the gastro-parietal band (**49** : 1). In alcoholic specimens this band has a marked backward flexure, due probably to the contraction of the coelomic walls. From this band, as well as from other bands, the genital products arise, to which further allusion will be made. The band is bluish white in color and is of considerable strength. When the coelomic cavity is crowded with genital products, a number of membranous strands, binding the mass together, are seen running in various directions (**49** : 2). The gastro-parietal bands are distinct enough as to their main points of attachment, and the membranous strands just alluded to appear to be proliferations from the edge of the gastro-parietal band. At **49** : 6 is shown the appearance of the intestine at the point of attachment of the gastro-parietal bands. From the posterior bend of the intestine, on the dorsal side, a band runs back connecting with the posterior wall of the coelomic cavity. This band seems to be split into several strands and is quite distinct from a genital band which appears in folds just above it (**49** : 1). Below this is a narrow band attached to the posterior bend of the intestine and connected with the coelomic walls; **49** : 3 represents a rough outline of *D. lamellosa* in longitudinal section in which attachments of these two bands are shown. In the early stages one of these bands shows very conspicuously (**50** : 15). I have called this band ilio-parietal, following Blochmann.

In *T. septentrionalis* (**56** : 2), a wide band stretches across the coelomic cavity transversely, passing over the intestine, to which it seems to be attached anteriorly, and involving the nephrostomes. Huxley compared this band with the nephrostomes suspended from it, to a landing net hanging in its frame. He was the first to call this band the ilio-parietal. From the posterior edge of this band and certainly below its edge, a narrow band arises which splits into one or more strands, and this band not only supports the "accessory hearts of Hancock," but the genital products, either ova or spermatozoa; for this reason they are called genital bands (**56** : 1, 2, 3). These bands, or at least their edges, support a strongly ciliated epithelium (**59** : 8), and during genital activity the edges become thickened by glandular growth (**56** : 2, g. g.). This same thickening of the edge of the ilio-parietal band is seen in *T. coreanica*, as will be shown in discussing the genitalia. In *T. coreanica*, the ilio-parietal band, in which the nephrostomes are involved, surrounds the stomach, becoming narrower in that part connected with the nephrostomes and sending out two narrower bands in front and laterally. Posteriorly it is connected with a median septum which runs back to the posterior coelomic wall. A strong median septum runs forward from the stomach to the anterior coelomic wall, and these two septa may be looked upon as the ventral and dorsal mesenteries respectively (**55** : 8). Other bands diverge from the stomach both laterally and posteriorly, and these are named, provisionally, ilio-parietal bands (**59** : 9).

How far these various bands are correlated in the various genera of brachiopods, it is difficult to determine. In some forms they are weakly developed, as for example in Cistella. According to Schulgin, there is no dorsal mesentery in Cistella,[1] though Kowalevski states that he has defined it. At the base of the body cavity Schulgin finds that the peritoneum forms an *excavatio peritonalis*, which plays an important part in the circulation of the blood. He also finds the inner surface of the body cavity, as well as the peritoneum, clothed with a low ciliated epithelium. Much further research will be required to ascertain the relation of the various bands and mesenteries.

Alimentary Tract.

The alimentary tract, from the mouth to the anus, is very simple. In the Testicardines it is straight with the exception of the abrupt dorsal flexure at the anterior portion, and terminates blindly. In Crania it opens posteriorly. In Discinisca it makes a simple turn to the right and opens through the lateral coelomic wall. In the *Lingulidae* it runs straight backward to the posterior wall of the coelomic cavity, then, turning to the left, it runs forward as far as the oblique muscles, to turn again, running back dorsally in line with the first segment of the intestine, and then turning to the right, terminates on the right side at a point midway between the oblique muscles and the anterior occlusor. These various lengths of the intestine are correlated with the size and extent of the coelomic cavity. In the *Lingulidae*, an elongated cavity permits the intestine to make two turns; in the less capacious cavity of Discinisca the intestine makes but one turn. In the Testicardines, where a remarkable abbreviation of the coelomic cavity is seen, the alimentary tract is concentrated into the smallest possible space; and in Crania, which has no peduncle and in which the dorsal shell is free around the entire periphery, the intestine terminates posteriorly, the only instance thus far known among living Brachiopoda. In this connection a consideration of the perforation or sometimes simply a notch in the beak of the dorsal shell of many of the fossil genera of Testicardine forms would be of interest.[2]

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[1] Argiope of Kowalevski and Schulgin.

[2] Dr. C. E. Beecher ('92) says, "The dorsal beaks of Amphigenia, Athyris, Cleiothyris, Atrypa, and Rhynchonella are usually notched or perforate. The perforation comes from the union of the crural plates above the floor of the beak leaving a passage through to the apex. A similar opening occurs between the cardinal processes in Strophomena, Stropheodonta, and allied genera, and the chilidium may also be furrowed, as in *Leptaena* (= *Strophomena*) *rhomboidalis*. This character is evidently in no way connected with the pedicle opening, but points to the existence, in the early articulate genera, of an anal opening dorsal to the axial line, as in the recent Crania. This dorsal foramen was described and figured by King, in 1850, Hall in 1860, and by several authors since, and has commonly been termed a visceral foramen.

"Oehlert suggests that it was probably occupied by the terminal portion of the intestine. The persistence of the foramen seems to indicate an anal opening."

In the *Lingulidae*, the nutrient canal has a definite pharynx, oesophagus, stomach, and gut. In Glottidia the mouth, as seen from below, is marked by very prominent lips; these are everted, the lower lip turning backward and at times being widely distended; the upper lip showing a continuous curve, the lower lip divided by a deep median depression or thrown into four folds, as shown in **50**: 3, 4.

The lips are very sensitive and mobile, and are a continuation of the brachial fold which runs the entire length of the coiled brachia. The strong ciliary movements of the cirri sweep the microscopic organisms, upon which the animals subsist, along this groove and directly into the mouth. These parts in Glottidia and Lingula are colored brown. The mouth and pharynx stand quite free from the anterior wall, as may be seen in the various longitudinal sections figured (**47**: 2; **50**: 1, 2). The extreme mobility of the brachia and the delicate movements of the lips and brachial fold justify the belief that when the young forms are observed the mouth parts will show great freedom of motion.

A longitudinal section of the pharynx in Glottidia reveals on its upper inside surface three transverse areas of irregular depressions (**50**: 6), the ridges separating these depressions being sharp and conspicuous. This structure suggests a triturating apparatus, as the lower floor of the pharynx is smooth and the folds of the stomach and intestine are longitudinal. An external view of the dorsal portion of this region shows longitudinal muscle fibres diverging anteriorly and two distinct sets of transverse muscles which are evidently connected with the triturating surface of the pharynx (**50**: 5). The pharynx and oesophagus ascend sharply to the stomach (**47**: 2; **50**: 1, 2). The anterior portion of the stomach is globular with a slight constriction behind and then an abrupt dilatation forming a sharp collar which becomes abruptly constricted as it enters the intestine. To this collar are connected the gastro-parietal band and other membranes below, making a partition which almost separates the perigastric cavity from the perivisceral cavity. A section of the stomach of Glottidia shows the interior membrane thrown into folds. The intestine follows the same general course as in Lingula, which has been repeatedly figured; it differs from Lingula, however, in the slight flexure seen in the first length that turns forward (**47**: 1). The figure shows this portion of the intestine removed to one side in order to expose the nephridium below. The intestine within is clothed with a ciliated epithelium.

In *Lingula lepidula*, the pharynx and oesophagus are longer than in Glottidia and may be elongated or shortened by the contraction of certain muscles as already described. In a retracted state (**47**: 4), the pharynx is slightly bulging, and on each side may be seen small, round glands which occupy precisely the same position that they do in certain chaetopods. I have therefore called these bodies pharyngeal glands. They doubtless occur in all the *Lingulidae* but owing to their small size have escaped notice in preserved specimens. The oesophagus is cylindrical, slightly bulging in a contracted state, and has broad longitudinal markings due to folds within. It enters the stomach as a straight tube (**47**: 5, 6). The stomach is quite different in shape from that of Glottidia, being acutely triangular, the base of the triangle being posterior and the sides curving slightly inward. When the oesophagus is retracted, the anterior portion of the stomach projects on each side like two horns (**47**: 5). The surface of the stomach is thrown into vermiform folds and in life these folds are continually in motion, expanding and contracting (**48**: 5). The intestinal canal, as in Glottidia, is strongly ciliated.

In Glottidia the rectum perforates the lateral coelomic wall obliquely and shows a distinct projection outside, the anus being marked by six flat tubercles (**50**: 10). In *L. lepidula* the rectum enters the coelomic wall in precisely the same manner. The anus is bordered by six folds or blunt scallops like the petals of a flower, the notches between these folds continuing within the rectum as lines, due to longitudinal folds (**50**: 11). This is its appearance in life, and the parts vary in their appearance as shown in **50**: 12. The anus in Glottidia was drawn from an alcoholic specimen. In both Glottidia and *L. lepidula* it will be observed that there are six tubercles or folds, and in life the anus of Glottidia would probably present the same petal-like appearance as seen in *L. lepidula.* The faeces appear as oval pellets.

In *D. lamellosa* the head is very prominent and is probably very mobile; the mouth, as in the *Lingulidae,* is turned abruptly downward and the oesophagus runs directly upward reaching nearly to the dorsal shell, where the parts are held in place by the dorsal mesentery (**49**: 3). The stomach shows but slight enlargement; the intestine descends posteriorly toward the ventral shell and is cylindrical throughout. The anus is a mere perforation in the coelomic wall and is marked by a few radiating wrinkles (**50**: 13). In the early stages the stomach appears as a large globular cavity; a slight constriction occurs as it enters the intestine, which turns to the right and which has a slight dilatation before it enters the narrow rectum (**50**: 14, 15; **61**: 7, 10). In *D. stella,* the head is dark brown and quite prominent. In the early stages, the stomach is large and globular, nearly filling the coelomic cavity; a short intestine follows, turned abruptly to the right. The animal is represented in **61**: 2 as seen from the ventral surface.

In *T. septentrionalis,* the wide expanded lips of the mouth show great mobility in the young; the lips are thrown into one or more folds and are in continual motion. The outer layer of the intestine is composed of longitudinal muscular fibres, and when cut through, the muscular layer contracts, drawing the cut edges back as shown in **50**: 16. The faeces in spiral fusiform shape, are ejected through the mouth.

In *H. psittacea,* the alimentary tract, when divested of its attachments, assumes its natural flexures (**50**: 17). The mouth is slightly dilated; the oesophagus is long, straight, cylindrical, and marked by encircling muscular fibres, and makes an abrupt turn just before it enters the stomach which is slightly dilated. A strong peristaltic action of the oesophagus continues some hours after its separation from the body. The stomach and intestine run downward parallel to the oesophagus; the intestine continues with a slight turn forward until near the end where it turns upward and dorsally, and terminates in a blunt point. There is no bulbous enlargement at the end, as figured by Hancock, though in his specimen the end of the intestine might have been packed with excrementitious matter. The intestine is cylindrical and retains the same diameter throughout, tapering only at the end, and is brownish in color. The stomach has smooth walls. The first part of the intestine presents a glandular appearance; halfway to the end of the intestine a few spiral markings are seen, and at the end a few longitudinal markings occur. The "heart of Hancock" is a testicular knob lying back on the stomach and narrowing at its point of attachment.

Stomachal Glands.

One of the marked characteristics of all Brachiopoda is the stomachal glands, usually known as the liver. These appear, at an early stage, as simple, wide diverticula of the stomach. At the outset these folds present the color which is ever after retained. These simple folds contract and expand independently of each other, and through life the same contractility is manifested by the individual coeca making up the mass. The young stages of Discinisca, Terebratulina, and Hemithyris present these features alike. The simple fold splits into separate branches and these subdivide again and again until there is formed a great tuft-like mass of branching coeca varying in certain features in each genus, being long and tubular in Hemithyris, branching like a stag's horn in Terebratulina, and assuming the shape of blunt clusters in the *Lingulidae*. The coeca, furthermore, seem as fully charged with diatoms and other food material as the stomach itself.

Similar diverticula of the digestive tract are seen among the worms, and their function has been interpreted as hepatic. Gegenbaur ('78) throws out a word of warning in his "Elements," wherein he says, "The glandular organs connecting with the mid-gut are ordinarily regarded as hepatic, or as the 'liver'. We must be careful not to attribute anything more than the value of a convenient distinction to these names." It is well known that these glandular conditions are found in the Polyzoa, Rotatoria, and other groups; the contents of the cells are different in color and therefore, says Gegenbaur, they might rightly be considered as secreting appendages. Dr. Arnold Lang ('96) calls attention to the fact that the mid-gut diverticula are universal in the Malacostraca, and that they are comparable to the mid-gut diverticula in the Entomostraca, and remarks that these organs are generally called livers. Taking into account their physiological activity in these animals, he thinks the name hepato-pancreatic the more suitable. Joubin, in his valuable memoir on Crania and Discinisca, has been the first zoölogist, to my knowledge, to question the accepted name for these parts. He insists that they are glandular in nature and would designate them simply as stomachal glands and this name I have adopted.

In the *Lingulidae*, the stomachal glands are largely developed, branching not only from the stomach proper but from the intestine, from which is sent out a mass which occupies no inconsiderable portion of the perivisceral cavity itself. The masses springing from the stomach quite fill the perigastric cavity. The main openings into the stomach and intestine are nearly as large as the diameter of the intestine itself. In Glottidia, the terminal coeca are in the form of blunt, shallow pouches in clusters of twelve or more; the mass is very compact and greenish in color and the cavities are filled with diatoms and other food material (**51**: 1; **57**: 1). In *L. anatina* the stomachal glands appear in the form of agglomerated lobular masses, the lobules coalescing, with a whitish, membranous partition between (**51**: 2). The cavities were filled with brownish granules and the usual mass of diatoms, etc. In the *Lingulidae*, the stomachal glands form irregular-shaped masses. In *D. lamellosa*, the stomachal glands appear in the young as long coeca, closely resembling, in this respect, Terebratulina (**51**: 3, 4, 5). In preserved specimens the coeca are yellowish in color and together form a rounded compact mass (**49**: 1, 2). In *D. stella*, the separate lobules are marked by a few parallel lines again resembling the Testicardines. The mass is light amber in color, and in life the usual contractions and expansions of the individual coeca are seen (**51**: 6). In *T. septentrionalis* the stomachal glands consist of long, irregular, branching coeca, marked within by longitudinal bands which are united at the tips of the coeca and continue down into the main branches (**51**: 7, 8). In life they are in continual movement. In my Early Stages of Terebratulina, I have figured and described the development of the stomachal glands from the first outfolding of the stomach wall. In *T. coreanica* the coeca are marked by six longitudinal bands looped in pairs at the tips (**51**: 9). In *Dallina grayii*, the coeca are more slender and the bands appear looped at the tips (**51**: 13). In *H. psittacea*, the stomachal glands present an appearance quite unlike that observed in any other form studied. In the youngest individual observed, the stomachal glands of one side consisted of three short lobules, within which were irregular brownish folds in pairs, resembling the appearance of wood-graining (**51**: 10). In a more advanced stage, these coeca were marked by brown granules leaving three clear interspaces which began to assume the spiral arrangement that they finally exhibit in a conspicuous degree (**51**: 11). In the adult, they form close clusters of long coeca, the individual coecum being often slightly bent at its end. In life, a pulling-down movement of the clusters is seen at intervals. The coeca are marked by very symmetrical, closely wound spiral bands in pairs (**50**: 18; **51**: 12). In the first-named figure, the appearance is given of a portion of the stomachal glands irregularly springing from the stomach; it will be observed that the main branches are very large, as they are in Glottidia (**47**: 2). Schulgin finds a primitive form of stomachal glands in *Cistella kowalevskii*, the lobules being reduced to eight on a side. He has discovered that when the creature is well fed, the cavities of the lobules are filled with cells converging from the wall and nearly meeting in the center, and that when the animal has been kept in filtered water for several days, or otherwise starved, these cells are shriveled, and that the development of the cells is evidently for the accumulation of nourishment.

In conclusion, the stomachal glands may be regarded as extensions of the absorbent surface of the digestive tract, and are probably hepato-pancreatic in their nature. The facts that they develop as simple folds of the primitive digestive sac, that these diverticula subdivide into numerous branches, that the main branches connecting with the stomach are in some forms nearly as large as the diameter of the stomach itself, that the various coeca are filled with food material and are continually dilating and contracting, all point to the same conclusion.

Sense Organs.

Among the most difficult features to make out in Brachiopoda is the nervous system. There are, of course, certain portions of this system which are always conspicuous, such as the central ganglion of Terebratalia or the oblique nerves in the *Lingulidae* and the *Discinidae*, but the ganglia about the oesophageal region and the termination of the smaller branches are certainly difficult to define. With staining and section cutting the work apparently becomes simplified. As an illustration of the obscurity of these parts, I may confess that, with all my studies of living Terebratulina, even the faintest trace of a nerve has never revealed itself to me. This fact is mentioned as an apology for the very meagre results to be presented.

The otocysts in mature *Lingula lepidula* and *anatina*, I was fortunate to make known first in a brief communication to the Boston society of natural history in 1877, afterwards published in the American journal of science and arts. In the *Lingulidae* and the *Discinidae*, a most casual examination of the coelomic cavity reveals the presence of a nerve running along the lateral walls of this cavity and terminating posteriorly. An examination of this nerve reveals at least the medullary sheath and neuraxis. In

Glottidia this nerve arises from the infra-oesophageal ganglia, runs outside of the anterior occlusor muscles, and then follows along on the inside surfaces of the oblique muscles. Hancock represents this nerve as entering and passing through the various muscles it encounters, whereas, in the three species of the family I have studied, the nerve simply passes over the surface of the muscle to which it adheres by sending out little twigs, which penetrate the muscle. At **51**: 19 is represented the appearance of these twigs branching from the main nerve. The infra-oesophageal ganglia arise just behind the brachial sinus and below the oesophagus, and the nerve passes around the anterior and lateral face of the anterior occlusor muscles. The flexures of this nerve, as shown in **51**: 14, are probably due to the contraction of the parts.

In *Lingula lepidula* the oblique nerves, one on each side of the coelomic cavity, follow in the same path and cling to the oblique muscle in the same way. Blochmann and others represent their appearance correctly. A pair of auditory vesicles is found a short distance back of the dorsal attachment of the anterior occlusor muscles and in close proximity to the inner corner of the opening of the large pallial sinus (**47**: 5, 6; **48**: 5, 6; **51**: 17, 18; **52**: 1, 2; **53**: 8, 9). In living *L. lepidula* these otocysts are very clearly defined. As the otocysts are near the dorsal surface, the separate nerves supplying them may be easily made out. These nerves originate from the infra-oesophageal ganglia. The otocyst is a clear, round vesicle, in one drawing (**51**: 18) appearing perfectly circular and containing a number of otoliths. In one otocyst twenty-five were counted. These are in constant vibration and these vibrations continue long after the parts are mutilated by dissection. The region in which the otocysts are found is a center of great activity. A number of muscles are found here, not only the termination of the great occlusors, but the gastro-parietal muscles and certain muscles that seem to control the great opening of the pallial sinus.

In *Glottidia pyramidata* the otocysts were not observed, though I am sure that, as the region in which they occur is now known, they will certainly be seen through the partially translucent shell. Professor Brooks discovered their presence in the extreme young of this species in 1878.

In alcoholic *Lingulidae* these vesicles have not been detected, though in life, when the shell is sufficiently transparent, they are easily seen. Even in *Lingula anatina*, where the shell is unusually opaque by the deposition of limy layers, I managed to find a small specimen in which the shell was sufficiently thin to make out, with great distinctness, these organs (**51**: 20). They were found in precisely the same position as described above in *L. lepidula*.

In Hancock's classical memoir, plate 61, figure 6, the dorsal aspect of the root of the oesophagus of *Magellania australis* is figured. On each side of this region and in close proximity to the nerve, a small circular body is shown which the author simply indicates as "tubercles, function unknown." It has occurred to me that these might be auditory vesicles, as they occur just where they might properly be found. If this supposition could be established, then the Testicardine as well as the Ecardine brachiopods may be considered as having auditory organs. That Glottidia and Lingula are sensitive to light there can be no doubt. They seem sensitive to the interruption of light that falls upon them and withdraw beneath the sand with a quick jerk. Any pigmentation sensitive to light, in the above genera at least, would naturally be looked for on those parts of the animal exposed above the sand, and one would expect to find these areas about the anterior portions of the pallium. Schulgin finds in Cistella an accumulation of pigmentary epithelia which at certain distances are found on the periphery of the pallium, and he is inclined to believe that these areas probably indicate rudimentary organs of sense; namely, the eyes. These parts, he says, receive nerve fibers.

In Glottidia the anterior margins of the pallium, both dorsal and ventral, are thrown into two deep and distinct folds, one on each side of a median line. The space between the folds and the shell has light brown, interrupted, and sinuous striae; the outside of this area is marked by dark brown dots, while the inner edge is marked by a dark brown stripe. The function of these folds in connection with the setal tubes has already been alluded to, but this definite pigmentation of the pallium in just the position where we might expect to find areas sensitive to light certainly suggests a function of this nature, and Blochmann has shown that a number of nerve branches run to this region in *L. anatina*; and so I venture the suggestion that these rich brown, pigmentary areas may function as sensory organs for the perception of light (**39**: 5, 6; **51**, 15, 16). *Lingula lepidula* shows precisely the same pallial folds richly pigmented. In all my drawings from life these anterior folds are seen, and I am inclined to believe that in *L. lepidula*, these folds appear only when the setal tubes are formed, and in this way, if the pigmented parts are sensitive to light, these parts are exposed at just the time when the animal is in an attitude to profit by this sensitiveness. In Glottidia, an adjustment of the setae is made, analogous to that of *L. lepidula* when it forms the setal tubes, and here again the strongly pigmented folds of the pallium become conspicuous.

In *Discinisca lamellosa*, the oblique nerves are found free in the coelomic cavity, as in the *Lingulidae*. They enter this cavity between the first anterior occlusor and the lateralis muscle. Joubin, curiously enough, does not figure this nerve. Blochmann, not only figures it, but represents it correctly as passing through the obliquus anterior and obliquus posterior muscles, but traces it no farther. He represents the posterior occlusor as being furnished with a twig from the lateral dorsal nerve, which is a peripheral nerve following the lateral wall of the coelomic cavity. My own observations show that after this nerve passes through the muscles above mentioned, it enters the posterior occlusor muscle on its inner face and there terminates in a ganglion giving off numerous twigs (**52**: 4, 5).

The marked difference between the oblique nerves of Lingula and Discinisca is seen in the fact, that, while in Lingula the nerve runs along the inner surface of the various muscles it encounters, sending twigs only to the muscular fibers within, in Discinisca the nerve not only passes directly through the muscles in its path but finally enters the posterior occlusor muscle where it terminates in the ganglionic enlargement above described.

In *D. stella*, owing to its diminutive size, but little information was secured regarding its nervous system. A central ganglion was seen on the anterior body wall below the mouth. There was no bilateral division or swelling of this central nerve; it was simply a ganglionic area from which were given off two diverging branches dorsally and two diverging ones ventrally with a median one ventrally; these were all branched (**52**: 3, 3*a*). In *T. coreanica*, an elongated oval ganglion is seen just below the mouth. This ganglion shows no bilateral division. From this ganglionic center, delicate nerves run off in bi-symmetrical arrangement to the pallium as well as laterally and ventrally (**52**: 6). The possible function of the pallial coeca as organs of tactile impression has already been alluded to.

PALLIUM.

A consideration of the pallium cannot be made without including the branchia as seen in the gill ampullae of Glottidia, the lacunal circulation, and finally a discussion of the vesicular organ recognized as the "heart of Hancock." The pallium is the principal respiratory organ, and the views of Cuvier, Vogt, and Owen were quite correct as to the nature of this highly vascular membrane.[1] Nor can we consider the pallium apart from the shell, for both hard and soft parts of this external covering belong literally to one and the same structure, and this has been recognized by students of the subject. Beyer ('86) in his interesting memoir on Glottidia, after describing in detail the structure of these parts as revealed in stained sections, says, "Their continuity renders the conclusion almost obvious, namely, that they are identical in structure; in other words the so-called horny layers of the shell of Lingula are nothing more nor less than a supporting substance." Every investigator of these parts has been baffled in an attempt to separate the shells from the lining membrane below.

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[1] There is no reason to doubt that the brachia, and other parts where the membranes are sufficiently thin, are instrumental in the work of oxidizing the blood, though Schulgin found the cirri of Cistella closed at their point of attachment and asserts that there was no evidence of a circulation of fluid within.

In life, the pallium in the *Lingulidae* exhibits on its inner surface and around its borders a rich brown pigmentation. In the anterior portion of the pallium, this pigmentation assumes a definite color pattern. It is possible that these markings may offer characters for specific determination, though they would have to be made out from living specimens, as in alcohol these colors entirely disappear. The perfect symmetry of this pattern on each side of a median line, the rich brown color of the design in contrast to the pure white or greenish tinge of the remaining surface, with the rosy tints of the red circulating fluid in the lacunae, render the pallium a most beautiful object in life. In **52**: 8, 9, 10, 11, are given figures of the anterior portion of the pallium of *Glottidia pyramidata*, *Lingula lepidula*, *Lingula anatina*, and *Lingula* sp. (Nagasaki), respectively. The pattern of ornamentation is seen to be quite different in each form though there is some individual variation. In **39**: 1, 3, an attempt has been made to show the color of this pattern in *L. lepidula*. Reference has already been made under *Sense Organs* to the anterior folds of the pallium, which are richly pigmented and which I have surmised to be sensitive to light. The most conspicuous feature of the borders of the pallium are the crowded setae which spring from setigerous follicles somewhat deeply buried in the pallium. In **52**: 7*a*, I have indicated by a figure of Glottidia, natural size, the portion of the pallium which has been removed and of which a greatly magnified figure is given just above. In a rough way, the setae and a few rows of gill ampullae are shown, as well as the general arrangement of muscle fibers involved in the movements of the setae, so far as they could be made out with a low power. After the truly superb details of the setal muscle in *L. anatina* given by Blochmann, it seems useless to present this drawing; nevertheless an idea of the gill ampullae and setae with their general relations and color patterns are fairly portrayed, and may be of some interest.

Viewing Glottidia from the dorsal surface, a treble, gourd-like outline is distinguished, which represents the boundaries of the coelomic wall. All markings within this outline are caused by the muscles, stomachal glands, genitalia, digestive tract, etc. All markings outside this outline are made by the brachia and the sinuses and lacunae of the pallium.

The region enclosed by the dorsal and ventral pallium, fore and aft and laterally, communicates freely with the sea water. The treble, gourd-shaped figure may be defined as follows: the anterior portion embraces the region of the dorsal attachment of the lateralis muscles and the pharynx and oesophagus, and might be called the peri-oesophageal cavity; the second gourd embraces the stomach, a portion of the stomachal glands, and the first and second anterior occlusors, and may properly be designated as the perigastric cavity; the third and largest gourd, forming the main coelomic cavity, is nearly circular in shape and includes the intestine, a portion of the stomachal glands, the nephridia and genitalia, and the oblique and posterior occlusor muscles; this region may be called the perivisceral cavity. For simplicity of reference, these cavities have been mentioned under the general name of coelomic cavity. The difference between the first and second gourd-shaped outline is slight; in fact, in a comparison with a double gourd-shaped wine bottle of the Japanese, the first division might be regarded as a very wide neck to the bottle. The constriction between the second and third, or largest bulb, is not only indicated by a deep indentation but organically it is the most marked region of the three cavities, for at the junction of these two outlines are seen the gastro-parietal muscles, the otocysts, and the great openings of the main pallial sinuses.

The two broad pallial sinuses, so characteristic of all the *Lingulidae*, start from the perivisceral cavity at its junction with the perigastric cavity (**53**: 1, o. s.). The openings to these sinuses are large and narrow and stand oblique to the median line of the body; indeed they follow the outline of the perivisceral cavity above alluded to. The two main sinuses run to the anterior portion of the pallium, and, in Glottidia (**53**: 1), make a graceful outward curve at the start and then a slight inward curve. The anterior terminations of these sinuses are only one third the distance apart which separates them at their origin. On the inner side of these sinuses there start short lacunae reaching nearly to the median line and slightly inclined anteriorly. On the outer side of the sinuses there spring from nine to eleven lacunae having the same anterior inclination and reaching nearly to the base of the setae in the lateral margin of the pallium. From these lacunae there arise the gill lappets, or ampullae, the discovery of which I first announced in 1870. These number from five to eight in each lacune depending upon the length (**53**: 3). The gill ampulla nearest the median line is largest, and the others diminish in size as they approach the lateral margin. They are very transparent and the blood corpuscles may be plainly seen flowing through them (**52**: 7). Ph. François ('91), in his brief note on *L. anatina*, says, in italics, that he did not find the gill ampullae as described by me, and from the way he expresses it, indicates that he was rather inclined to question their presence in any of the *Lingulidae*. It may also be added that I failed to find them in *L. anatina*, nor were they observed in the little transparent *L. lepidula*, a species which outwardly so closely resembles Glottidia. The gill ampullae of Glottidia may well be considered another strong generic character. The folds observed by Vogt in the pallium of *L. anatina* were probably due to a contraction of the parts in alcohol. The effect of alcohol in causing the sinuses to bulge may be seen in a section of Glottidia (**47**: 3). Between these gill-bearing lacunae is a brown pigmentation which unites with the brown lateral margin of the pallium (**39**: 4; **53**: 2). The current passes outwardly along the inner side of the great pallial sinus, running into all of the inner lacunae in turn, then, reaching the anterior end of the sinus, it returns on the outer side, running into each gill-bearing lacune in turn and coursing through each gill lappet. The arrows in **53**: 1, will explain the course of this current. Nearly on a line with the anterior occlusors, are a few short lacunae which have no gill ampullae. In alcohol, as we have seen, the pallium contracts and the region of the gill ampullae is thrown into a strongly bulging fold from which the gill lappets hang and these do not appear to contract (**47**: 3). Another sinus turns directly backward from the opening of the main pallial sinus and follows along close to the lateral margin of the pallium sending a series of branching lacunae to the shallow posterior portions of the pallium. This I have indicated as the lateral pallial sinus (**53**: 1, l. p. s.). Beside the main pallial sinus and the lateral pallial sinus, there is another which turns abruptly back from the main sinus opening, runs along on each side of the gourd-shaped outline of the perivisceral cavity, inclining slightly toward the median line, and disappears in a distinct round opening near the posterior lateral border of this outline (**53**: 1, c. s.). This I have designated the coelomic sinus. It was somewhat difficult to make out the precise limits of the sinus against the dark color of the viscera within. There is seen on the dorsal side a very marked sinus running in the median line from the posterior occlusor muscle to the posterior border of the perivisceral outline. This sinus becomes filled with coloring matter when injected from the peduncular cavity. I have termed this the median sinus (**53**: 1, m. si.). Is this a trace of the dorsal vessel in annelids? The sinuses and all the lacunae, to the smallest twig, have a central ridge of ciliated epithelium which springs from that portion of the pallium next to the shell. It does not separate the sinuses and lacunae into two distinct channels or tubes. In life, the lacunae, distended by the flow of blood within, appear almost tubular, as seen in *L. lepidula* (**53**: 11, 12). There is nothing to prevent the currents, which continually flow in opposite directions, from intermixing, yet, in life, this crossing of the currents has not been observed. In **53**: 4, 5, 6, 7, are sketches of transverse sections made through the pallium, intercepting some of the smaller branching lacunae. These sections show the thickness of the pallium next to the pallial chamber, and the extreme tenuity of the membrane separating the cavities of the lacunae from the shell. That the ciliary ridges, though they separate the currents flowing in the sinus, do not separate the sinus into two tubes, may be seen in *T. coreanica*, where at certain times the sinuses are packed to repletion with eggs, and all signs of the ciliary ridges disappear; only in the terminal lacunae, in which the eggs are not found, do the ciliary ridges become apparent (**57**: 11, 11*a*). In **53**: 13, is a drawing of a portion of the lateral sinus on the right side of the posterior lobe of the pallium of Glottidia. For convenience of adjustment in the plate, the lateral margin of the pallium is horizontal, the left of the figure being posterior. By this and other figures on this plate, it will be seen how sharply defined are the sinuses and lacunae, and yet there are apparently no walls in these channels. Shipley ('83) finds the same condition in Cistella; he says, "The blood is contained in a number of vessels which run irregularly in the tissues of the body, but which chiefly lie in the mantle and that part of the body wall lining the shell. It is not possible to make out very distinct walls to these vessels which appear to be mere slits in the tissue." The pallium of *L. lepidula* shows marked differences from that of Glottidia in the disposition of the main pallial sinuses and of the smaller lacunae (**53**: 8). In *L. lepidula*, the main sinuses run nearer the lateral margins of the pallium, and their terminations are wider apart than in Glottidia; furthermore the sinus has a uniform outward curve. The lacunae, which run off to the right and left with such regularity in Glottidia, are irregular and branched. The difference is of that kind mentioned by Hancock in a species which he distinguishes as *L. affinis* in contrast to the pallium of *L. anatina*. In *L. lepidula*, the lacunae, as they branch from the great sinus, appear tubular (**53**: 11, 12). In figure 12*a* an outline of the animal, natural size, is given, with dotted line to indicate the point from which the greatly magnified drawings of the lacunae are made. The ridge of ciliated epithelium appears like an acute pyramid with apex inclined backward. On each side of the circular outline of the lacune, appear smaller sections of other structures, whether of lacunae or not, I was unable to ascertain. The courses of the currents in **53**: 8, which are indicated by arrows, are precisely the same as seen in Glottidia. My notes record no appearance of the gill ampullae. At the proximal end of the great pallial sinus is seen the opening which apparently leads to the perivisceral cavity. It is a long, narrow opening, lying oblique to the median line (**53**: 8, 9, 10). Near the inner side of this slit-like opening is seen the otocyst; small lacunae appear in the immediate vicinity but their outlines are not clearly made out. The blood pours out of this opening in a vigorous current on the inner side, runs along the inner side of the great pallial sinus, coursing through all the lacunae successively and then returns on the outer side, following up and down each lacune in turn. As the current approaches the main pallial opening, a part of the current is diverted to the outside of the lateral sinus, where it runs to the posterior end of the body to return on the inner side of the sinus, back to the main pallial opening into which it is directed. The sinuses, lacunae, and all details are symmetrically developed on each side of the median line. In **53**: 9, 10, is represented the right opening into the sinus with a portion of the right sinus as seen from the dorsal surface. The anterior wall of this opening seems to be continuous with the perivisceral wall. This opening abruptly closes at intervals, entirely checking the flow of the blood, and the corpuscles immediately dam up the entrance both inside and outside, showing that the action of the ciliary ridges is not arrested. As the openings slowly part, an impetuous rush of the corpuscles takes place, and while these remain open, the blood circulates with great rapidity (**53**: 10). This closing of the openings takes place the moment the shells begin to oscillate; the moment this oscillation ceases, the openings part and the circulation begins again. The outer side of the sinus first discharges the accumulated mass of corpuscles into the perivisceral cavity, and then the inner side of the sinus receives the outflow. The closing of these openings is always synchronous with the oscillations of the shells, and it would seem that the contraction of the oblique and other muscles involved in causing this oscillation, simply brings the dorsal and ventral shells together and the pressure thus exerted, mechanically closes the openings and checks the flow of the current. It would seem, also, that these openings are in a way controlled by definite muscles which may be seen in **52**: 1. These muscles have a thickened base of attachment and are apparently animated by a nerve which branches from the auditory nerve. These openings seem never to close, however, except when the shells are oscillating or are otherwise in movement. In my first observations of *L. lepidula*, I thought I detected a flat valve controlling the sinus opening and made a schematic drawing in section of what I conceived to be the position of this valve, but later I interpreted the behavior of these parts as above described. Blochmann, however, describes and figures a valve in *D. lamellosa* in precisely the same position as I had supposed it to exist in *L. lepidula*, though if the valve really occurred in Lingula this acute observer would certainly have discovered it. It is difficult to realize, unless one has seen it, the vigorous character of the flow of these currents. When the damming of the current takes place and a rapid accumulation of blood corpuscles piles up at the closed openings, the flood is impetuous when it starts again. The volume of this flow is so great that if any special organ was implicated in its propulsion it would easily be detected. No such organ, however, has been found.

The coelomic sinuses described in Glottidia were not so easily made out in *L. lepidula*, owing to the dark color of the organs below. There appeared in the same region, however, somewhat deeply buried, a strong ridge evidently of ciliated epithelium, which I surmised to be a ciliated ridge whose posterior end turned towards the median line and was widened and digitated, indicating a number of lacunae branching from the supposed sinus (**48**: 6, 7, v. r.).

The result of a colored injection through the peduncular cavity of Glottidia, led to an unexpected result; instead of filling the coelomic cavity and the pallial sinuses as one might naturally expect it would do, the fluid ran along each side of the posterior occlusor muscle, followed the median sinus dorsally, and then filled a vascular membrane which lined the coelomic cavity. Not a trace of the injected fluid was found in the perivisceral cavity or in the pallial sinuses. The contraction of the parts in alcohol evidently closed all the openings to these regions. Much further study is necessary to illuminate the mystery of the pallial and coelomic circulation of these animals. The injection, however, revealed the presence of a vascular sheath lining the coelomic cavity like a peritoneum.

In the peduncle of Glottidia, the inner tubular cavity shows a continuous circulation of fluid, the corpuscles coursing down the centre to the extreme end and returning on either side, probably in the deep folds which are shown in a transverse section of this part. In a peduncle in the last stages of dissolution, the blood was seen circulating as usual, though the peduncle had been for two days separated from a body black with decay. Here again is a circulation of the blood induced solely by ciliary action and not by any propellent organ.

In *L. anatina,* the shell was too opaque to observe the circulation of blood in the pallium, though the pallial sinuses and lacunae of this species have often been figured and described. The anterior border of the pallium is light brown and this color extends around the entire margin; just within this brown border, the pallium becomes the purest white and toward the centre a greenish tinge is seen. The pattern of brown pigmentation of the pallium is figured in **52**: 10. From the above observations on the circulation of the blood in the *Lingulidae,* it is certain that a propellent organ or heart is wanting in these animals.

In *D. lamellosa,* the body cavity is somewhat quadrangular in shape, occupying the posterior half of the boundaries made by the orbicular shell. It is rounded behind, dilating somewhat toward the anterior portion on a line with the stomachal glands, then narrowing in line with the anterior occlusors, which stand oblique to the median line, and terminating in front with a median depression just behind the head which projects considerably (**49**: 1). From the shoulder on each side of this anterior depression spring the anterior sinuses and on the side where the coelomic wall slightly projects, spring the lateral sinuses. The anterior sinus follows very near the median line and terminates in two slender branches. A short distance from its origin a branch turns abruptly backward and recurves upon itself; this sinus sends a number of branches toward the anterior portion of the pallium. The lateral sinus has two branches, one turning abruptly forward and the other abruptly backward. These branches supply three fourths of the pallial area with its lacunae; they divide and subdivide into minute ramifications which cover every portion of the pallium. The pallium is remarkably rich in these minute ramifying lacunae, and, so far as these were traced, the central ciliated ridge was observed in all of them. Blochmann, in his drawings, shows a narrow dark center to these ciliary ridges and in every case represents a slight interspace where they branch off from the central one, and this follows down to the minute branches. In *D. stella* the pallium is bordered with dark brown and at the base of the setigerous follicles a distinct red line is observed. At the base of the setae, which are deeply inserted, a sinus runs parallel to the pallial border. This sinus has slight swellings at uniform short intervals, and within each swelling was observed an elongated nucleus which I supposed to be a ciliary fold. The radiating pallial sinuses were not observed (**44**: 4, 5).

In *T. coreanica* (**57**: 11) the pallial membrane has a strong reddish-salmon color derived from the color of the shell. The main sinus in the dorsal pallium runs parallel to the outer lateral border of the shell and nearly midway between the outer border and the median line. It sends out twelve lacunae which subdivide once or twice before reaching the border of the pallium. The ventral pallium sends two sinuses running irregularly forward, the inner one, near the median line, sending its branches to the anterior border, the outer sinus covering the remaining surface of the pallium with a less number of branching lacunae. The two sinuses are connected with a single lacune near their origin. The terminal lacunae are shown in **57**: 11*a*, and in these may be seen the middle ridges of ciliated epithelium. The sinuses and làcunae, when filled with eggs, are dark purple in color, as shown in **39**: 14. The sinuses and lacunae in *T. transversa* seem to have the same disposition in the pallium as in *T. coreanica.*

In closing the description of the pallium I must again emphasize the fact that not only the sinuses and lacunae of the pallium support the ciliary ridges which divide and subdivide with the ramifications of the lacunae, but the minute lacunae in the nephrostome of Lingula, the papillary prominences in the nephrostome of Terebratulina, and these channels wherever seen, present the same ciliary ridges. So far as I have observed, the circulation of the blood is due to ciliary action and to the agency of this action alone; as in other groups, however, the contraction of the body must cause volumes of blood to surge back and forth.[1]

BLOOD CORPUSCLES.

In the blood of Glottidia (**54**: 3), are seen three kinds of corpuscles. These consist first: of long, oval, and fusiform bodies ranging from simple oval bodies with pointed ends to elongate forms with one or two swellings, and in a few cases showing a bifurcation at one end; these are amoeboid and bend and turn in rounding the corners of a lacune or in crowding through some narrow opening; second: small, rounded corpuscles with a constriction in the centre resembling in appearance a partially collapsed rubber ball; these are nearly uniform in size and are much smaller; third: round or oval bodies showing a slightly granulated structure and varying greatly in size; these are probably ova. The blood is rosy in color and causes the rosy hue of the pallium and peduncle. In *L. lepidula* (**54**: 4) the corpuscles resemble very closely those found in Glottidia; the

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[1] In 1861, Macdonald, in the Transactions of the Linnean society ('61) announced the discovery "of a determinate circulation of spherical, and violet tinted corpuscles in all the ramifications of the pallial sinuses, not dependent on the contractions of the pallial cavity, but upon the undulations of a ciliary lining." This paper of Macdonald's has been singularly overlooked by English and continental workers on the subject.

elongate, fusiform bodies are more slender and without swellings; the round corpuscles have precisely the same appearance; the third kind was not present. In *L. anatina*, (**54**: 5) the blood is a pale crimson lake, or violet, in color. The various corpuscles have often been figured and described, yet it will be of interest to recall their appearance in life. The long, fusiform bodies show the processes of longitudinal division; the round corpuscles are like those of Glottidia; a few round bodies were seen with granulated structure. The filiform body seen in the figure is probably foreign. In the alcoholic *D. lamellosa* (**54**: 6) the blood contained irregularly rounded bodies tinged with brown, these had a slight depression in the centre; larger oblong oval bodies with granulated surface were ova floating in the fluid. The micropyle is shown between the two drawings. In *T. septentrionalis* (**54**: 8), a variety of irregular, apparently amoeboid particles was found in the blood; Hancock figures similar bodies as occurring in Hemithyris. From the external glands I squeezed out similar bodies; certain particles not to be distinguished from these in form were ciliated and were probably fragments of ciliated epithelium. The true blood corpuscles are exceedingly minute and I have no observations on them.

In *T. coreanica*, the blood was filled with brown granulated cells of minute size, small colorless cells, and colorless granulated cells (**54**: 7).

The appearance of the corpuscular elements of the blood of the few forms of Testicardines examined was widely different from that of similar elements in the Ecardines. An examination of the blood of living *D. lamellosa* will be necessary before a comparison can be made with the blood corpuscles of the *Lingulidae*.

"HEART OF HANCOCK."

Having described the lacunal circulation of the blood and the inducing cause of it, and the manner in which it permeates every part of the body, it remains to discuss the so-called heart of Hancock, a vesicular organ which was supposed, by Hancock, to be the true heart, and which is clearly present in most Testicardines and as clearly absent in the Ecardines. This curious little vesicle, which when present is found on the median dorsal surface of the stomach of Terebratulina, Terebratalia, Hemithyris, and other genera of the Testicardine group, is certainly an enigmatical organ. It is pyriform in Terebratulina and Hemithyris, and crenulate in Terebratalia. It is an organ very easily detected in those forms possessing it.

Hancock had discovered in 1852 that the organs which Cuvier, Owen, Vogt, and others had regarded as hearts, opened externally and were in fact oviducts. In a paper read before the British association for the advancement of science in 1856, he announced this discovery and, furthermore, stated that the true blood-propelling organ was the pyriform vesicle described by Huxley ('56) as appended to the dorsal surface of the stomach, and, until recent years, Hancock's interpretation has been the one usually accepted. Joubin ('92) finds Hancock's description of this vesicle absolutely correct in detail, the disposition of the muscular fibers alone excepted. But what Hancock mistook for arteries, Joubin designates as lymphatic lacunae and he considers the "heart of Hancock" intimately related to the digestive system, in fact an absorbent lymphatic system with a propellent heart which directs the nutrimental fluid derived from the intestine, toward the various organs of the animal. In one figure Joubin shows a series of openings which he believes connects the heart with the alimentary tract. This may be a fair interpretation of the pyriform vesicle if it can be shown to be pulsatile. The accessory "hearts of Hancock" are equally puzzling. Joubin considers these vesicles as accidental and says they are anomalous and inconstant. They certainly vary greatly in their form and appearance, as I shall show farther on, but they are not anomalous.

An organ fulfilling the functions of a heart as a propellent structure is a rhythmically pulsating organ, whether it be in the shape of a pyriform, or globular vesicle, or tubular in form. In life, it is seen to pulsate; muscle fibers to induce this pulsating behavior are found, and distinct vessels or lacunae to conduct the circulating fluid back and forth are defined. Semper ('62, '64), Lankester ('73), Shipley ('83), Schulgin ('84), Beyer ('86),[1] and others who have studied the Testicardine brachiopods alive have failed to find these conditions fulfilled by this so-called heart; on the contrary Joubin and Blochmann aver that the organ in question is pulsatile. In the Ecardine forms, where the volume of circulation is the greatest and most active, this vesicle has not been found. Neither Glottidia, Lingula, nor Discinisca reveals the presence of any vesicular organ on

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[1] Carl Semper, in a review of a previous account of his on living Lingula, says, "In spite of the desire to verify by researches on the living animal the statements of Huxley and Hancock which seem to be most exact, I could only convince myself of the correctness of my representations formerly published which to be sure, I can improve in unimportant details, but on the whole must remain as found then. In vain have I searched for that which Huxley is pleased to call the heart."

Lankester says in regard to *Terebratula vitrea*, "I entirely failed to convince myself that the organ regarded by Mr. Hancock as a heart really has the function of one in *T. vitrea*. I repeatedly opened fresh specimens with rapidity, in order to witness its contractions, if any, but never saw such contractions; nor could I find vessels in connection with it, nor evidence that it had muscular walls. Dr. Krohn, of Bonn, had equally been unable to obtain evidence that this curious little dilatation has the function of a heart."

Shipley in his studies of Cistella says, "Like other recent observers I have been unable to find anything corresponding to a central circulatory organ, or to the system of arteries and accessory pulsatile organs described by Hancock."

Schulgin, writing of Cistella says, "The particles of blood are kept in circulation by the ciliated epithelium. Argiope [= Cistella] is, therefore, devoid of a heart and of a closed vascular system."

Joubin, in his study of Crania says, "There is no trace of the existence of a heart or arterial system. All the organs are bathed in the colorless liquid filling the perivisceral cavity."

Beyer says, in regard to *Glottidia pyramidata*, "Our own observations have been only confirmatory of the views held by Shipley, Schulgin and Morse, and the most careful search after the central propelling organ over the posterior slope of the stomach invariably proved unsuccessful in every new series of transverse sections which was made."

the dorsal side of the stomach, or anywhere along on the digestive tract, or anywhere else in the anatomy. Glandular conditions arise on the edge of the gastro- and ilio-parietal bands as well as upon the mesenteries during genital activity and if this growth takes place on the dorsal mesentery, it might easily be mistaken for the so-called heart. I have examined with the greatest care many living Terebratulina and numbers of the large *Terebratalia coreanica, Dallina grayii*, and *Hemithyris psittacea*, solely for the purpose of studying this problem. I have opened individuals quickly, yet with great care, and have never seen the slightest signs of contractility or change of form either in the central or accessory organs denominated as hearts, nor could these vesicles be made to contract by the application of external stimuli, such as pricking with a needle. This is all the more singular, since all other parts of the organism are in constant movement. No matter how rudely the shells were torn apart (and in this operation almost the only parts that were not ruptured by this mutilation were the intestine and the dorsal vesicle) the various movements of the parts have continued for hours after this rough treatment. The various lobules of the stomachal glands are incessantly expanding and contracting, the stomach and oesophagus exhibit peristaltic and other movements hours after excision, the lips of the mouth and the delicate brachial fold at the base of the cirri continue to bend and wave, the cirri are continually turning and swaying in various directions, the circulation of blood goes on actively in the sinuses and lacunae of the pallium and in other parts, and an equally active circulation is seen in the tubular cavity of the peduncle, even days after its separation from the body black with decay, and yet the so-called heart gives no sign of contraction. It may be said without exaggeration that the only part of the anatomy which manifests no movement, which is absolutely inert, is the so-called heart. As to the well defined veins which Hancock describes in the pallial sinuses and lacunae, we have seen that they are ciliary ridges which continue into the minutest ramifications.

In any discussion as to whether the "heart of Hancock" is really a propellent organ and implicated in the circulation of the blood, two matters must be considered: first, that the Brachiopoda are remarkably alike in all leading structural details, and for this reason it is difficult to conceive of so fundamental a structure as a pulsating heart being present in one group and not even a vestige of it to be found in another group; second, one has only to realize the active and abundant flow of blood in the perivisceral and pallial circulation, to be convinced of the utterly inadequate character of the little pyriform vesicle to induce such a flow, and when one turns to Glottidia and Lingula and witnesses the voluminous and impetuous flow of blood through the sinuses and yet finds no trace of a heart or a pulsating organ to induce this current, he is compelled to find some other explanation for the function of this vesicle in the Testicardines.

Another question must be asked: are the central and accessory vesicles related organically? They certainly appear to have a similar structure. In *T. coreanica* the curious lamellated central organ, the so-called heart, is connected with the lateral vesicles through a colored and glandular thickening of the edge of the ilio-parietal band. Now this thickening is, I believe, associated with genital activity, and later I shall show that the immediate region of the accessory hearts becomes changed during genital activity and a number of glandular prominences make their appearance on the genital band at this time. The central and accessory hearts appear so identical in structure and color that it would seem they were related functionally. I shall discuss the accessory "hearts of Hancock" under genitalia, but must remark here that these hearts appear in every case in close proximity to the nephrostomes, and as these in the Testicardines appear at the coelomic termination of the great pallial sinuses, the accessory hearts are found also in close proximity to these terminations. Hancock represents them in *Magellania flavescens* as attached to a band, the end of which is actually imbedded in the termination of the pallial sinus. I have not observed this condition in associated forms. Hancock also represents in *M. flavescens*, four accessory vesicles, two dorsal and two ventral, corresponding to the pallial sinuses, yet in this species there are only two nephridia. In *H. psittacea*, there are four nephridia and also four accessory vesicles. In *T. septentrionalis* there are four pallial sinuses, yet only two accessory vesicles. It is somewhat singular that a careful study of Lingula, Glottidia, and Discinisca failed to reveal the presence of any organ corresponding to the "heart of Hancock" or to the accessory hearts, though the nephridia are conspicuous organs, as they are in all brachiopods; on the other hand there is no feature more constant than the pallial sinuses, yet with this constancy in structure we find the "heart of Hancock" and the accessory heart, with few exceptions in the Testicardines only. In other words, in those brachiopods in which the coelomic cavity is contracted to the smallest space and the greater mass of the genitalia arise in the pallial sinuses, the central and accessory vesicles are present, while in the Ecardine forms, in which the coelomic cavity is capacious and the genitalia are confined to this cavity alone, these vesicles are absent. I think, therefore, that the accessory vesicles at least, may with reason be considered under genitalia and not under the circulatory apparatus.

NEPHRIDIA.

The paired oviducts in Brachiopoda are so identical in form, attachment, and function with similar organs in the chaetopod worms that I formerly designated them segmental organs from the name first given by Williams ('51), to the oviducts of annelids.

This name was adopted by Claparède in his remarkable researches on the annelids of the Bay of Naples. So absolutely identical are these organs in details of structure, attachments within, their associated parts and external openings, with those of certain chaetopod worms that the description of these parts might be taken from Claparède with hardly the alteration of a single word. The wide divergence in the form of these organs in worms is, with the exception of the length and convolution of the tube, paralleled in the Brachiopoda, as may be seen by an examination of the figures given in plates **54**, **55**, **56**. Gegenbaur ('78) properly objected to the name segmental organs as other organs and parts are repeated segmentally. There is, however, no end of inappropriate names for organs and groups in the animal kingdom. What more ridiculous than the name Mollusca or more preposterous than the name Brachiopoda as applied by Cuvier, based on false homologies. Nevertheless as these organs are now recognized under the name nephridia in worms and other divisions of the animal kingdom, it is well to apply the same name to these parts in the Brachiopoda. It is not yet established that these parts are renal in their nature. One thing, however, is certain and that is, that they are plainly oviducts, and this would be a far more appropriate name for them.

In a general way, it may be stated that, with the exception of Hemithyris which has two pairs of nephridia, the genera thus far observed have but a single pair. In the *Lingulidae*, the nephridia are quite constant in their form and position, while those of Discinisca and Crania are quite different in form. Among the Testicardines, the nephridia vary greatly in the different genera. In *T. coreanica*, the tube is abruptly bent upon itself. In *T. septentrionalis*, the nephrostome stands at a slight angle from the tube. In *Dallina grayii*, the nephrostomes are close together and the tubes are straight, the nephrostome much exceeding, in diameter, the tube. In Hemithyris, the nephridia are quite wide apart, and the tube is short, and wider in diameter than the nephrostome. In all, however, the nephrostome is crenulated and strongly ciliated, and in all, with the exception of Discinisca and Crania, a more or less sharp constriction separates the nephrostome from the body of the nephridium, and in all, with the exception of Discinisca, the body of the nephridium is thickened, glandular and has a pronounced color. In Glottidia, it is a rich dark orange; in *L. anatina*, it is marked by dark, maroon lines; in Terebratulina, it is a yellowish brown; in *Dallina grayii*, it is a rich, rose color streaked with darker areas.

The position of the nephridia in the *Lingulidae* has been so well defined by authors that it is only necessary to call attention to their appearance in life. In Glottidia (**54**; 9), the body of the nephridium lies parallel to the lateral body wall, the central axis of the nephrostome standing at nearly right angles to the longitudinal axis of the organ. The nephrostome is turned closely to the body wall. It is rather deep, slightly flaring at the rim and foliated within. It is held firmly to the body wall by the ilio-parietal band (**47**: 1). This band is divided into several strands, one of which, rather wide, passes directly behind the nephrostome and is attached to the body wall; another, very narrow, passes obliquely backward to the body wall, and still another, a very narrow one, passes obliquely backward toward the median line. The appearance of the inner portion of the nephrostome is shown in **54**: 10. The blood in active circulation is seen rushing through the various lacunae which cover the surface of the nephrostome. The whole organ is highly vascular throughout and it would seem that the endothelial lining of the coelomic cavity ensheathed every organ within. The body of the nephridium is a rich orange color, and in *L. lepidula* the color is so persistent that after a lapse of twenty years, in alcohol, the color through the shell appears just as bright. The body of the nephridium in Glottidia has an oblong, slightly ovate form, narrowing quite rapidly to its outer termination; it has a few wide longitudinal markings which probably indicate folds within. In *L. lepidula* (**54**: 11, 12, 13), the nephridia occupy precisely the same position as in Glottidia. The nephrostome is somewhat different; in shape it is like a cup with the rim sharply reflected, and just below the rim a deep constriction, and then the wall rounds out again to taper rapidly to the body of the nephridium which it joins at nearly right angles to its axis (**48**: 4, 8). The side of the nephrostome next to the coelomic wall is so closely adherent to it that the wall itself forms part of the border of the nephrostome (see particularly, **54**: 12, 13). In Glottidia and *L. anatina*, the rim of the nephrostome is entire, while in *L. lepidula* the rim merges with the body wall. The folds within the nephrostome (**54**: 14, 14*a*) are in the form of loops giving the appearance of a deep fluting. The folds are strongly ciliated and the ciliary action is vigorous. No current was seen to pass through the nephridium; corpuscles were drawn into the nephrostome only to be whirled out again. Here is an evidence that in some way the animal controls the discharge of matter through it. In Terebratulina, I have followed an egg from its release from the pallial sinus to its entrance into the nephrostome and final discharge at the exterior opening (**58**: 4). There are a few branching lacunae on the walls of the nephridium which is a rich, dark orange, and the color is so pronounced as to show through the shells. The tube follows along the side of the coelomic wall and passing through it obliquely, opens on the anterior wall. The external openings appear as simple slits (**48**: 4, 8). The nephridia of *L. anatina* are not unlike those of Glottidia. The body is thick, wide, flattened, and glandular; the nephrostomes seem a little more closely appressed to the coelomic wall and the folds converge slightly to the anterior end, as such lines would on an oblong and tapering body. The folds are finer and run parallel to the inner incurving outline of the nephridium. These folds are a rich maroon color. A reference to **55**: 1 will better explain these features. The nephrostome is not so deep as in Glottidia or in *L. lepidula* but is more flaring and the rim is slightly undulating. The body of the nephridium is held to the perivisceral wall by a narrow band immediately behind the obliquus internus, and this may be a continuation of the ilio-parietal band. A greatly enlarged view of the nephrostome and a portion of the nephridium is given in **55**: 2. It is seen to be highly vascular; large branching lacunae run from the base of the nephrostome to the periphery; these divide, and just before reaching the rim they appear, in the drawing, to be recurved. This appearance is due to the incurving edge of the flaring rim which is very thin and transparent. The lacunae have a delicate light brown tint. The ciliated ridge is seen running in the centre of each lacune and the blood follows up and down the branches, the current being divided by this ridge. In the undetermined species of Lingula, the nephrostomes were turned toward the perivisceral cavity (**40**: 18). Whether during genital activity the nephrostome has the power of turning in this way, is not known. In *D. lamellosa* (**55**: 3) the nephridium, while occupying a position similar to that in the *Lingulidae*, is quite different in its attitude. The nephrostome is turned towards the coelomic cavity and obliquely toward the dorsal shell. It is wide and flaring with regular radiating folds running from the inside nearly to the periphery. It is held to the lateral body wall by a band which seems continuous with the membrane composing the nephrostome. This flaring mouth connects at once with the tubular portion of the nephridium without the usual constriction seen in the nephridia of other forms and there is no glandular enlargement or thickening. The tube tapers gradually to its termination in the anterior wall of the coelomic cavity. These openings are seen externally just below the mouth on each side and about midway between the dorsal and ventral parietes. The external openings stand oblique and incline to each other (**55**: 4). A view from within this wall shows that the tubes follow along the ventral floor of the coelomic cavity and then turn upward along the body wall, piercing the wall obliquely (**55**: 5). Externally the openings are as simple as in *L. lepidula*. In the early stages of *D. lamellosa*, the nephridium has a long, narrow nephrostome suggesting somewhat the appearance of the same part in Crania as figured by Joubin, though his figure represents the nephrostome as bifurcated. The edge appears to be minutely fringed and the tube shows a slight enlargement in its course (**55**: 6). The small circle associated with the figure indicates the size of the specimen from which the nephridium was drawn.

We have seen in the *Lingulidae* a constancy in form and position of the nephridia quite in accordance with those resemblances, in structure seen in all the parts. In Discinisca, the nephridia are quite unlike those of the *Lingulidae*, as is the animal itself. Crania stands quite apart from all in the form of this organ. In the Testicardine Brachiopoda, the nephridia vary from one another quite as much as does the internal structure of the different forms, or the external appearance of their shells.

In *T. septentrionalis*, the nephridia are suspended from the gastro-parietal band on each side of the intestine, with the nephrostomes opening toward the dorsal shell (**56**: 2). This figure represents the right nephridium with a portion of the intestine and the divaricator muscles. The band, by which the nephrostomes are held, stretches across the coelomic chamber and adheres to the intestine as well. In **56**: 1, is shown the left nephridium in profile. The nephrostome is wide, and within, the surface is thrown into a number of irregular folds which on one side gradually merge into papillae. Two of these are shown more highly magnified, within which may be seen the ciliary ridge (**56**: 2*a*). The agaric-like regularity of these folds, as figured by Hancock, in *T. caput-serpentis,* is not observed in *T. septentrionalis*, at least in its living state, and I may add also that Hancock represents the nephrostomes as quite close together, while in *T. septentrionalis* they are widely separated from each other, as may be seen in **60**: 1. This peculiarity adds another distinction justifying the separation of the two species. The body of the nephridium has a rich brownish-yellow color (**39**: 9), and is marked by varicose ridges; the surface, more highly magnified, shows very irregular markings, transverse to the long diameter of the tube (**56**: 2*b*, 2*c*). The nephridial tubes viewed in front through the coelomic wall (**60**: 1, 2), run nearly parallel and turning abruptly, pierce the wall and project beyond in the form of prominent nipples (**56**: 7). Dall ('71) describes the external openings of the nephridia in *Dallina floridana* as teat-shaped with very small orifices. Doubtless in related forms this protuberant end will be found, though in *Terebratalia coreanica,* as we shall see, it is in the form of a simple slit in the parietes. The appearance of the orifice in the nephridium of *T. septentrionalis,* viewed directly in front, is shown in **56**: 6. The nipple is nearly circular, the larger diameter being vertical; the opening is circular and an indication of a lozenge-shaped escutcheon is seen surrounding the orifice, this appearance arising from muscle fibers which possibly control the orifice. The interior of the opening, as well as the channel within, is strongly ciliated. It will be seen in **56**: 1, 2, that a band, or bands, quite separate from the ilio-parietal band, originate at the edge of the nephrostome and run ventrally; upon this is found the accessory vesicle as well as clusters of ova. This is the genital band and is well shown in **56**: 1. In **60**: 1, the attitude of the nephridia in relation to the mouth and brachia is shown. In **56**: 4, 5, the appearance of the nephridia in very young specimens is given. The flaring edge of the nephrostome instead of being lamellated has a distinct, thickened rim; the rim of the nephrostome seems to be interrupted, as if its attachment were like that seen in *L. lepidula,* that is, that the band, or wall to which it is attached, forms part of the boundary of the nephrostome. In *T. coreanica,* viewed from the dorsal surface (**55**: 8), the nephrostomes open obliquely backward. The inner surface is marked by thin, sharp, radiating folds which in appearance suggest the actinoid coral, Fungia (**55**: 9). The folds are vertically marked or plicated. A slight constriction is seen just below the nephrostome; it then widens into a thick body and continuing for half the entire length of the nephridium turns abruptly upon itself, tapers slightly, and pierces the anterior wall obliquely, ending in a wide, simple opening more nearly resembling the exterior openings in *L. lepidula* or Discinisca, and in no way resembling Terebratulina (**55**: 8). At **55**: 7, is another drawing showing the attitude of the nephridia in relation to the body. In *Dallina grayii,* the nephrostomes are united by a band and are so close together as to be almost in contact (**56**: 8). The plane of the nephrostome is only slightly inclined to the longitudinal axis of the nephridium, which is straight and tapers only slightly to the exterior opening, which is very wide and simple. A deep constriction is seen on the outer side of the nephridium. The rim of the nephrostome is thrown into deep crenulations (**56**: 9). The nephridium is rose color with deeper longitudinal markings (**39**: 8). The nephridia of *H. psittacea* are quite unlike those of other genera here described, the nephrostomes alone excepted, which bear some resemblance to those of Glottidia. Instead of a long, tapering body with narrow external opening, it is only twice as long as broad and there is only the slightest tapering to the external opening. In the other forms here studied, with the exception of the *Lingulidae,* the diameter of the nephrostome far exceeds that of the body. In Hemithyris, in one example, the diameter of the nephrostome is the same as that of the body, in another it is narrower than the body (**55**: 10, 11). As Hemithyris has two pairs of nephridia, my two sketches probably represent one of each pair, a point I did not make clear at the time of observation. The axis of the nephrostome is at a slight angle to that of the body, is slightly flaring, and the rim is thrown into deep folds which extend within and are strongly ciliated. A sharp constriction marks the junction of the nephrostome with the body of the nephridium which is short and broad. The surface is marked by a few deep, irregular and anastomosing folds; these folds mark the boundaries of the lacunae in which an active circulation is seen; **55**: 10*a* shows a much enlarged view of the edge of the nephrostome and **55**: 11*a* one of the anastomosing folds of the nephridium, greatly enlarged. The marked difference in the form of the external mouths will be noticed; the "heart of Hancock," as well as certain masses which are probably ova, may be seen attached to the genital band.

Genital Products.

In Glottidia, the masses of eggs fill the perivisceral cavity in compact clusters. A transverse section through the intestine shows a ventral mesentery as thick as the walls of the intestine, an inner vascular space is defined, branches are given off to the right and left, and these send out other bands from which the gonads spring. In these masses to be developed into ova, every stage is seen from the small cell to the distinctly nucleated egg

(**57**: 5, 5*a*). The egg has a radially striated cell membrane, not the *zona radiata* of embryologists (**57**: 5*b*). I have observed at the same period, individuals with the body cavity filled with yellow masses, easily distinguished by the unaided eye as ova, while other individuals were equally filled with white sperm masses. The spermaries form large irregular bunches springing from the genital band; they consist of agglomerations of sperm cells and the spermatozoa are detached in groups (**57**: 2, 2*a*). The irregular shape of the stomachal glands, as well as of the ovarian masses is well shown in **57**: 1, while **57**: 1*a* and 1*b* show the appearance of the two masses respectively. In *L. lepidula*, the ova are in rounded clusters, a clear interspace showing at the end of each egg (**57**: 4). In *L. anatina* the masses recognized as testes were lobulated, these lobules numbering seven or more in a group (**57**: 3). The whole mass was white in color, differing in this respect from the ova. Each lobule was filled with minute, round cells. In another drawing of *L. anatina* (**47**: 7) there appeared an irregular digitated band running midway between the intestine and the oblique muscles on each side which, at the time of observation, I noted as testes. Certain lobular masses in this figure are either immature ova or testes, and if ova, what are the digitated bands? They cannot be testes as the sexes are distinct in Glottidia and presumably in all the *Lingulidae* if not in all the Ecardines. In *D. lamellosa* the eggs are attached in clusters to the gastro-parietal band. In **57**: 7, the attachment of this band is shown running from the sides of the intestine to the outer and posterior dorsal edge of the great occlusor. In the figure, this band is turned forward to show more clearly its relation to the surrounding parts. In **57**: 8 is represented a portion of this band more highly magnified; the strands running off from the edge of the band and loaded with eggs are the result of proliferation; **57**: 9 presents the appearance of four clusters of eggs united by genital strands, and **57**: 10 shows the appearance of a single cluster. The eggs are globular and of all sizes. In the figure may be seen a thread running down on one of the strands, upon which are exceedingly minute cells which are probably immature eggs. The eggs are brownish in color and this is probably their natural color unaffected by their preservation in alcohol. In *Discinisca stella* the eggs are light brown (**57**: 6). Adult individuals were filled to repletion with eggs, and in separating the animal from the rock, eggs escaped in profusion. In *T. septentrionalis*, the eggs are spermaceti-white in color, opaque, and resemble a fine white powder when deposited.

The eggs are thrown out of the pallial cavity and accumulate in piles in front of the animal as well as hang in festoons from the setae. In some instances the eggs were active on the day of their discharge and moved away by the action of the cilia that encircle them; in other instances the eggs did not move away for three days. At **58**: 1 is represented an adult individual in the act of ovipositing. Eggs were found in abundance in individuals measuring only 5 mm. in length and were found in equal abundance in all sizes up to the mature form. These eggs were apparently ripe and ready to be discharged; the dates upon which the animals were found with eggs in this condition were May 31, June 26, July 12, and August 29. An examination of hundreds of adult individuals revealed the fact that in some, the sinuses were entirely free from eggs, while in others they were packed to repletion. In many, what appeared to be *corpora lutea* were observed. The appearance of the eggs in the lacunae is shown in **58**: 2, 3, 4, 6. As previously described, the eggs have been distinctly and repeatedly traced from their dehiscence and escape from the pallial lacunae into the coelomic cavity, their entrance into the nephrostome, their passage, one by one, through the nephridium to their final discharge from the nipple-like exterior openings into the pallial chamber (**58**: 4). Eggs are also found attached to the genital bands and hanging free in the coelomic cavity (**56**: 1, 3). The eggs are of all sizes as shown in **58**: 5, in which a cluster of eggs is represented attached to the genital band. In *T. coreanica* (**57**: 11), the pallial sinuses and lacunae when filled with eggs, are deep purple in color (**39**: 14). The eggs are found in clusters composed of leaf-like processes in radial arrangement (**57**: 13). The clusters were irregularly oval in shape and varied in size (**57**: 12). In **57**: 15, is shown the appearance of one of the radial segments, each leaf holding one or two rows of eggs, with four or five eggs in a row. These leaves were slightly folded in their long diameters, the distal edges rounded like a carpenter's gouge. With transmitted light, the leaves were light purple in color, their outer edges tipped with light yellowish-brown, while the eggs were light pink in color (**39**: 13). There were from twenty to twenty-four rows of leaves in each cluster. A side view of one of these masses presents an imbricated appearance as shown in **57**: 14. Claparède ('69) figures a group of ovaries in a chaetopod annelid, *Pachydrilus verrulosus*, which suggests a similar feature in the egg clusters. The arrangement of the egg clusters in *T. coreanica* is so far unique among the Brachiopoda.

Testes.

The long disputed question as to whether the sexes are separate or united in the individual is still a debatable one. That the male and female sexual products arise from the same parts is unquestionable, that they do not arise at the same time in one individual, at least in Terebratulina, is, according to my observations, equally certain. I am strongly inclined to believe that in the Testicardines, as well as in the Ecardines, the sexes are separate, yet in Terebratulina I cannot positively aver that an individual filled with clusters of spermatozoa, may not at another time be found with eggs. I have not been able to detect any differences, external or internal, which would suggest sexual variation.

Schulgin found only females in Cistella; Kowalevski, however, states that he found a number of males, but Schulgin asserts that the organs found by Kowalevski preclude all possibility of hermaphroditism. In *T. septentrionalis*, the spermaries are found in the lacunae of the pallium, every portion being filled with this substance (**58**: 11). When the spermaries arise from the genital bands upon which is found the accessory "heart of Hancock," they appear in the form of a cluster of long threads converging to a common centre of attachment, either upon the accessory heart or in its very immediate vicinity. These threads to the number of hundreds form a rounded tuft-like mass twice the diameter of the nephridium at its junction with the nephrostome. The relation of this spermary tuft to the nephridium is shown at **58**: 7. These threads have a knob-like glandular tip colored a deep reddish-yellow (**39**: 10, also **58**: 9, 10). Just below this glandular tip is a fusiform mass of cells which tapers gradually and occupies one fourth the length of the thread; these cells are masses of spermatozoa attached by their heads. The threads are a proliferation from the genital band identical with what was seen in *D. lamellosa*. The spaces between these threads are filled with a granular protoplasmic mass (**58**: 8). In some instances the spermary masses are not cylindrically fusiform. This appearance is due to the separation of clusters of spermatozoa from the mass. The spermary threads enlarge at their ends and are sometimes bent. No eggs were found in specimens bearing these spermary tufts. In specimens in which the pallial lacunae were filled with eggs, the genital bands were also found supporting clusters of eggs; so in individuals in which the spermary tufts were present, the pallial lacunae were also packed with spermatozoa, the little reddish-yellow cells being interspersed in the mass (**58**: 11). The clusters of spermary threads I have found only in Terebratulina. Where should we look for a similar structure in other groups of the animal kingdom? Lang ('96) describes the genitalia of worms as cellular thickenings, sometimes massive knobs, or tufts of strands. Gegenbaur, in his "Elements," in describing the form elements of the sperm in echinoderms, says that they are very generally filamentous structures provided with a small head. The testes of Lumbricus, according to Bloomfield ('80) arise in pairs on each side of a median line, and these start from a membrane much as they do in the Testicardines. There are two pairs and each cell of the testis itself is the source of many spermatozoa. He applies the name spermatospore to the constituent cell of the testis. The spermatoblasts, as a rule, stand out like buds from the cells which generate them. "When the spermatoblasts have reached a suitable size the coat of protoplasm, which has been enveloping the nucleus, begins in each case to collect a small cup or knob-like mass at the distal end." This description, as I shall presently show is certainly like the granular appearance seen on the accessory vesicles of Terebratulina during genital activity. It may be observed that these bodies described by

Bloomfield in Lumbricus arise in close proximity to the nephrostomes. Beddard ('89) also shows that in *Acanthodrilus annectens*, the testes are in close proximity to the inner mouths of the nephridia. From these descriptions I am led to believe that it is among the chaetopod worms we are to look for structures similar to what has just been described in Terebratulina.

Accessory Hearts.

These curious organs have already been fully described by authors and have been briefly alluded to here in connection with associated parts. It is left for me only to describe their appearance in life. We have found that they really occur on separate strands which are not aligned with the ilio-parietal band. I expressed the conviction ('73b) that these organs did not bear Hancock's interpretation, and that they properly belong to the genital system and not, as stated by him, to the circulatory system. Subsequent studies of these parts in Terebratulina and Terebratalia have only strengthened me in this conviction; yet precisely what part they play in this role I am at a loss to say. The form and size of this vesicle vary more or less in every individual, as may be judged by an examination of plate **59**, which is devoted to a representation of its appearance in *T. septentrionalis* and *T. coreanica*. Whether the animal be charged with ova or spermatozoa, the vesicle is always present. Sometimes there are two or more of these vesicles in close proximity, and this duplicature has been noted by Hancock. It would seem that if this organ functioned as a heart, there ought to be some constancy about it in form and size. In some individuals the vesicle has a long peduncular attachment and is testicular in shape (**59**: 4, 7). In a careful study of a number of these vesicles, there was found no cavity within, and in no case was there seen any vascular connection with the genital band from which it sprang. The mass appeared to be glandular throughout and was distinctly tinged with a reddish-yellow, like the nephridium. In a number, the surface was covered with globular, transparent cells tipped with minute yellow granules apparently identical with the knobs already described as tipping the filiform spermaries which, we saw, arose from the vesicle, or from its immediate vicinity and also identical with the reddish-yellow cells marking the spermaries in the pallial lacunae. In some, a secondary vesicle was found (**59**: 3*a*), and in others incipient vesicles were budding in close proximity (**59**: 1). A number of my drawings show externally a granular surface and a structure within, that in one case seemed to be a round, distinct cavity with light reddish-yellow walls. In another instance, I observed what appeared to be an elongated cavity which made nearly a complete turn within the vesicle, one extremity being larger than the other (**59**: 2). In another case a varicose mass ran over the surface of the vesicle (**59**: 4, 7). Under various pressures, no fluid, or other contents could be forced out at its point of attachment with the genital band, nor was any opening or duct found upon its surface. There was a slight glandular thickening on the edge of the genital band (**59**: 8), and a similar thickening was found on the posterior edge of the ilio-parietal band, as shown in **56**: 2. In *T. coreanica*, the edge of the ilio-parietal band is not only thickened, but it has the reddish-yellow coloration that we have seen associated with the spermaries, and which also tinges the vesicle in those forms studied. This colored glandular thickening of the edge apparently runs from the central vesicle to the accessory vesicle without a break. In **39**: 12, this feature is shown in color. The central vesicle resting on the posterior dorsal surface of the stomach was bluntly triangular in shape, with the base anterior, and the sides of the triangle strongly lobulated. From the median line in front, the band, which Hancock mistook for an artery, divides and passes forward and downward on the sides of the stomach and then, laterally, making three short flexures, turns abruptly backward to terminate in the accessory vesicles. It may be observed that these flexures are the result of the loose folding of the ilio-parietal band and this so-called artery arises from the edge of it. It will be observed that this structure, from the central to the lateral vesicles, is distinctly tinged a reddish-yellow and, as before observed, it is the color which tips the filiform spermaries and other parts of the genital apparatus already described, but I have not observed this color associated with the eggs in Terebratulina, though the purple ovarian leaflets in *T. coreanica* were tipped with it. It is a very significant fact that no blood vessel, sinus, or lacune shows a trace of this color. In another specimen of *T. coreanica*, the central vesicle was oblong and was thrown into a series of folds or plications (**59**: 10, 11). The folds were slightly darker in color. With transmitted light, no cavity was detected within, and it seemed to be made up of irregular masses of radiating tissue which appeared glandular. No channel could be detected at its point of attachment, nor was a trace of muscle fibers discerned. The lateral or accessory vesicles (**59**: 12, 13), seem to have the same structure without folds or plications. The exterior surface of the accessory vesicles was granulated with minute cells, with a yellowish substance interspersed.

Precisely what role these various parts play in the organization of the animal, I have not made out, but that they are intimately related to the genitalia, there can be no doubt. It may be added here that while the nephridia, as well as many other parts of the anatomy, in all species examined, reveal the presence of ramifying lacunae through which the blood is seen rapidly circulating, these vesicles, central and accessory, are about the only organs which show no trace of any circulating fluid within or without.

External Glands.

A curious paired organ of which I published a short account some years ago ('72) has, with this exception, never been observed before. These organs are found clustered around the exterior nipple-like openings of the nephridia in *T. septentrionalis*. Plate **60** is devoted to illustrations of these bodies. They form conspicuous, white, lobulated masses arising from the space between the external orifices of the nephridia. The lobules, to the number of ten or twelve, vary in shape from one another, and are by no means alike on each side; in this respect forming a marked exception to the strictly bilateral and symmetrical repetition of parts in the Brachiopoda. In one instance a peculiar lobulated structure ensheathed the nephridial tube, apparently within the coelomic wall (**60**: 8). It seemed to be of the same nature as the external glands. A distinct wall surrounds each lobule, though this wall varies in thickness, being somewhat thicker at the extremities. The lobules stand quite free from each other and have a narrow base of attachment. They all seemed to be clothed with a ciliated epithelium. Under pressure, irregular granules were forced out and these vibrated in such a manner that I first mistook them for spermatic particles. At **60**: 12, is represented the appearance of these lobulated masses as seen from below. They stand quite free and prominent from the coelomic wall. Between these masses is seen a distinct prominence; viewed from in front, this prominence is bordered by an encircling line (**60**: 6). In **60**: 1, its position in relation to the mouth and other parts is shown; in this figure, also, a clear idea may be had of the position of the external glands in relation to other parts of the structure. In **60**: 13, a rough outline is given representing a longitudinal section of *T. septentrionalis* for the purpose of indicating the exact position of the external glands in relation to other parts of the anatomy. The spiculae which abound in the pallium, brachia, and cirri of this animal, are also found in the external layer of these glands (**60**: 5, 7, 10).

Precisely what may be the function of these external glands I do not know. Mucous secretions occur abundantly about the external openings of the nephridia and the mouth, and it may be that these are simply mucous glands. Whether they may be compared to the dermal glands of the chaetopod worms is a question, though it is stated that the dermal glands in worms form an investment for the ova; but the ova of Terebratulina are not invested with mucus. With the idea that they are glandular, I have given to them the name of external glands. I have not observed them in other Testicardine forms, though they will doubtless be found. From their intimate association with the external ducts of the nephridia, it seems reasonable to believe that in some way they are connected functionally with the genitalia.

The nearest approach to these organs has been described by Schulgin in Cistella. He says, "Argiope [= Cistella] has not far from the mouth, on the integument an accumulation of cells which play the part of an organ of sense. This organ consists of two longish heaps of cells lying parallel to one another, of which that lying nearer the mouth is formed of specific cells and that farther away from it of epithelial cells." Schulgin figures these organs as projecting from the coelomic wall and describes them as one above another in a median line. He makes no remark about their relation to the external openings of the nephridia, yet there would seem to be some relation between these bodies he describes and the external glands.

EARLY STAGES.

In the previous pages, reference has often been made to the early stages of the shell and the soft parts of these animals; there are other features to be briefly alluded to, however, and in plate **61** I have brought together a number of outlines of the early and nepionic stages of various forms for purposes of comparison. The illumination which Beecher ('92) has shed upon the phylogeny of the Brachiopoda from what little we yet know of the ontogeny, has been based upon material of this kind. In this study he has found a confirmation of certain principles of evolution first enunciated by the lamented Hyatt. In the plate above referred to, I have taken the liberty of reproducing for convenience of comparison four outlines of the early stages of Terebratulina from my Embryology of that species. In **61**: 1 is represented the posterior portion of the shell of an undescribed Lingula from Nagasaki. I made only the briefest observation of the animal, and have no idea of the meaning of the structure outlined within. The nepionic outline with the straight posterior margin is similar to that seen in *L. lepidula* (**42**: 3, 4), except that it is somewhat broader. In *D. lamellosa*, at an early stage, the bases of the oblique muscles are slightly flaring, a feature not seen in maturity. In a very early stage (**61**: 11), these muscles are excessively flaring at their point of attachment. In a stage where the brachia are well formed, numbering thirty or more cirri, the various muscles may be clearly defined, except that the separation of the anterior occlusor into two muscles is not apparent though the lateralis is well developed. The anterior and posterior occlusors are compacted within a short space. In **60**: 10, a supernumerary muscle, apparently a repetition of the obliquus posterior, is shown on the right side. Blochmann has figured, in an adult specimen, the same anomaly on the left side. The disproportionate size of the anterior and posterior setae in the young is well shown in the drawings. The nepionic shell (**61**: 11) is absolutely circular; in this figure the few cirri, seven or eight in number, are turned towards the mouth. The coelomic wall shows distinctly two sets of muscles crossing each other obliquely (**61**: 8*a*). A septum seems to divide the two sides anteriorly. The setigerous follicles start from the edge of the coelomic wall and as the animal grows, this line is carried beyond the coelomic wall. The same displacement is seen in other parts; as the animal increases in diameter the attachments of the various muscles, which were compacted before, become more widely separated. The sinuses and lacunae are wide and irregularly branching, the main branches showing the ciliary ridges. The stomachal glands, in an early stage, appear as solid masses (**61**: 10), but shortly after, break up into numerous coeca. In all the early stages of *D. lamellosa*, the stomach is distinctly bulbous. In the young of *D. stella*, the anterior setae are much longer than in the corresponding stage of *D. lamellosa* (**61**: 3). In quite an advanced stage, the stomach is large, round, and apparently fills the entire coelomic cavity (**61**: 2).

In the young of *H. psittacea* (**61**: 17), the shell is quadrate, slightly narrowing behind, with corners widely rounded. The peduncular portion is large and more than one third the length of the dorsal shell. The peduncular opening is very large. In this stage, the lophophore appears circular, as in the early stages of Terebratulina; the stomachal glands show two or three coeca on each side, the setae are long and extremely tenuous, and appear only on the anterior and lateral portions of the pallium; in the specimen figured, seventeen were counted. Near the peduncle, the muscles and interlocking processes of the shell were partially made out.

Since these pages were written, a very interesting communication has appeared, on the habits of Lingula by Naohide Yatsu.[1] His notes relate to the large Lingula, *L. anatina*. He remarks on the great vitality of the species in surviving conditions which kill most other marine animals. He records that his friend, Mr. Namiye, detected the burrows of this Lingula by the appearance of three holes on the surface of the mud in which they were imbedded. It would appear from this observation that the species formed the three setal tubes as described in *L. lepidula* (p. 319). He also presents evidence showing that *L. anatina* lives more than one year. His memoir on the development of Lingula is announced as in press, to be published in the journal of the college of science of the imperial university, Tokyo.

Professor Edwin G. Conklin has kindly sent me the advanced proofs of a forthcoming memoir of his on the embryology of a brachiopod (*Terebratulina septentrionalis*), which will soon be published by the American philosophical society in vol. 41, no. 168. In this communication he shows that the embryo of this brachiopod, at least, belongs to the tro-

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[1] Annotationes zoölogicae Japonenses, March, 1902.

chophore type and bears a close resemblance to Phoronis and a certain resemblance to the Polyzoa. He expresses the opinion that the Brachiopoda, Polyzoa, and Phoronis should be classed together in a phylum distinct from the Annelida, Mollusca, or Chaetognatha.

With the appearance of this contribution and the promised one by Yatsu on the development of Lingula, a great flood of light will be thrown upon the relations of this ancient group.

Professor Conklin in his memoir refers to the work of Mr. Ikeda[1] and says, "Mr. Ikeda has given by all odds the most complete account of the embryology of Phoronis yet published." In view of the remarkable work being done by Japanese scholars in embryology, histology, and morphology as shown in the various memoirs by Mitsukuri, Iijima, Watase, Ishikawa, Sasaki, Oka, Miyoshi, Gotō, Inaba, Hatta, Tanaka, Kishinouye, Matsuda, Hiroto, Hirase, Ikeda, and others we may safely say that in the future the greatest illumination on this ancient and closed type of animals will come from the investigations of the young naturalists of Japan. Their work is abreast of the best work done abroad. Their observations are keen, their artistic skill is accurate and refined, their lithographers we would gladly utilize for the reproduction of our own drawings. Japan is the home of the brachiopods. While European and American naturalists have but few forms to study, not only have the Japanese about all the material we have, but their seas contain many genera which we do not find. We may, therefore, safely look to them for further elucidation of this fascinating group of animals.

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EXPLANATION OF PLATES.

ABBREVIATIONS USED.

a. — anus.
a. b. l. — anterior branch of lateral sinus.
a. cl. — anterior cluster of setae.
a. f. — anterior folds of pallium.
a. h. — accessory "hearts of Hancock."
ap. — aponeurosis of muscle of main pallial sinus opening.
a. p. s. — anterior pallial sinus.
az. — azygos process.
b. — brachia.
b. f. — brachial fold.
b. g. — brachial groove.
b. g. m. — brachial groove muscles.
b. l. — border lip of pallium.
b. p. — border of pallium.
b. s. — brachial sinus.
c. — collar.

c. c. — coelomic cavity.
ci. — cirrus or cirri.
ci. m. — cirri muscles.
c. l. — corpora lutea.
c. m. — cutaneous muscles.
c. o. — central oblique muscle.
c. r. — ciliary ridge.
cru. — crura.
c. s. — coelomic sinus.
c. t. — connective tissue.
c. w. — coelomic wall.
D. — dorsal shell.
di. — divaricator muscle.
e. — eggs.
e. e. — ectodermal epithelium.
e. g. — external glands.
en. — endothelial lining of pallium.
e. o. — external oblique muscle.
e. s. — encircling sinus.
f. — faeces.
f. f. — folds of funnel.
f. y. — fibrous yoke.
g. — gut.
g. a. — gill ampullae.
g. b. — genital band.
g. b. s. — great brachial sinus.
g. en. — glandular enlargements.
g. f. — gill fold.
g. g. — glandular growth on edge of ilio-parietal band.
gl. — gland cells.
gp. — gastro-parietal band.
g. p. a. — ganglion of posterior adductor muscles.
gp. m. — gastro-parietal muscle.
g. t. — glandular tip of spermary thread.
H. — "heart of Hancock."
i. — intestine.
i. b. — inner band of pallial muscles.
in. — infra-oesophageal ganglion.
ip. — ilio-parietal band.
i. t. — inner tube.
l. — lateralis muscle.
la. — lacunae.
l. b. — lateral branch of anterior sinus.
l. i. — lumen of intestine.
l. p. — lateral parietal band.
l. p. s. — lateral pallial sinus.
l. s. — lateral septa.
m. — mouth.
m. cl. — median cluster of setae.
m. f. — muscle fiber.
m. g. — median groove of pallium.
m. p. — main pallial sinus.
m. s. — median septum.
m. si. — median sinus.
m. t. — muscular tube.
n. — nerve.
n. b. — nephridium body.
n. ba. — nephridial band.
ne. — nephridium.
nf. — nephrostome.
n. o. — nephridial opening (external).
n. p. — nephridial papillae.
n. s. — natural size.
n. t. — nephridial tube.
o. a. — obliquus anterior muscle.
o. b. — outer band of pallial muscles.
oc. — anterior occlusor muscle.
oc. I. — occlusor externus muscle.
oc. II. — occlusor internus muscle.
oe. — oesophagus.
o. e. — obliquus externus muscle.
o. h. s. — outer horny sheath.
o. i. — obliquus internus muscle.
o. l. s. — opening of lateral sinus.
o. m. — obliquus medius muscle.
o. p. — obliquus posterior muscle.
o. p. s. — outer pallial sinus.
o. s. — opening of main pallial sinus.
ot. — otocyst.
ov. — ovaries.
pa. — parasite.
p. b. — posterior band.
p. b. l. — posterior branch of lateral sinus.
p. c. — peduncular cavity.
p. ca. — peduncular canal.
p. ch. — pallial chamber.
p. cl. — posterior cluster of setae.
pe. — peduncle.
ph. — pharynx.
ph. g. — pharyngeal gland.
ph. m. — pharyngeal muscles.
p. m. — perivisceral membrane.
p. n. — peduncle notch.
p. o. — posterior occlusor muscle.
pro. — protegulum.
p. s. — peduncular septum.
p. si. — peduncular sinus.
r. — rectum.
r. b. — retractor brachia muscle.
re. — rectus muscle.
ro. — rostrum.
s. — sinus at base of cirri.
s. b. — shell border.
s. b. s. — small brachial sinus.
se. — setae.
s. f. — setigerous follicles.
s. g. — stomachal glands.
s. g. d. — stomachal gland duct.
s. g. o. — stomachal gland opening.
s. m. — setal muscles.
sp. — spermatospore.
spe. — spermaries.
spi. — spiculae.
spm. — spermatozoa.
sp. t. — spermatic threads.
s. s. — supporting substance.

s. t. — setal tubes.
sto. — stomach.
su. — supernumerary muscle.
t. — testes.
V. — ventral shell.
v. m. — ventral mesentery.
v. r. — ciliary ridge of visceral sinus.
v. t. — vascular twig.

PLATE 39.

Reproductions of original drawings to illustrate color in living Brachiopoda.[1]

Fig. 1. *Lingula lepidula* from ventral side.
Fig. 2. Brachia of *L. lepidula* showing color of border and cirri.
Fig. 3. Anterior portion of pallium of *L. lepidula.*
Fig. 4. Portion of pallium of *Glottidia pyramidata* showing three rows of gill ampullae and pigmentation between.
Fig. 5. View of pallium showing anterior pallial folds.
Fig. 6. Enlarged view showing pigmentation of pallial fold.
Fig. 7. Cirrus of *G. pyramidata* showing pigmentation.
Fig. 8. Nephridia of *Dallina grayii.*
Fig. 9. Nephridia of *Terebratulina septentrionalis.*
Fig. 10. Spermary thread of *T. septentrionalis.*
Fig. 11. Border of pallium of *Terebratalia coreanica*
Fig. 12. Stomach and immediate parts of *T. coreanica.*
Fig. 13. Ovarian leaflets of *T. coreanica.*
Fig. 14. Pallium and pallial sinuses of *T. coreanica* filled with eggs.

PLATE 40.

Appearance in life of various forms.

Fig. 1 to 5. *Glottidia pyramidata.*

Fig. 1. Dorsal view, at rest.
Fig. 2. Dorsal shell, oscillating.
Fig. 3. Side view, dorsal shell elevated.
Fig. 4. Side view, dorsal shell depressed.
Fig. 5. Peduncle showing vermiform convolutions with posterior end inclosed in sand tube.

Fig. 6 to 15. *Lingula lepidula.*

Figs. 6, 7, 8, and 9. Various attitudes.
Fig. 10. Burrow in sand.
Fig. 11. Eleven individuals attached to bottom of bowl by sand accretions; compare with Glottidia (**41** : 13).
Figs. 12 and 13. Showing attitude in sand, with setal tubes formed.
Fig. 14. Front view showing anterior pallial folds and setal tube openings.
Fig. 15. Side view with lateral setae vertical and meeting.

Fig. 16 to 18. *Lingula anatina.*

Fig. 16. Showing end of peduncle encased in mud tube.
Fig. 17. Young specimen with brachia extended laterally.
Fig. 18. Dorsal view of partially grown individual.
Fig. 19. Side view of *Discinisca lamellosa* from alcoholic specimen.

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[1] For explanation of details of these figures see succeeding plates.

PLATE 41.

Life attitudes of *Glottidia pyramidata.*

Fig. 1 to 10. Various attitudes in the sand.

Fig. 3. With peduncle broken away, burying itself head first in the sand.

Fig. 11. Anterior portion projecting above the sand with a pile of sand in front.

Fig. 12. With peduncle broken away, burying itself sidewise.

Fig. 13. Eight individuals attached to bottom of bowl by rude sand burrows; compare with similar group of *Lingula lepidula* (**40**: 11).

Fig. 14. With case of sand around posterior end of body.

Figs. 15 and 16. Injured peduncle with inner tube partially withdrawn from outer sheath.

Fig. 17 to 25. Various attitudes, some with sand tube preserved.

Fig. 26 to 30. Portions of peduncle broken away, with globular masses of sand at end.

Fig. 31 to 33. Various attitudes.

PLATE 42.

Dorsal and ventral shells of various forms.

Figs. 1 and 2. *Glottidia pyramidata*, dorsal and ventral shells.

Fig. 3 to 8. *Lingula lepidula.*

Fig. 3. Ventral view of posterior end showing protegulum and portion of peduncle.

Fig. 4. Posterior end, ventral view. Arrows indicate direction of circulation.

Fig. 5. Outlines of shells in life showing extent of individual variation.

Fig. 6. Appearance of shells when dried.

Figs. 7 and 8. Posterior end of dorsal and ventral shells.

Fig. 9 to 13. *Discinisca lamellosa.*

Fig. 9. Orbicular nucleus.

Fig. 9*a*. Polygonal structure of shell.

Fig. 9*b*. Fracture of shell margin.

Fig. 10 to 13. Dorsal and ventral shells showing protegulum stage.

Fig. 14 to 17. *Discinisca stella.*

Fig. 14. Portion of ventral shell showing radiating ridges.

Fig. 15. Greatly enlarged view of two ridges.

Fig. 16. Nucleus of ventral shell.

Fig. 17. Longitudinal section. (The lower of the two figures should have been lettered 17*a*.)

Fig. 17*a*. Dorsal view of ventral shell.

PLATE 43.

Peduncles of Lingula, Glottidia, Discinisca, and Terebratulina.

Fig 1 to 3. *Lingula lepidula*, showing severed ends of peduncle.

Fig. 4 to 13. *Glottidia pyramidata.*

Fig. 4. Showing withdrawal of inner tube and muscular tube from end of outer sheath.

Fig. 5. Portion of peduncle.

Figs. 6, 7, and 10. Appearance of peduncle after death and separation from body.

Figs. 8 and 9. Portions of peduncle; arrows indicate direction of circulation.

Figs. 11 and 12. Transverse sections of peduncle.

Fig. 13. Peduncle as it issues from body.

Fig. 14. Peduncular end of *Discinisca lamellosa* from ventral surface, showing peduncular muscles.

Fig. 15. End of peduncle of young of *Terebratulina septentrionalis.*

PLATE 44.

Setae of various forms.

Figs. 1 and 2. Setae of *Glottidia pyramidata.*

Fig. 1. Setae projecting from side of pallium, with color indicated by shading.

Fig. 2. Proximal portion of seta.

Fig. 2*a*. Termination of seta.

Fig. 3 to 5. Setae of *Discinisca stella.*

Fig. 3. Various forms of setae.

Figs. 4 and 5. Appearance of setae springing from pallium.

Fig. 6 to 10. Setae of *Discinisca lamellosa.*

Fig. 6. Setae of extreme young.

Fig. 7. Setae of adult.

Fig. 8. Portion of pallium showing setae springing from setigerous follicles with setellae turned back.

Figs. 9 and 10. Setae of young.

Fig. 11. Seta from extreme young of *T. septentrionalis,* with setigerous follicle.

Fig. 12. Border of pallium of *Terebratalia coreanica* showing setae.

Fig. 13. Border of pallium of *Terebratalia minor* showing setae.

Fig. 14. Seta of *Laqueus rubellus.*

Fig. 15. Border of pallium of *Hemithyris psittacea* showing setae.

PLATE 45.

Various life attitudes of the brachia of *Glottidia pyramidata* and *Lingula lepidula.*

Fig. 1 to 12. *Glottidia pyramidata.*

Fig. 1. Dorsal view.

Fig. 2. Ventral view.

Fig. 3. Dorsal view.

Figs. 4, 5, 6, and 10. Anterior views.

Fig. 7. Oblique anterior view with shells slightly parted.

Fig. 8. View of brachia from ventral side.

Fig. 9. Left brachium, ventral surface uppermost.

Figs. 11 and 12. Lateral view.

Fig. 13 to 15. *Lingula lepidula.*

Fig. 13. Dorsal view.

Fig. 14. Anterior view.

Fig. 15. Ventral view.

PLATE 46.

Brachia and cirri of various forms.

Figs. 1 and 2. End of cirrus of *G. pyramidata.*

Fig. 3. Portion of brachia with collar and one cirrus of *L. lepidula.*

Fig. 4. Brachia of *L. lepidula*, with cirri removed.

Fig. 5. Terminal half of cirrus of *L. lepidula*, showing pigmentation.

Figs. 6 and 6*a*. Cirrus of *L. anatina*.

Fig. 7. Brachia of small Lingula, species unknown, from Nagasaki, Japan.

Fig. 8. Anterior end from ventral side of above species showing notches in ventral shell.

Fig. 9. Cirrus of *D. stella*.

Fig. 10. Transverse section of brachium of *D. lamellosa*, made at point marked A, B, on fig. 2, plate **49**.

Fig. 10*a*. Highly magnified view of gland cells from small brachial sinus.

Fig. 10*b*. Portion of cirrus.

Figs. 11 and 12. Young *T. septentrionalis* showing cirri projecting beyond border of shell.

Fig. 13. Anterior view of *T. coreanica*, showing brachia.

Fig. 14 to 18. *Hemithyris psittacea*.

Fig. 14. Brachial coils projecting.

Fig. 15. One brachium greatly extended.

Fig. 16. Brachia slightly uncoiled.

Fig. 17. Portion of brachia with surrounding parts from median line.

Fig. 17*a*. Portion of brachium near mouth showing extreme mobility of collar.

Fig. 18. A few cirri.

Fig. 18*a*. Portion of cirrus highly magnified.

PLATE 47.

Details of structure.

Fig. 1 to 3. *Glottidia pyramidata*.

Fig. 1. Dorsal shell removed exposing coelomic cavity, from which have been taken the stomachal glands and genital products.

Fig. 2. Longitudinal section in median line.

Fig. 3. Transverse section of right half of pallial region showing gill fold, gill ampullae, etc.

Fig. 4 to 6. *Lingula lepidula*.

Fig. 4. Brachia with anterior part of alimentary tract showing pharyngeal glands.

Figs. 5 and 6. Stomach and parts adjoining, showing contracted and extended attitudes.

Fig. 7. Dorsal view of *L. anatina*.

PLATE 48.

Details of structure.

Fig. 1. Musculature of *G. pyramidata*.

Fig. 2. Musculature of *L. lepidula*.

Fig. 3. Posterior portion of body of *G. pyramidata*.

Fig. 4. Anatomy of *L. lepidula* from ventral side.

Fig. 5 to 8. Details of anatomy of *L. lepidula*.

PLATE 49.

Details of structure.

Fig. 1 to 6. General anatomy of *Discinisca lamellosa*.

Fig. 1. Dorsal shell and most of the genital products removed.

Fig. 2. General view showing pallial sinuses, lacunae, etc.

Fig. 3. Longitudinal section.

Fig. 4. Bend of intestine and peduncular canal.

Fig. 5. Peduncular canal.

Fig. 6. Stomach with gastro- and ilio-parietal bands.

Fig. 7. *D. stella*, showing head and brachia.

PLATE 50.

Details of alimentary tract of various forms.

Fig. 1 to 10. *Glottidia pyramidata.*

Figs. 1 and 2. Longitudinal sections of mouth parts.

Figs. 3 and 4. Mouth and brachia from ventral side showing mobility of the lips.

Fig. 5. Dorsal view of pharyngeal region.

Fig. 6. Roof of pharynx from inside, showing triturating ridges.

Figs. 7 and 8. Ventral and dorsal views respectively of stomach and portion of intestine.

Fig. 9. Transverse section of intestine showing attachment of ilio-parietal band.

Fig. 10. Anus.

Figs. 11 and 12. Rectum and anus of *L. lepidula.*

Fig. 13. Portion of right coelomic wall of *D. lamellosa* showing anus.

Figs. 14 and 15. Gut of *D. lamellosa* from an early stage.

Fig. 16. Section of gut of *T. septentrionalis.*

Fig. 17. Digestive tract of *H. psittacea*, with stomachal glands removed.

Fig. 18. Anterior portion of digestive tract of *H. psittacea* showing stomachal glands.

PLATE 51.

Stomachal glands, sense organs and nerves of various forms.

The following figures represent a single coecum, or a cluster of coeca of the stomachal glands, unless otherwise mentioned.

Fig. 1. *G. pyramidata.*

Fig. 2. *L. anatina.*

Figs. 3, 4, and 5. Showing the entire cluster on one or both sides of the stomach of young *D. lamellosa.*

Fig. 6. *D. stella.*

Figs. 7 and 8. *T. septentrionalis.*

Fig. 9. *T. coreanica.*

Figs. 10 and 11. *H. psittacea*, young.

Fig. 12. *H. psittacea*, adult.

Fig. 13. *Dallina grayii.*

Fig. 14. Longitudinal section of mouth parts of *G. pyramidata*, showing infra-oesophageal ganglion and nerve.

Fig. 15. Pallial folds with pigmentation, supposed to be sensitive to light, *idem.*

Fig. 16. Greatly enlarged view of pigmentation of one fold.

Figs. 17 and 18. Nerve and otocyst of *L. lepidula.*

Fig. 19. Nerve with nerve twigs and section of nerve of *G. pyramidata.*

Fig. 20. Otocyst of *L. anatina.*

PLATE 52.

Nerves and other details of various forms.

Figs. 1 and 2. Otocyst and surrounding parts of *L. lepidula.*

Fig. 3. Infra-oesophageal ganglia of *D. stella.*

Fig. 4. Right half of coelomic cavity of *D. lamellosa*, showing oblique nerve and its termination in the posterior occlusor muscle; in this figure the retractor brachia muscle is turned up to expose course of nerve.

Fig. 5. Ganglion of posterior occlusor muscle, greatly enlarged, *idem*.

Fig. 6. Infra-oesophageal ganglia of *T. coreanica*.

Fig. 7. Portion of pallium showing gill ampullae, setae, etc., of *G. pyramidata*.

Fig. 7*a*. Natural size of object showing region from which fig. 7 is drawn.

Fig. 8 to 11. Color markings of the pallium of various species of *Lingulidae*. The setae are purposely omitted in these figures except in fig. 9.

Fig. 8. *G. pyramidala*.

Fig. 9. *L. lepidula*.

Fig. 10. *L. anatina*.

Fig. 11. Lingula, species unknown, from Nagasaki.

PLATE 53.

Details of circulation in *Glottidia pyramidata* and *Lingula lepidula*. Arrows indicate direction of currents.

Fig. 1 to 7. *Glottidia pyramidata.*

Fig. 1. Dorsal view showing main and lateral pallial sinuses with lacunae, and coelomic and median sinuses.

Fig. 2. Portion of pallium showing three rows of gill ampullae.

Fig. 3. A single row of gill ampullae, greatly enlarged.

Figs. 4, 5, and 6. Transverse sections through lacune of pallium. Appearance of polygonal cells of endothelium.

Fig. 7. Showing regions of above sections.

Fig. 8 to 12. *Lingula lepidula.*

Fig. 8. Dorsal view. The left brachium is shown with cirri removed.

Figs. 9 and 10. Opening of main pallial sinus and adjacent parts.

Fig. 11. A portion of main pallial sinus showing diverticular lacunae; these appear quite circular in section.

Fig. 12. A single lacune, in section, greatly enlarged. In the drawing of Lingula, at one side, is indicated the region from which figs. 11 and 12 were taken.

Fig. 13. Lateral sinus of *G. pyramidata*; this is figured on the plate laterally.

PLATE 54.

Circulation, blood corpuscles and nephridia of various forms.

Fig. 1. Side view of *G. pyramidata*, showing result of injection of red fluid through peduncular cavity.

Fig. 2. Dorsal view of same. It will be seen that in this experiment the fluid filled the median sinus and the minute vessels of the perivisceral lining, but did not enter the coelomic cavity or the sinuses of the pallium.

Fig. 3. Blood corpuscles of *G. pyramidata*.

Fig. 4. Same of *L. lepidula*.

Fig. 5. Same of *L. anatina*.

Fig. 6. Same of *D. lamellosa*.

Fig. 7. Same of *T. coreanica*.

Fig. 8. Same of *T. septentrionalis*.

Fig. 9. Left nephridium of *G. pyramidata*.

Fig. 10. Greatly enlarged view of portion of nephrostome, *idem*.

Figs. 11, 12, and 13. Nephrostome of *L. lepidula*.

Fig. 14. Nephrostome from the under side, *idem*.

Fig. 14*a*. One fold of nephrostome greatly enlarged showing ciliary ridge, *idem*.

PLATE 55.

Nephridia of various forms.

Fig. 1. Right nephridium of *L. anatina.*

Fig. 2. Greatly enlarged view of nephrostome from below, showing lacunae, *idem.*

Fig. 3. Left nephridium of *D. lamellosa.*

Figs. 4 and 5. Anterior coelomic wall showing terminal portion of nephridial tubes and their external openings, *idem*

Fig. 4. From outside.

Fig. 5. From inside.

Fig. 6. Nephridia from very young *D. lamellosa.*

Fig. 7. Nephridia *in situ* of *T. coreanica.*

Fig. 8. Dorsal section of *T. coreanica*, showing position of nephridia in relation to other parts and their slit-like openings outside.

Fig. 9. Nephridium of *T. coreanica.*

Figs. 10 and 11. Nephridia of *H. psittacea*, showing genital band with accessory vesicle, etc.

Fig. 10*a*. Enlarged view of border of nephrostome, *idem.*

Fig. 11*a*. A sinus from body of nephridium greatly enlarged, *idem.*

PLATE 56.

Nephridia of *Terebratulina septentrionalis* and *Dallina grayii.*

Fig. 1 to 7. *Terebratulina septentrionalis.*

Fig. 1. Left nephridium.

Fig. 2. Right nephridium with divaricator muscles, segment of intestine, ilio-parietal band, etc.

Fig. 2*a*. Nephrostome papillae.

Figs. 2*b* and 2*c*. Appearance of surface of nephridium.

Fig. 3. Nephridium, with genital band, accessory vesicle, etc.

Fig. 4. Peduncular end of young specimen showing nephridia.

Fig. 5. Very young specimen showing nephridia.

Fig. 5*a*. Nephridium greatly enlarged.

Fig. 6. External opening of nephridium, front view.

Fig. 7. Side view of nephridial opening showing nipple-like form.

Fig. 8. Nephridia of *Dallina grayii.*

Fig. 9. Nephridium of last, showing more clearly the crenulated character of nephrostome.

PLATE 57.

Genital products, etc., of various forms.

Fig. 1. Ovaries and stomachal glands of Glottidia.

Fig. 1*a*. Portion of stomachal glands.

Fig. 1*b*. Portion of ovaries.

Fig. 2. Mass of spermaries of Glottidia.

Fig. 3. Mass of spermaries of *L. anatina.*

Fig. 4. Mass of eggs of *L. lepidula.*

Fig. 5. Mass of eggs of Glottidia.

Fig. 5*a* and 5*b*. Eggs in various stages.

Fig. 6. Eggs of *Discinisca stella.*

Fig. 7. Stomach, stomachal glands, and right occlusor muscle of *D. lamellosa* with ilio-parietal band turned forward to show ovaries arising from it.

Fig. 8. Greatly enlarged view of ilio-parietal band from above; figure showing proliferation of genital strands with eggs in masses.

Fig. 9. A group of eggs attached to genital strand, *idem*.

Fig. 10. A group of eggs attached to genital strand, greatly enlarged. *idem*.

Fig. 11. Dorsal and ventral half of pallium of *T. coreanica*, with main pallial sinuses and lacunae filled with eggs; see **39**: 14, for color.

Fig. 11*a*. Terminal lacunae, showing ciliary ridge.

Fig. 12. Masses of eggs, *idem*.

Fig. 13. A single mass of eggs, greatly enlarged, *idem*.

Fig. 14. Side view of portion of mass, *idem*.

Fig. 15. A highly magnified view of a few leaflets filled with eggs, *idem*; see **39**: 13, for color. The yellowish border so characteristic of all membranes associated with genital activity may be seen in the last reference.

PLATE 58.

Genitalia of *Terebratulina septentrionalis*.

Fig. 1. Animal in the act of ovipositing.

Figs. 2 and 3. Small lacunae and spiculae with *corpora lutea*.

Fig. 4. Showing eggs escaping from the lacunae of the pallium, passing through the nephridium, and issuing from the external opening.

Fig. 5. Cluster of eggs from genital band.

Fig. 6. Eggs in lacune.

Fig. 7. Left nephridium with cluster of thread-like spermaries below.

Fig. 7*a*. Sperm threads under a compressor.

Fig. 8. Greatly enlarged view of a few sperm threads.

Figs. 9 and 10. Individual sperm threads showing glandular tip and spindle-shaped termination with spermatozoa; see **39**: 10, for color.

Fig. 11. Lacunae filled with sperm masses.

Fig. 11*a*. Portion of same.

Fig. 11*b*. Spermatozoa.

PLATE 59.

Vesicular organ known as "accessory heart of Hancock," of *Terebratulina septentrionalis*, and central and accessory vesicles of *Terebratalia coreanica*. The accessory vesicle will be designated as genital gland.

Fig. 1 to 8. *Terebratulina septentrionalis*.

Fig. 1. Genital gland springing from genital band with supplementary vesicles near.

Fig. 1*a*. Enlarged view of surface showing spermatoblasts.

Fig. 2. Genital gland more developed with glandular growth at base.

Fig. 3. Genital gland with supplementary gland at side.

Fig. 3*a*. Much enlarged view of same.

Fig. 4. Genital gland arising from slender stalk with glandular outgrowths on surface.

Figs. 5, 6, and 7. Genital glands in various stages of development.

Fig. 8. Portion of genital band thickened and strongly ciliated.

Fig. 9 to 13. *Terebratalia coreanica*.

Fig. 9. Stomach with so-called heart and genital glands at end of main pallial sinus, with glandular cord connecting them with the so-called heart; see **39**: 12, for color.

Fig. 10. So-called heart.

Fig. 11. Another view of same organ slightly compressed.

Figs. 12 and 13. Different views of genital gland.

PLATE 60.

External glands of *Terebratulina septentrionalis.*

Fig. 1. Shells thrown widely apart rupturing anterior coelomic wall, showing brachia, position of nephridia and relation of external glands to nephridial openings.

Fig. 2. Another view of nephridia with external glands.

Fig. 3. External gland compressed with glandular particles forced out.

Fig. 4. Greatly enlarged view of lobule of external gland showing ciliated epithelium.

Fig. 5. External gland showing spiculae on surface.

Fig. 6. Nephridia with external glands surrounding their terminations.

Fig. 7. Greatly enlarged view of right nephridial tube with external gland.

Fig. 8. Tubular portion of nephridia ensheathed by external gland.

Fig. 9. Another view of nephridium surrounded by lobules of external gland.

Figs. 10 and 11. External glands.

Fig. 12. Ventral view of anterior wall of coelomic cavity showing prominent character of external glands with azygos process between.

Fig. 13. Longitudinal section of *T. septentrionalis*, showing position of external glands projecting into pallial cavity.

PLATE 61.

Early stages of various forms.

Fig. 1. Lingula, species unknown, from Nagasaki.

Figs. 2, 3, and 4. *Discinisca stella.*

Fig. 5 to 12. *D. lamellosa.*

Fig. 13 to 16. Various stages of *T. septentrionalis*, reproduced from the author's memoir on early stages of this species.

Fig. 17. *Hemithyris psittacea.* The natural size is indicated by the small outline.

Printed, July, 1902.


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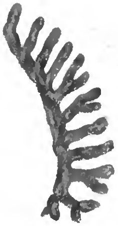
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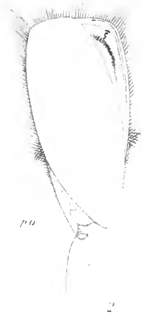

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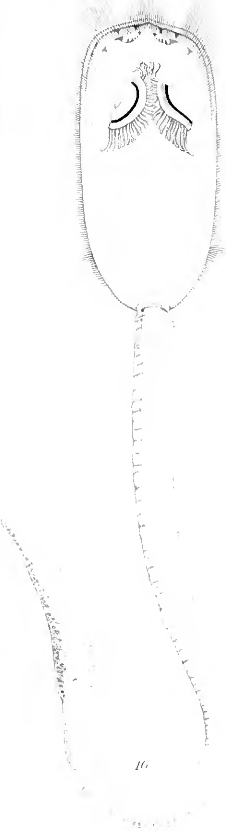

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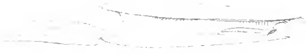

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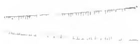

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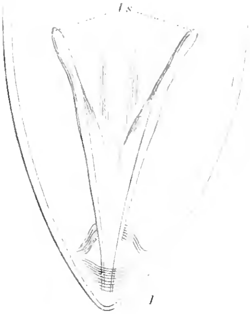
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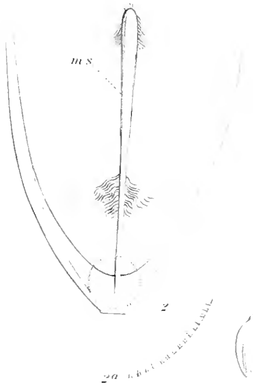
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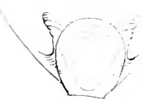
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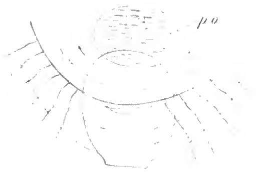
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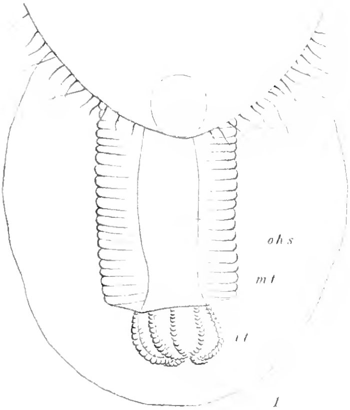

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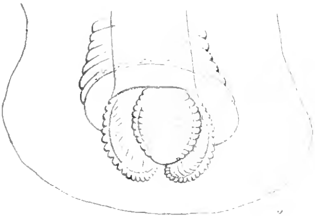

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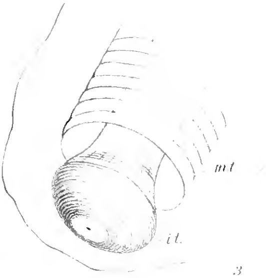

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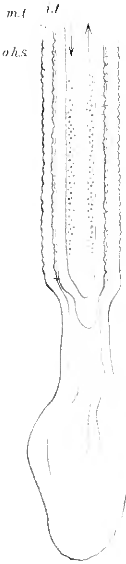

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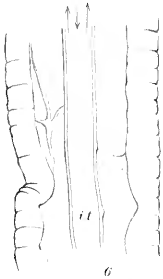

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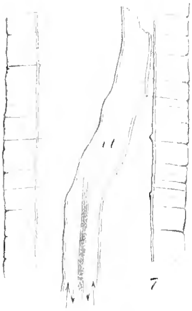

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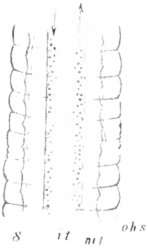

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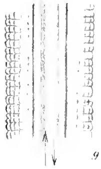

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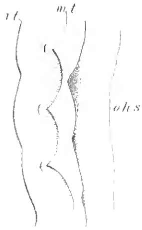

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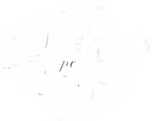

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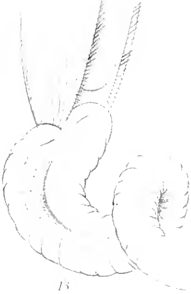

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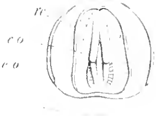

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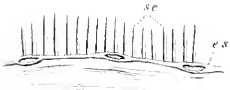
E. S. Morse del. [illegible]

MORSE ON LIVING BRACHIOPODA.



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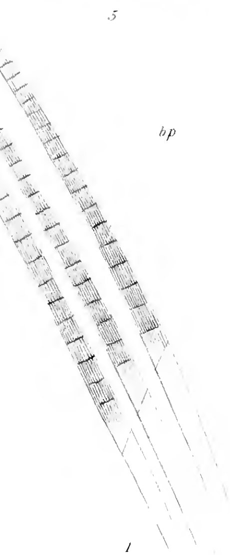

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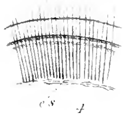

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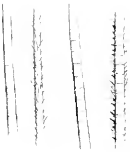

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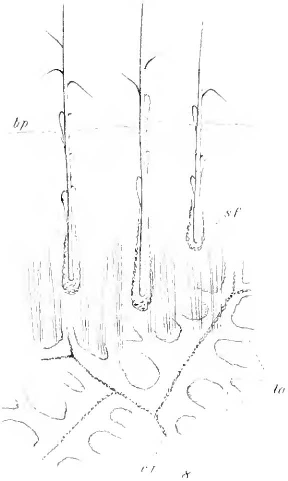

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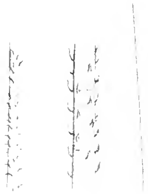

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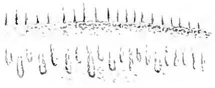

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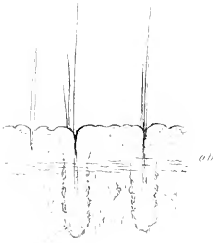

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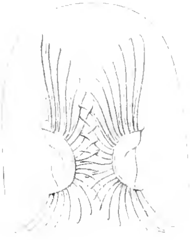
Morse del.

Morse on Living Brachiopoda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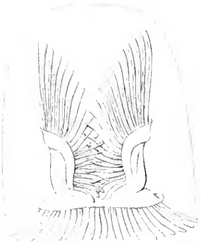
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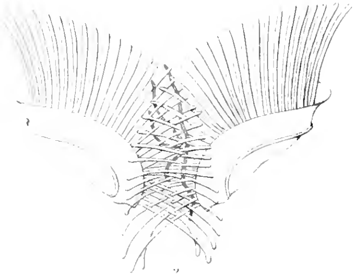
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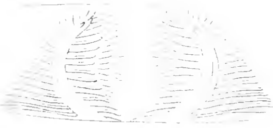
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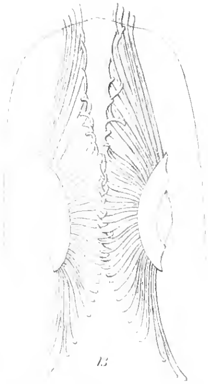
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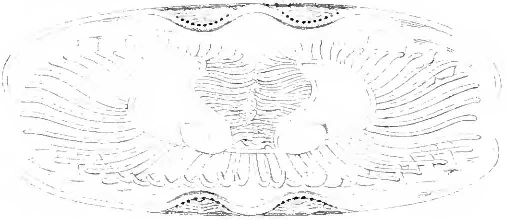
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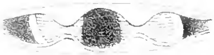
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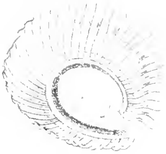
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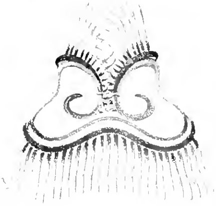
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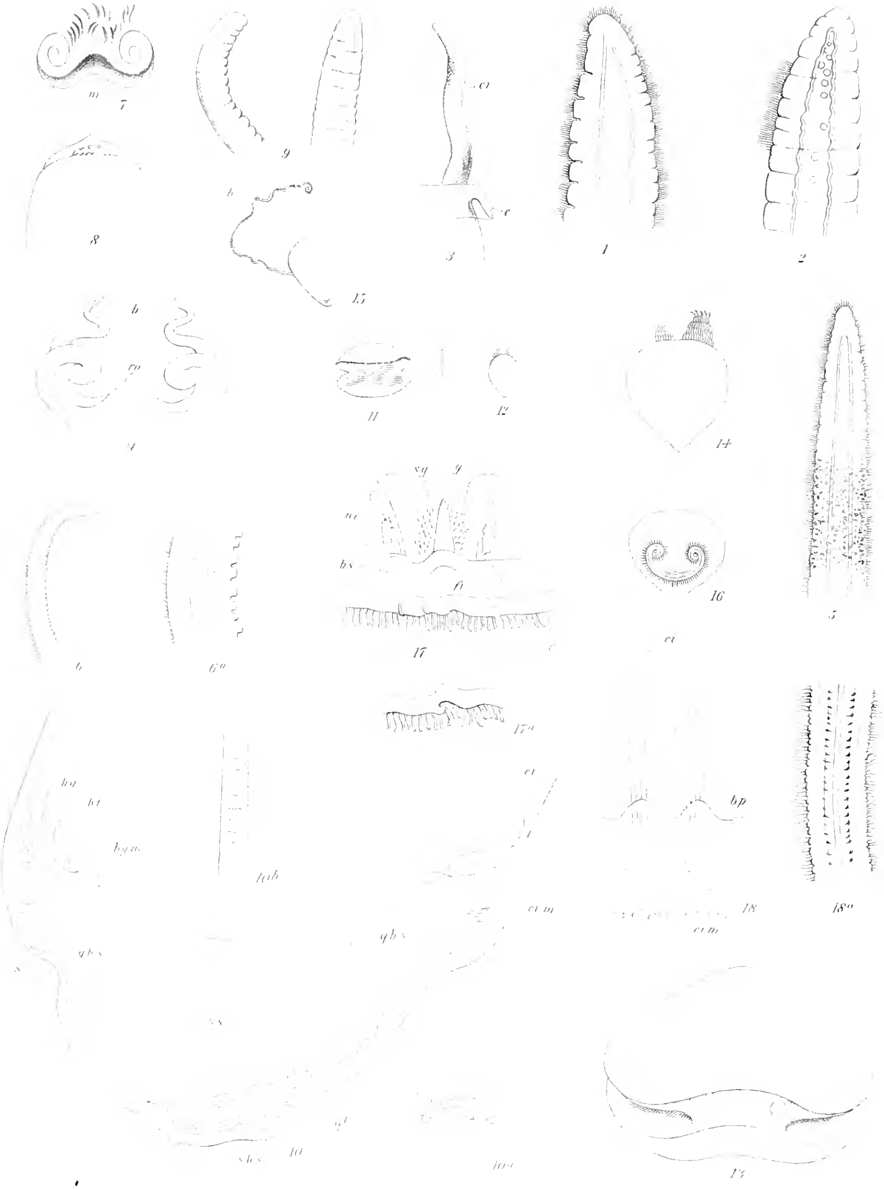
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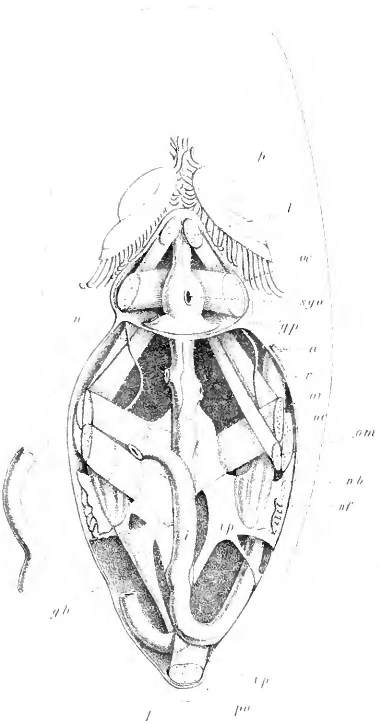

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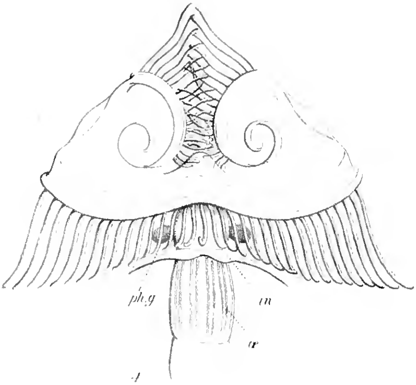

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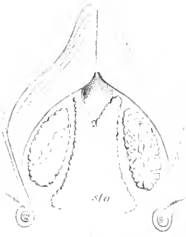

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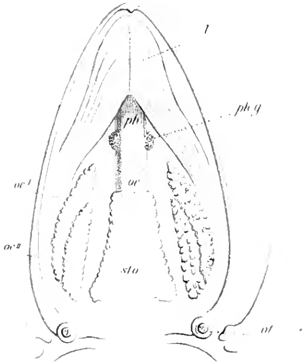

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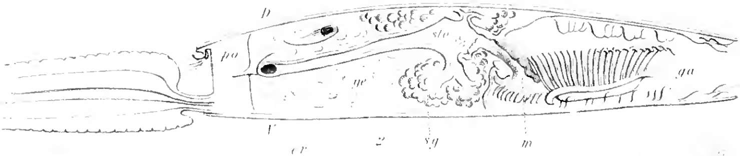

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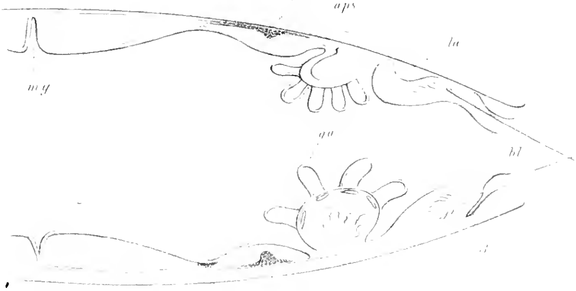

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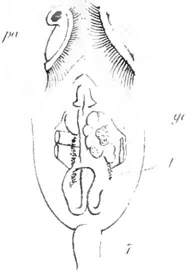

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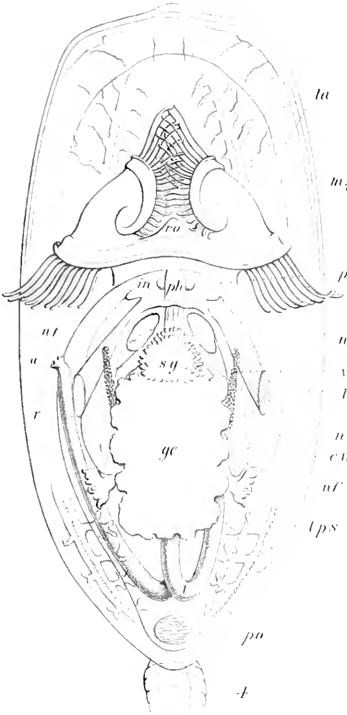
E. S. Morse del.

F. Meisel lith. Boston.

MORSE ON LIVING BRACHIOPODA.



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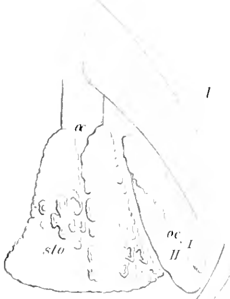

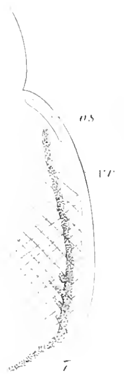

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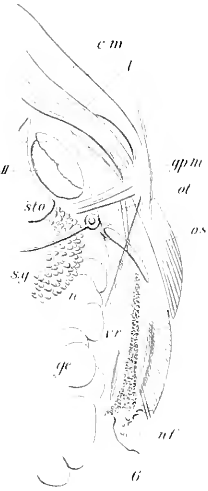

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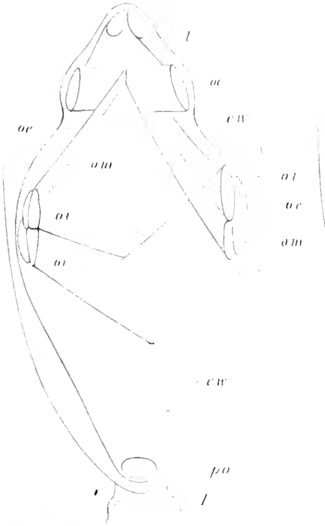

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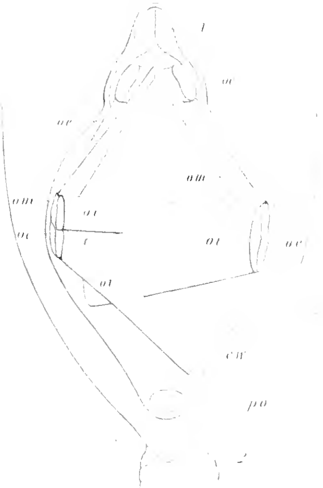

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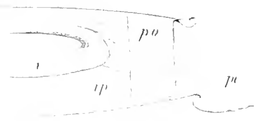

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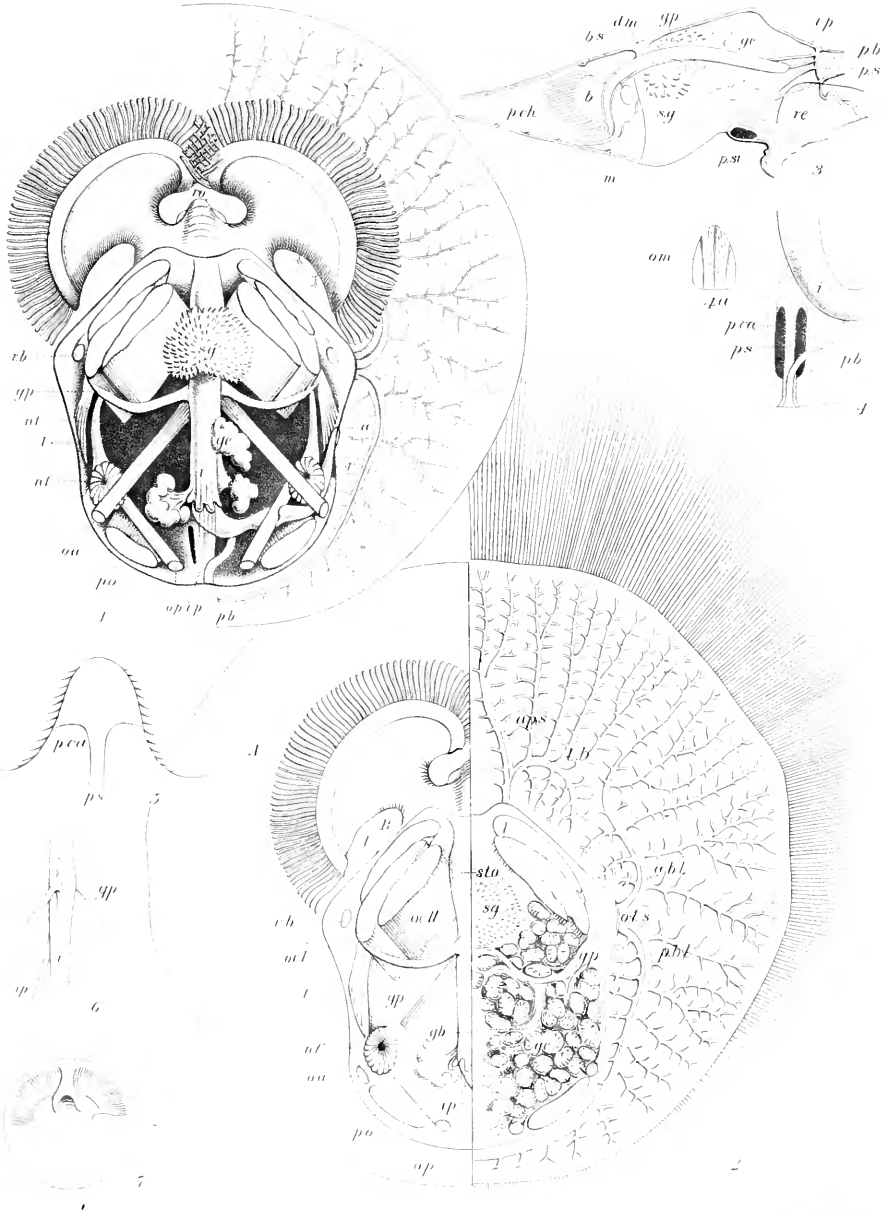
E. S. Morse del.

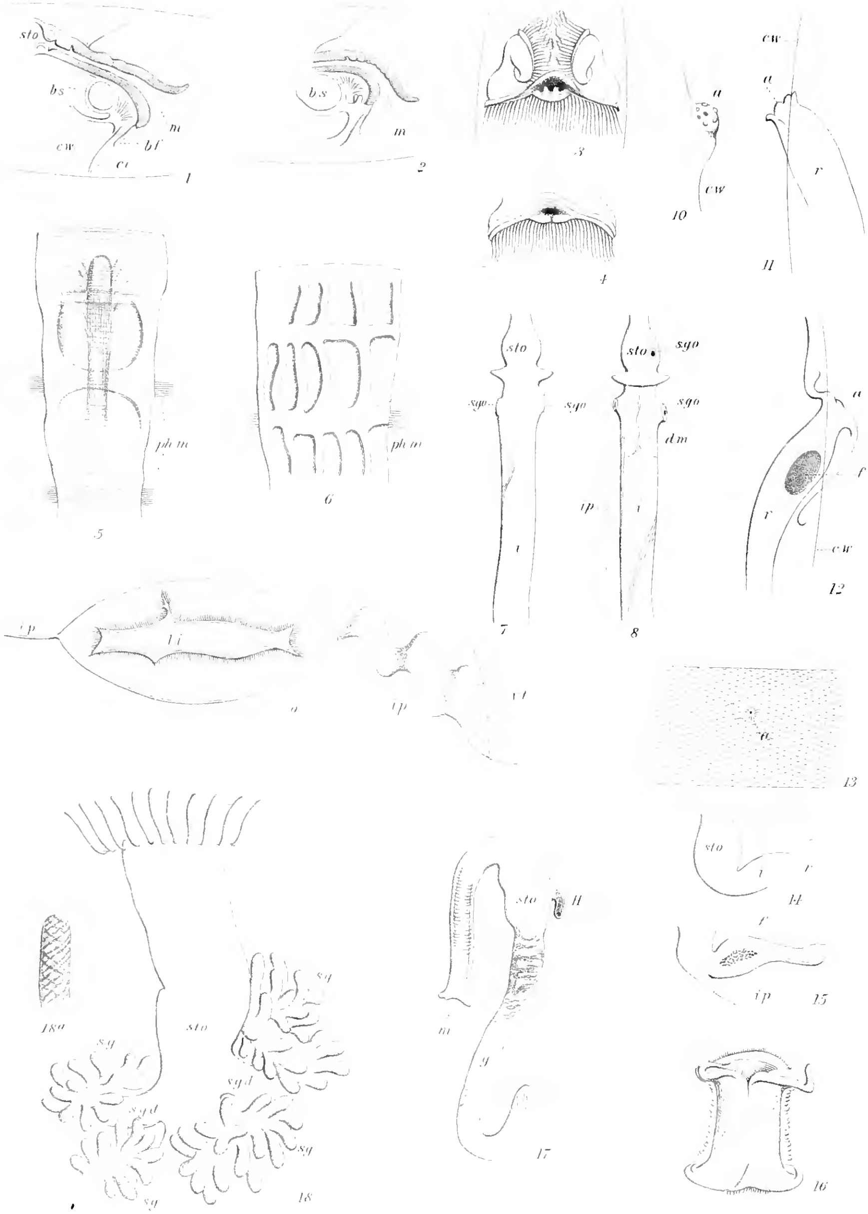
B. Meisel lith. Boston

Anatomy of Lingula Pyramidata.



E. S. Morse del.

MORSE ON LIVING BRACHIOPODA



E. S. Morse del. B. Meisel lith. Boston

MORSE ON LIVING BRACHIOPODA.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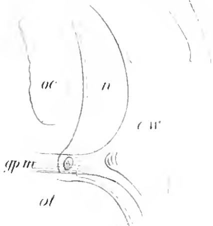

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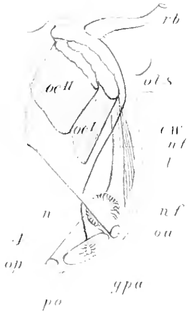

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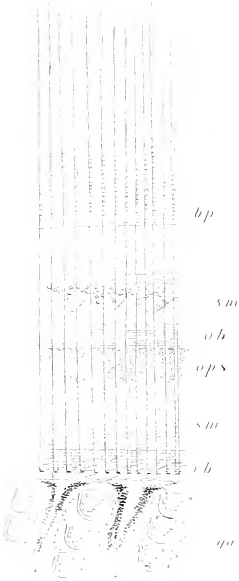

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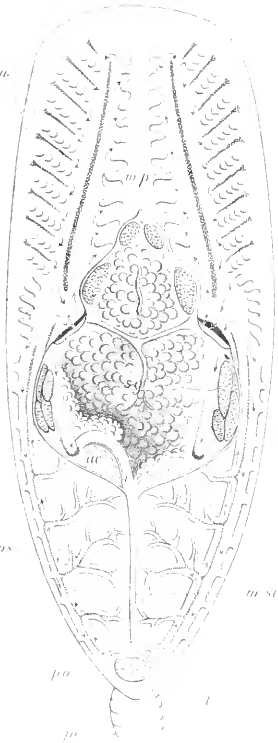
E. S. Morse del.

[illegible] Boston.

[illegible] ON LIVING BRACHIOPODA.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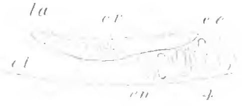
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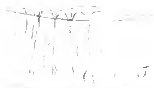
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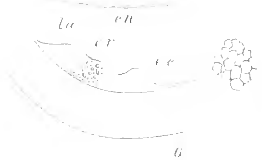
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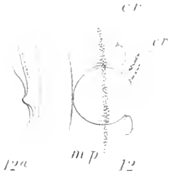
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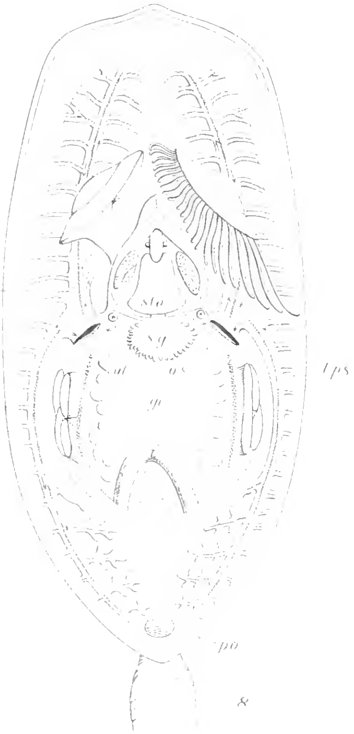
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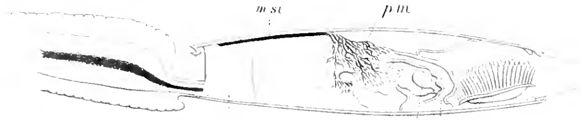

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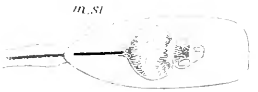

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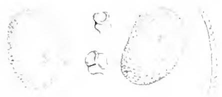

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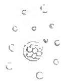

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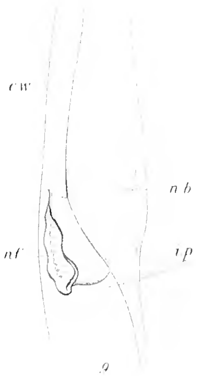

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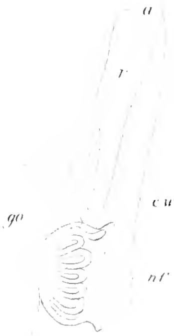

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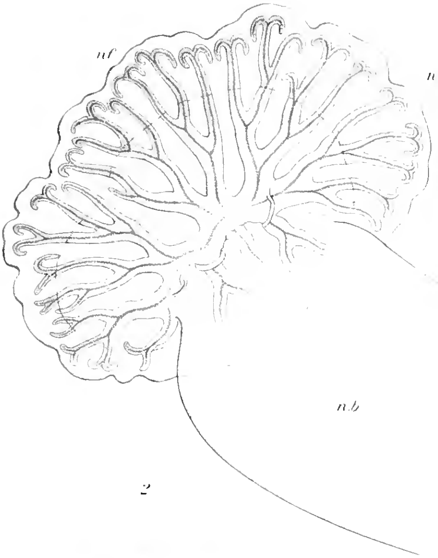
E. S. Morse del

MORSE ON LIVING BRACHIOPODA



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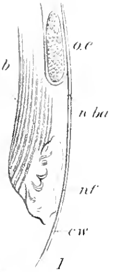

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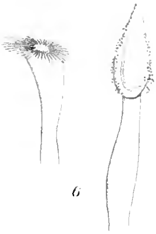

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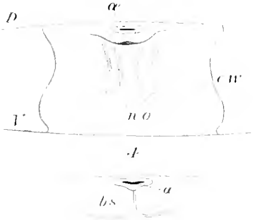

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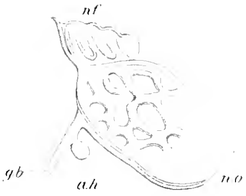

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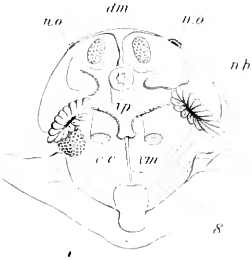

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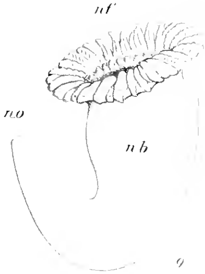

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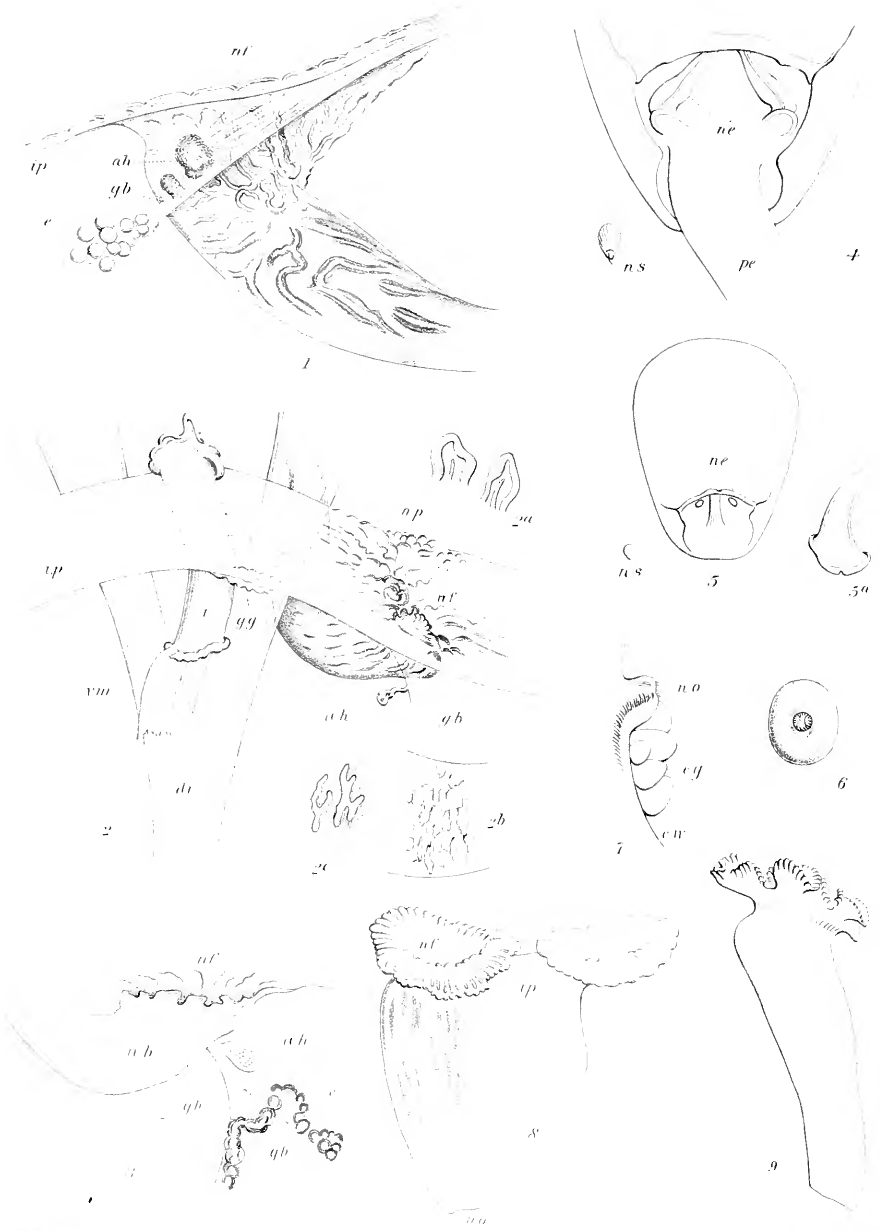

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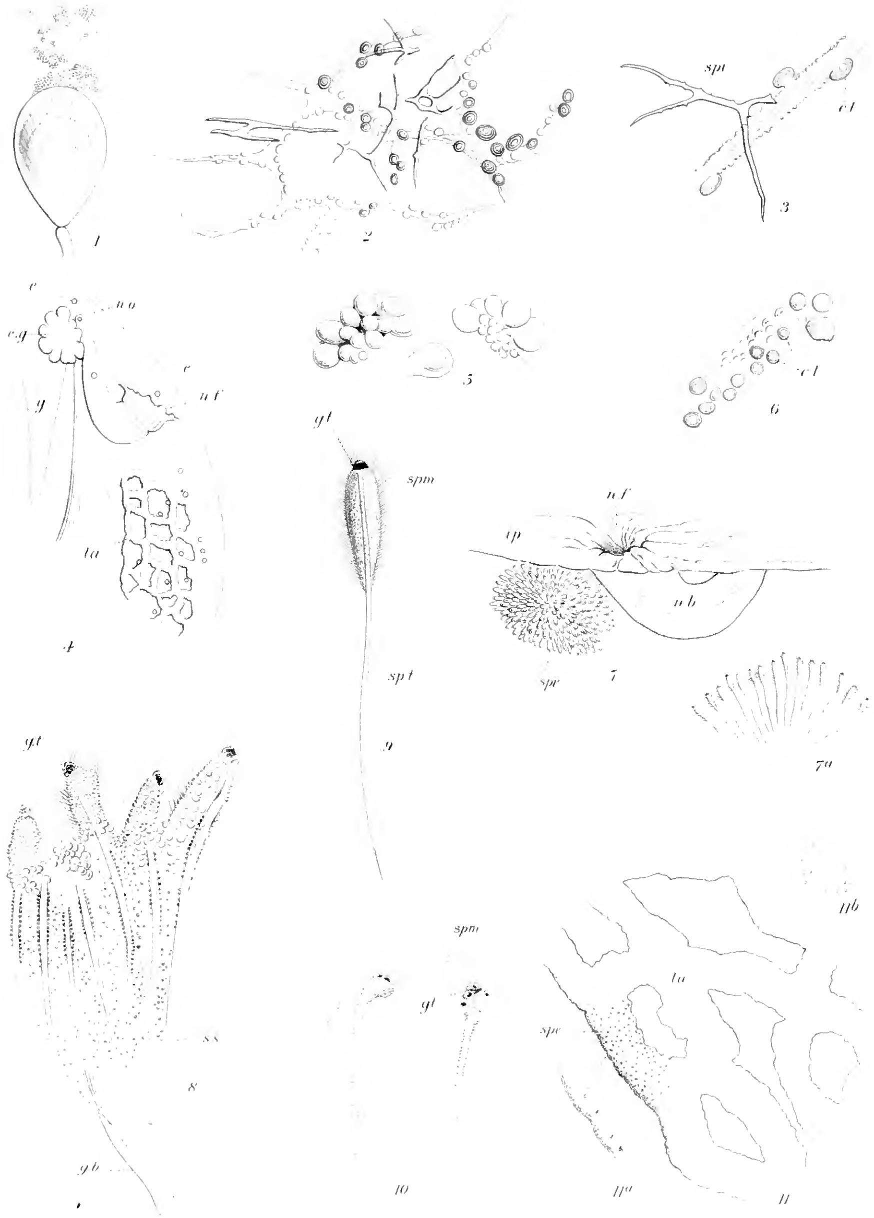

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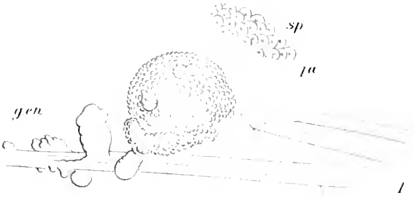

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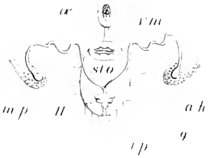

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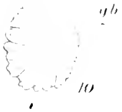

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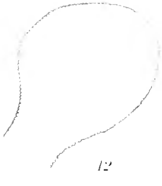

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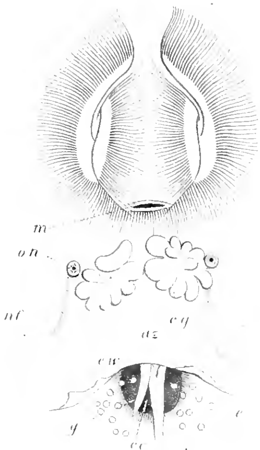

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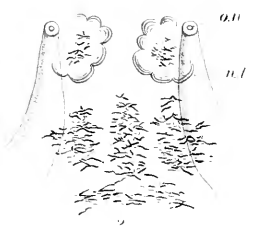

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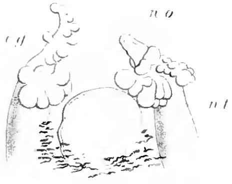

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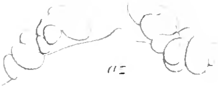

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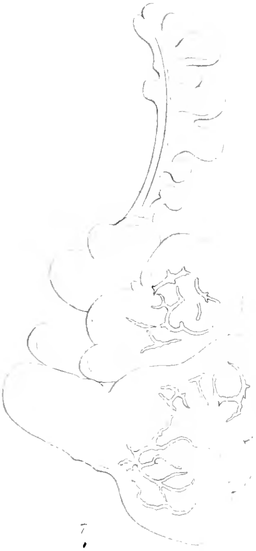

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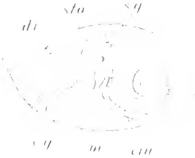

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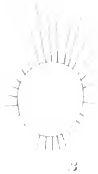
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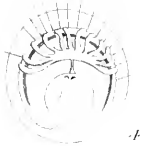
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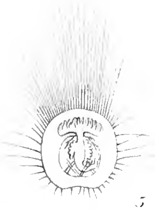
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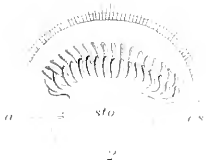
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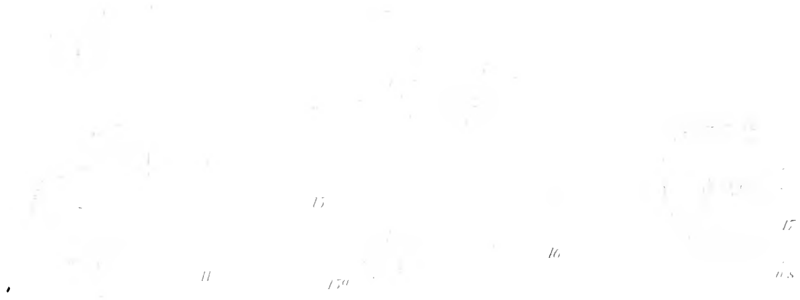
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