Some Activities of Polar Bodies. By E. A. Andrews.

The acceptance of the view that the polar bodies given off by the eggs of animals are but imperfect eggs incapable of fertilization, and having no part to play in the development of the true egg, has naturally tended to lessen interest in their fate. That they often remain attached to the egg shell, and may permanently remain, fused with the developing egg, makes it of great interest to inquire whether the polar bodies of other animals have posed to be limited to certain Protozoa, and that the polar bodies soon become, after fertilization acts very like many filose rhizopods: the protoplasm is seen to project itself out from the mass in the form of delicate, flowing processes have the power to unite with or separate from one another to lengthen or to shorten, to become thick or thin much as do the pseudopodia of the Astérías common at Roscoff, France. Under this magnification of more than one thousand diameters, the polar bodies are plainly connected with each other and with the surrounding cells of the blastula by delicate threads of protoplasm that constantly change. There are also characteristic tufts or brushes of more delicate threads sent out from each polar body; these also constantly change.

It will be noticed that the cells about the orifice also show threads stretching from one to the other as well as to the polar bodies.

On the threads protoplasmic masses flow along to or from the polar bodies or from cell to cell; and on the threads side spinnings may take place, producing such branching, rootlike tufts and anastomosing complexes as are partly represented in the figure.

The peculiar contractile powers of the material of these threads is illustrated in the figure in the case of a curved connective that joins the angle of one process to the angle of another. These processes extend from the two polar bodies to two separate cells on the margin of the orifice, or cleavage-pore, and the curved connective seems as if tending to draw the processes closer together by bending itself (compare 1, p. 352–3).

Passing over many significant facts, we note that the polar bodies may pass through the cleavage-pore into the interior of the blastula, and be connected with the complicated mass of threads joining the mesenchyme cells with the ectoderm and entoderm in the gastrula stage.

Thus in these animals the polar bodies long continue to act like Heliozoa, and acquire a living continuity with the embryo which may extend to the gastrula stage in such a way as to make them permanently part of the organism.

In the large Nemertean, Ceratobranchs dentes Verrill, I find some spinning activities of the egg and its cells, and most marked activity of the polar bodies. Soon after their formation the polar bodies send out delicate Heliozoa-like rays, and later characteristic star-like groups of processes that may develop into long proboscis-like outgrowths armed with lateral threads. From the first, the polar bodies are continuous with the egg and with one another by means of an exceedingly delicate film of material that sometimes shows fine threads and nodules within it, and seems living protoplasm rather than passive excretion or "slime.

In figure 17, the processes from the two polar bodies are indicated as seen under ocular 8, objective 2 mm. and draw tube 160 mm. and drawn, largely, with the camera lucida. The egg was in the four-celled stage and about to divide again so that there were more than eight cells fifteen minutes later. The double membrane is indicated by two lines, some distance from the egg.

At this period the activities of the polar bodies have passed through their first phases and are gradually approaching their more permanent, later phases.

A more detailed account of these will be given elsewhere, but we will here note that the polar bodies continue to adhere to one another and to the egg for a long time, even if the membrane be removed and they be exposed to the sea-water. When the larva becomes ciliated, the polar bodies break loose and float about in the liquid between the larva and its membranes, but they still adhere to one another, and are sometimes seen attached to the egg membrane. Probably they are lost when the larva breaks out from the egg membranes.

The first and the second polar bodies are markedly different: the first tends to remain more nearly spherical and to continue its radiating Heliozian-like activities; the second early assumes, somewhat the shape of a spindle, and is prone to send out long polar processes looking from the end view like stars and strongly suggesting free astrospheres, and from the side view somewhat like test-tube brushes. In later phases, the spindle may be much elongated, slender and with a marked atmosphere-like mass at each end, so that the entire figure is strangely like similar appearances in Caryokinesis.

With exceptional light, some of the spin-threads are seen to pass up to the egg membrane and to branch; others go to the surface of the egg. Here, as in the star-fish, the changes that take place, the making of new processes and the withdrawal and bending of old, makes it difficult to represent the actual appearances, even if it were possible to adequately express by black lines the optical effect made by these clear protoplasmic filaments, which bear as much resemblance to fine spun-glass-work as to any other common, gross object.

In a nudibranch mollusc, Teviji despectus, there are often three polar bodies that remain in close association till the larva is a pyramidal, many-celled mass. In some cases a connection was seen, a changing process or processes, extending between a polar body and the egg, and between one body and another; generally, the connection escaped observation though the bodies acted as if held together. In the case shown in figure 18, the small objects near the largest polar body were seen to change position and may have been either foreign, or loose, particles, or else enlargements upon filose processes so fine as to escape detection with the 6 ocular and 2 mm. objective.

Similar objects near the next polar body proved to be a group of blunt, pseudopodia-like outgrowths borne upon a common stalk. From the remaining polar body similar, blunt processes projected in various directions, separately, and one very long process extended upward to the egg membrane, where it branched and seemed attached by its several side threads. This last polar body also sent out a process that apparently attached itself to the surface of the egg, which was still in an undivided state. In other cases, blunt processes, and long slender processes, were sent out and again drawn in; within a minute a long, slender process extended out from a polar body to the egg and seemed to join to it and later was represented by a tuft of short, pointed, contracted processes. In many cases the polar bodies showed ameba-like changes of form, with or without, pseudopodia: in one case, where there were but two polar bodies, they crawled over one another with much of the appearance of amoebe, one of them having a tuft of pseudopodia.

In a lamellibranch mollusc, Nucula delphinidonta, the formation and activity of the polar bodies was observed only in some eggs that were, probably, not fertilized and that did not develop beyond an incomplete first cleavage. The two polar bodies were seen to be connected by a cylindrical mass of clear substance and, as seen in figure 19, one polar body was seen connected to the egg by means of a long filament as well as by an extensive sheet of faintly refracting material similar to that seen in Cerebratulus.

In this case the cleavage had passed in toward the centre of the egg. The small eminence on one side illustrates one of the several ectosarcal processes that at first were much like protuberances found in Cerebratulus, and there giving rise to brushes of fine spin-threads. Here, however, such ectosarcal processes are followed by hernia-like protrusions containing yolk and indicating the abnormal state of the egg.

With the 8 ocular and 4 mm. objective, large star-like radiations and central refracting areas were seen near the first polar body as the second one was being formed. Comparing these with appearances seen with the same powers in Cerebratulus, there is no doubt that there were here, also, radiating branches of processes similar to those so common at the ends of the second polar body of Cerebratulus. The first polar body also showed very fine Heliozia-like radiations in one case. One polar body showed marked ameboid change of outline with a rounded, blunt pseudopodium.

Such ameboid changes of polar bodies are most pronounced in another lamellibranch, Angulus tener. As represented in figure 20, the larger, first...
polar body takes on a somewhat cylindrical shape, at a time when the second is rounded and not entirely free from the egg, and sends out blunt pseudopodia: the two bodies remaining closely appressed. Besides the rounded pseudopodia, which are represented as dark, there were also clear, delicate lateral sheets or lamellae of wavy protoplasm, which are indicated in outline. All these parts rapidly changed, as may be seen by comparing the left hand view with the right, an interval of scarcely a minute having passed between these two sketches of the same polar body. As these observations were made with the 6 ocular and 2 mm. objective, the failure to see spinthetrons here does not disprove their existence: in one case there seemed to be something connecting the first polar body with the egg and passing as a filament between them: but the general character of these polar bodies was that of amoebe and not that of filose rhizopods.

To sum up, we find that the polar bodies in certain representatives of the groups, Echinodermata, Mollusca, and Nemertini, show marked activities, differing in different groups and in different sub groups. In several groups the polar bodies have not only ameboid but strongly marked Heliolaza activities. The polar bodies in several groups remain vitally connected with one another and with the developing embryo, for some time after their extrusion.

How far these phenomena are normal, and how much of what is above recorded may prove to be pathological, cannot be at present decided, but in any event it has been shown that the protoplasm of polar bodies has powers hitherto un-suspected. These need not imply close relationship between polar bodies and Protozoa, but may serve to show that protoplasm expresses itself in radically the same characteristic, "protoplactic" way in Metazoa and in Protozoa. These new facts may be added to those recently presented in a comparative study of Protoplasm, and help to bring us toward the new standpoints there reached.

October 15, 1897.

On the Leaf and Sporocarp of Marsilia. By Duncan S. Johnson.

[An Abstract.]

The following are some of the principal results of a study of the development of foliar structures in Marsilia quadrifolia, carried on during the past two years in the biological laboratory of this university.

The leaf begins its development with the formation, on the upper surface of the stem apex, of a typical two-sided apical cell. This apical cell continues its activity (Fig. 21) until about fifteen pairs of segments have been cut off, giving rise thus to a slightly tapering papilla-like organ lying nearly parallel to the stem and with its ventral or upper side facing the latter. The segments of the apical cell are nearly semicircular blocks which divide up soon by five nearly radial longitudinal anticlines, leaving a wedge-shaped marginal cell between the last two walls formed (Fig. 22).

In the lower or older segments each of the six divisions breaks up into many cells forming the vascular bundle, mesophyll, and epidermal structures (Fig. 22), of the cylindrical petiole. Between the mesophyll cells of this are formed the fourteen longitudinal air canals each broken into many short ones by the several transverse partitions formed in each segment.

In the younger segments of the tip, by the growth of the marginal cells in certain regions and the formation in these of many anticlines alternately parallel to each of its lateral walls, are developed the pinna or divisions of the lamina.

From the marginal cell of one of the lower segments is developed the sporocarp by the formation of a two-sided apical cell like that of the leaf. This cuts off segments, to the number of about twenty-four on each side, which break up by anticlines in a manner similar to those of the petiole of the leaf (Fig. 23), but forming six instead of five divisions besides the marginal cell.

The four or five oldest pairs of segments develop into the stalk of the sporocarp, a structure much like the petiole but of more compact tissue. The remaining segments form the so-called capsule containing the sporangia. In eight or nine pairs of these latter segments the basal marginal cells are surrounded and enclosed by the more vigorous growth of the other divisions of the segment. A row of macrosporangium mother cells and two rows of microsporangium mother cells is then formed from a part of each marginal cell, forming thus the eight or nine pairs of sori of the capsule, each with its own indusium formed partly from portions of the marginal cells themselves and partly from the above mentioned outgrowth ventrally of the other divisions of the segments. The walls of the capsule thus arise very differently from the pinna of the leaf, which, as we saw above, were developed by the continued formation of anticlines in the marginal cell.

The soral cavities or canals arise by the separation of the sporangium mother cells from the cells of the indusium lying median to them, beginning at the ventral surface, and continuing inward till all the sporangia formed from the mother cell stand out freely into the cavity formed by this separation of the cells.

The gelatinous ring seems to replace vascular tissue in one part and mesophyll in another.

In conclusion, then, Marsilia quadrifolia agrees with most other Leptosporangiates in the origin of the leaf, in the growth of this by a two-sided apical cell and in the formation of the pinna by the continued activity of the marginal cells in certain regions.

The sporocarp is a fertile portion or branch of the leaf arising from an apical cell like that of the leaf itself formed in a marginal cell of the petiole. But the fertile branch does not develop any structure homologous with the lamina of the sterile branch, the capsule being morphologically the swollen end of the petiole, if we may call it such, of the fertile branch. The tissue surrounding the sori is a true indusium arising by the outgrowth of the cells of the ventral surface of the branch to surround the sori in which the microsporangia are derived from sister cells of the macrosporangium mother cells, and not from segments of the apical cell of the latter as described by Russow and Büsgen.


*Explanations of Figures.*

**Fig. 21.**—Approximately horizontal section of a young leaf, with the apical cell of a sporocarp just formed.

**Fig. 22.**—Half of transverse section of young petiole of a sterile leaf.

**Fig. 23.**—Similar section of a young capsule.