

and show much variation in size and appearance in correspondence with the phases of activity of these cells. The ducts from these sacks are the channels by which the secretion is conveyed to the surface of the animal. The radiating threads surrounding the sacks are probably continuations of the reticulum of the cytoplasm.

THE HISTOLOGICAL STRUCTURE OF THE EYES OF CUBOMEDUSÆ.

By EDWARD W. BERGER.

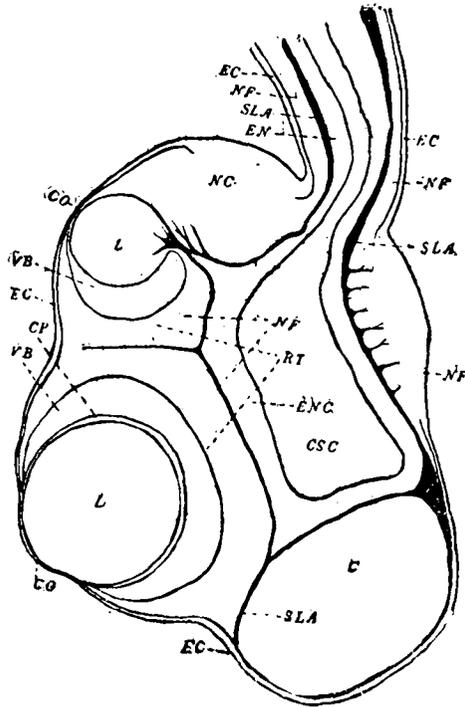
While in Jamaica with the Johns Hopkins Marine Laboratory, during the summer of 1897, Dr. Conant preserved material and tried experiments for the purpose of continuing his research on the Cubomedusæ, begun the year previous and now published as his thesis by the University. Upon the unfortunate death of Dr. Conant this material and notes were placed in the present writer's hands by Dr. Brooks. It is intended in the following paper to give only the principal results obtained by a careful study on the histology of the eyes of these medusæ, leaving their fuller discussion, together with Conant's physiological notes, for a more complete paper. The present work was done wholly on *Charybdea xaymacana*, while Conant's own work was in part done on *Tripedalia*.

For a complete description of the anatomy of the Cubomedusæ Dr. Conant's thesis, "The Cubomedusæ," or the "Johns Hopkins University Circulars," No. 132, November, 1897, should be consulted.

Roughly speaking, the Cubomedusæ, as the the name implies, are cubes with their tentacles (four in *Charybdea* but twelve in *Tripedalia*) arranged at the four corners of the lower face of the cube. These tentacles are said to lie in the interradii. Half way between any two points of attachment of the pedalia (the basal portions of the tentacles) and a little above the lower margin of the bell, hang the sensory clubs, one on each side,

four in all. Each sensory club hangs in a niche of the exumbrella and is attached by a small peduncle, whose central canal is connected with one of the four stomach pockets and in the club proper forms an ampulla-like enlargement.

Each club is said to lie in a perradius, and belongs to the subumbrella, as is shown by the course of the vascular lamellæ,



Explanation to *Fig. 1*. This is an outline taken from Schewiakoff's *Fig. 7* and is placed here to show the general relations of the different parts of a club. Since this drawing represents a section the simple eyes are not indicated. *C*—concretion cavity; *CO*—cornea; *CP*—capsule; *CSC*—cavity of sensory club, *EC*—ectoderm; *EN*—endoderm; *ENC*—endoderm of sensory club; *L*—lens; *NC*—network cells; *NF*—nerve fibers; *RT*—retina; *SLA*—supporting lamella; *VB*—vitreous body.

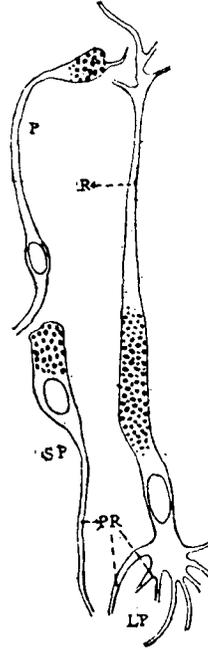
bands of cells, which passing through the jelly from endoderm to ectoderm all around the margin, form the line of division between sub- and exumbrella.

Each club has six eyes. Two of these on the mid-line of

the club facing inwards are called the larger and smaller (lower and upper) complex eyes because of their more complex structure, while the other four simple eyes are disposed laterally, two on each side from the line of the two complex eyes. All of these eyes look inwards through a thin transparent membrane of the subumbrella into the bell cavity. Besides the eyes and ampulla already referred to, a concretion fills the lowermost portion of the club, and a group of large cells having a network-like structure and called network cells by Dr. Conant fill the uppermost part of the club between the smaller complex eye and the attachment of the club to its peduncle. What is evidently nerve tissue, fibers and ganglion cells, fills the rest of the club. A ciliated epithelium covers the club except where interrupted by the eyes.

A nerve ring, underneath the ectoderm of the subumbrella, passes from near the origin of the tentacle at the margin to the origin of the peduncle of the sensory clubs a little above the margin and gives off a branch to each club. In the course of this nerve ring are found ganglia in the interradii (pedal ganglia) and in the perradii (radial ganglia).

The structure of the four simple eyes may first be considered. These are little invaginated cups of epithelium, the cells of which have become pigmented. Their cells are crowded very closely in many places so that the nuclei

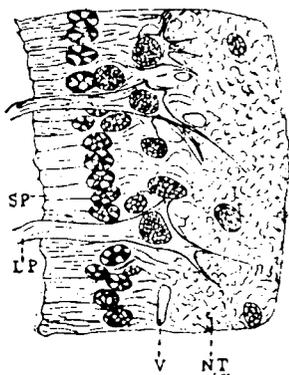


Explanation to *Fig. 2.* This figure represents three pigmented cells drawn from a maceration preparation of Conant's. The long pigment cell (*LP*) shows its several processes (*PR*) passing centrally, a pigmented portion, and more distally its rod (*R*) which also branches. *SP*, a short pigment cell, shows its single central process (*PR*), and distally its pigmented portion, beyond which should be continued its prism with a central fiber. This cell may also be taken to represent one of the retinal cells of the simple eyes in which case it should have a fiber at its distal end similar to cell *P* which is evidently a cell from the simple eyes.

come to lie at different levels and many of the cells become spindle shaped. Every cell, however, extends to the cavity of the cup and ends in a rod or fiber probably homologous with the cilia of the epithelium (Fig. 2, *P*). The cup of each of eye is filled with a homogeneous substance probably a secretion of its cells and into this lens the rods from the cells project.

While Schewiakoff (Morph. Jahrb., Bd. XV, H. 1.) maintains the existence of two kinds of retinal cells (pigmented, supporting cells, and spindle shaped, or visual cells) for these eyes, as well as for the complex eyes, to be distinguished principally by their pigmentation and location of nuclei, neither Conant nor myself have been able to demonstrate any such two kinds of cells for the simple eyes.

The larger complex eye is the more complicated of the complex eyes and consists of the following parts: a cellular



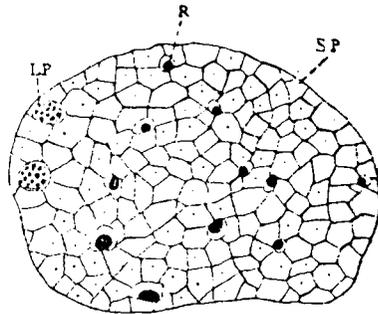
Explanation to Fig. 3. This figure shows only a small portion of a retina with its underlying nerve tissue. It shows the central processes of the long pigment cells nicely and seems to show the cells themselves in a retracted condition. This retina was killed in the dark but contained little pigment. *LP*—long pigment cell; *SP*—short pigment cell; *NT*—nerve tissue; *V*—vacuole.

cornea continuous with the surface epithelium, a cellular lens, a homogeneous capsule to the lens, a vitreous body composed of prismatic elements, and a retina of pigmented cells whose central processes pass into the nerve tissue lying centrally from the retina. Figs. 1, 4, 5.

The points in Schewiakoff's paper which neither Conant nor myself could verify relate to the structure of the retina and the vitreous body and these will here be specially considered. I, myself, believe I can readily demonstrate two kinds of cells in the retina of the larger complex eye, but not on grounds of pigmentation and position of nuclei as Schewiakoff maintained, but from four reasons: 1st, the pigment of the one kind, the long pigment cells (to retain Conant's nomenclature), may be

in part projected into the vitreous body while that of the other kind, the short pigment cells, is not projected; 2nd, both kinds are distally continued into rods which are readily to be distinguished by their difference in size and by the fact that the rods of the long pigment cells pass between the prisms while those of the short pigment cells pass through the prisms of the vitreous body; 3d, by a probable difference in their nuclei; 4th, by their central continuations,—the central end of the long pigment cells being continued into several processes, while that of the short pigment cells is continued into a single process. Fig. 5, also 4, 3 and 2.

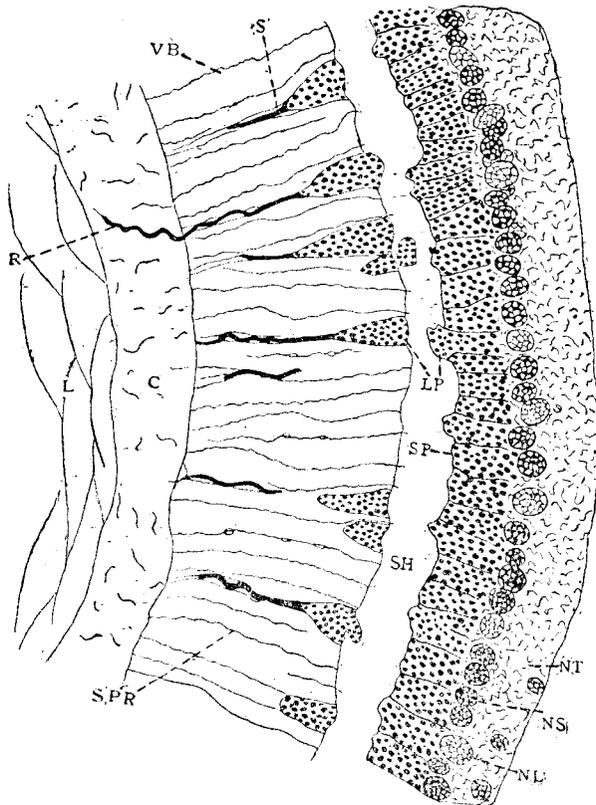
Conant maintained that two kinds of cells could not be distinguished by their pigmentation, and although he had evidence of the existence of two kinds of rods in the vitreous body he was not certain but that the short pigment cells might be changed to the long pigment cells by simply projecting their pigment. This I do not think can be the case for in the first place the two kinds of rods are too unlike and without doubt the one kind passes between the prisms while the other kind through the prisms. Conant simply left the question open, hoping to clear up the point on the new material which he preserved.



Explanation to *Fig. 4.* This shows a transverse section of the vitreous body quite near to the retinal cells. The section is not exactly transverse, but nearer to the retina on the left side than on the right, in consequence of which the pigmented portions (*LP*) of the long pigment cells are cut on the left while more to the right their rods (*R*) only are taken. These long pigment cells and their rods are readily seen to lie in the spaces between the prisms represented by the polygonal areas. *SP* refers to a prism with its central rod represented by a dot.

To Conant wholly belongs the credit of having first demonstrated the prismatic structure of the vitreous body. This can readily be seen in transverse sections of the vitreous body

where the sections of the prisms appear as polygonal areas (Fig. 4), but is not so readily demonstrated in sagittal sections.



Explanation to *Fig. 5*. This figure represents a portion of a sagittal section of a larger complex eye with a heavily pigmented retina. This retina was killed in the light and shows the long pigment cells well projected into the vitreous body. The prismatic structure of the vitreous body is not shown but the smaller lines seen in it and marked *SPR* represent the rods from the short pigment cells. Some of these rods are seen to extend into the shrinkage space *SH*. *L*—lens; *C*—capsule; *VB*—vitreous body; *LP*—long pigment cell; *SP*—short pigment cell; *R*—rod from a long pigment cell seen in this case to pass into the capsule; *NL*—nucleus of a long pigment cell; *NS*—nucleus of a short pigment cell; *NT*—nerve tissue; *SH*—shrinkage space; *S*—space about rods of long pigment cells.

As Conant suggests, each prism is evidently a continuation, a part, of a short retinal cell and not simply a secretion from

such a cell. Conant also suggests that these prisms with their central fibers are the true visual rods. What then are the long pigment cells with their rods?

Since I believe I have evidence to show that the long pigment cells can project themselves with a part of their pigment into the spaces between the prisms of the vitreous body during exposure to light while they retract themselves with their pigment when in darkness, may these cells not be solely for this purpose—to check the diffusion of light in the vitreous body?

The capsule of the lens seems to be homogeneous and according to Schewiakoff a secretion of the lens cells. The rods from the long pigment cells pass into this capsule (Fig. 5, R.) and the rods of the short pigment cells (better called prism cells) perhaps also do. At all events numerous smaller fibers are seen in the capsule (Fig. 5).

The lens and cornea I shall not further discuss. Schewiakoff suggests that the eye is of ectodermal origin and that it is an invagination which becomes pinched off as a hollow sphere, the outer portion of which forms the lens the inner the retina and vitreous body.

The structure of the smaller complex eye is very similar to the larger one except that it has no capsule (Fig. 1) to its lens and lacks the long pigment cells in the retina. Dr. Conant gives an excellent figure of this eye in his thesis but does not show the prismatic structure of the vitreous body nor the rods from the prism cells.

One may regard the three kinds of eyes, the simple, the smaller complex and the larger complex, as so many stages in development. The retinas, the most important parts of eyes, would be homologous and quite at the same stage of development; the lenses of the complex eyes would be homologous, but not with those of the simple eyes. The capsule of the larger complex eye stands alone. The vitreous bodies in the complex eyes being homologous cannot be homologised with any thing in the simple eyes unless one regards the so-called lenses of those eyes vitreous bodies and the vitreous bodies of

the complex eyes as secretions from the retinal cells, which view does not seem probable.

Finally, it may be added that *Charybdea* is very sensitive to light, as is fully shown by Conant's physiological experiments, but none of these trace the seat of sensation directly to the so-called eyes of the sensory clubs, so that the evidence that these are real eyes is almost wholly histological.

Johns Hopkins University, August 23d, 1898.

A CONTRIBUTION TO THE NERVOUS SYSTEM OF THE EARTH-WORM.

By H. R. FLING.

The past three years, under the direction of Dr. C. O. Whitman, at Chicago University, and at the Marine Biological Laboratory at Wood's Hole, Mass., I have been carrying on investigations to determine the typical segment of the Earth-worm and to homologize as far as possible the head segments with the typical segment. I take this opportunity of presenting some of the reconstructions which I have made, reserving until a later time the details and discussion of homologies.

In 1894 Dr. Richard Hesse published an article entitled "Zur Vergleichenden Anatomie der Oligochaeten," in the "*Zeitschrift für wissenschaftliche Zoologie*," 3 Heft, Band 58. Besides giving a description of the nerves in a typical segment, he reconstructed the nervous system of the head segments. The following year Miss Langdon published an article "Lumbricus Agricola Hoffm," in *Journal of Morphology*, XI, pp. 193-234.

In both of these papers the arrangement of the nerves in the typical segment was described as consisting of a ventral cord with a ganglionic enlargement at the posterior part, from which two nerves take their origin, and a third nerve leaving the anterior smaller part of the cord. These three nerves, after leav-