A STUDY OF THE NEURONE THEORY.*

By MARTIN H. FISCHER.

(*From the Pathological Laboratory of Rush Medical College, Chicago.*)

PLATES XXIII AND XXIV.

The opinion is now widely accepted, that the nerve cells throughout the central nervous system are independent structures. The cell processes, it is thought, invariably run out to end free, and one nerve cell has no further connection with any other than that of mere contact. This, in brief, constitutes the neurone theory which is so vigorously maintained by von Lenhossék, Golgi, Ramón y Cajal and others.

The claim for the independence of the nerve cells is based almost entirely upon the use of Golgi's silver impregnation method, and the embryological researches of His. The investigations of the latter may indeed show that all the dendrites of a nerve cell develop from the neurocyte, and that they do not anastomose with each other; but when in mature cells such anastomoses are demonstrated anatomically, the observations of His lose some of their significance. But notwithstanding the fact that Golgi's method demonstrates only individual elements, and these for the most part only imperfectly; and notwithstanding the fact that the pictures presented are so crowded with artefacts as to cause every statement concerning the histology of the cells to be made with the greatest reserve, still as a result of its use, the old observation of Gerlach (1), that the nerve cells anastomose with each other, has been discarded, and the more modern neurone theory substituted.

Held (2) does not believe in the neurone conception and maintains that anastomoses between nerve cells are demonstrable by Golgi's method. My own observations have led to a similar conclusion.

* A preliminary communication was read before the Chicago Pathological Society, April 10, 1899.

Even after obeying von Lenhossék's instructions to choose for investigation only single, isolated impregnated cells, anastomoses have been demonstrated, whose genuineness, to my mind, is not to be doubted. My observations are based upon a study of the cerebral cortex, basal ganglia, and motor spinal ganglion cells of the white rat and of the spinal cord of man.

In the cerebral cortex, the pyramidal cells are usually connected in a sort of end-to-end manner, the large dendrite of one cell passing upward and into the body of another cell directly above (Plate XXIII, Fig. 1) or above and to one side of it. This same condition has been described by Růžicka, who, however, working with toluidin blue, employed a totally different technique. Thus two entirely different methods have given the same results. A few times I have found these pyramidal cells to be connected by transversely running dendrites, which join together cells lying in about the same plane in the cerebral cortex (Plate XXIII, Figs. 2 and 4). In the basal ganglia, the cells are connected in various ways, the usual arrangement consisting of short protoplasmic bridges which connect the two cell bodies (Plate XXIII, Fig. 5). The spinal ganglion cells furnish interesting pictures of anastomosing cells. For the most part two cells are found connected by a common dendrite; but three are not uncommon, and in one case an anastomosis between five cells was noted (Plate XXIII, Fig. 3).

Since, however, the upholders of the neurone theory will in no case admit an anastomosis which is demonstrated by Golgi's method (condemning such in every case as only apparent), we are driven to adopt another method to settle this dispute.

Dogiel, who has demonstrated anastomoses between the nerve cells of the retina, has employed Ehrlich's method of the intravenous injection of methylene-blue. Bethe (3) has used molybdic-acid toluidin blue, while Růžicka (4) has worked with plain toluidin blue; both have found that the nerve cells not only come into contact with each other, but actually anastomose.

In my investigations of this subject, I have employed, besides Golgi's method, the following modification of Nissl's method:

(a) The tissue is hardened in a 10 to 20 per cent solution of formalin, cut with a freezing microtome, or dehydrated, embedded in celloidin or paraffin, and sectioned.

(b) The sections, which should not be too thin, are stained from one to twenty-four hours in a solution of Grüber's soap methylene-blue which has been diluted with an equal amount of water.

(c) The specimen is rinsed in water and dehydrated and differentiated in aniline-oil alcohol (1-20).

(d) Cleared in oil of cajeput and mounted in Canada balsam.

I consider this method superior to Ehrlich's intravenous injection of the dye for this purpose, as the pictures obtained are more intensely stained. Ružička's method is, I think, improved by the use of formalin instead of corrosive sublimate, as formalin acts as a powerful mordant for the dye, and this permits of a longer period of differentiation in alcohol, making the resulting pictures stand out more prominently.

The nerve cells in specimens colored by the method I have given are overstained. The cell processes are stained for long distances from the cell body, as are also the branchings and subbranchings. Furthermore, all neighboring structures are stained, so that the true relation of these to the neurones can now be studied to better advantage. The Nissl bodies are plainly visible in the cells and dendrites, so that the identity of these structures is never doubtful. The nucleus appears usually as a somewhat lighter blue spot in the centre of the cell body.

It is now an easy matter to see that the nerve cells are not separate individuals, but frequently anastomose with each other. The relation of two cells is not always one of mere contact only, but one of actual connection between the protoplasm of one cell and that of the other.

The two cell bodies are in these cases connected with each other by a common dendrite (Plate XXIV, Figs. 6, 7, 8), which is in every way similar to that ordinarily observed. The process arises from the one cell by its usual, broad, wedge-shaped base, and its connection with the other cell is marked by a similar base. The Nissl bodies can be traced throughout the entire length of the dendron. The connecting dendrite is usually a short, protoplasmic bridge (Plate

XXIV, Fig. 6), but quite often extends to a greater length (Plate XXIV, Figs. 7 and 8). There is never any doubt as to whether the anastomosis is a true or only an apparent one. The dendrites are not opaque as in Golgi's method, but translucent, so that in every case it can be easily seen whether the protoplasmic processes really connect with each other or only touch each other. Thus far I have found anastomoses only between cells of the same group, and never between cells of different groups, an observation which is in harmony with that of Růžička.

Unfortunately the methylene-blue staining does not lend itself well to photomicrography, so that I have been forced to use drawings to illustrate my observations.

Sala (5), working with Golgi's method, has put forth the claim that the dendrites embed themselves in the blood-vessels. His position has been substantiated by Růžička, but is severely criticised by von Lenhossék. That some of the dendrites do actually embed themselves in the walls of the capillaries, is, to me, an established fact. The tip of the cell process, before it connects with the wall of the capillary, widens out into a wedge-shaped end (Plate XXIV, Fig. 9). The occurrence of this condition leads me to believe that the dendrites have, besides the generally accepted nervous, also a nutritive function.

As the result of this study, I would point out the following:

First. The neurone theory, in so far as it claims the absolute independence of the neurones is an untenable one, as anastomoses between them have been found.

Second. The dendrites, which are generally believed to have but nervous function, may have also nutritive function, if such an inference is permissible from the existing anatomical relations, which show some of the dendrites embedding themselves in the walls of the capillaries.

DESCRIPTION OF PLATES XXIII AND XXIV.

PLATE XXIII.

Fig. 1. Photograph showing anastomoses between the pyramidal cells of the cerebral cortex of white rat. Method of Golgi.

Fig. 2. Anastomosis between the nerve cells of the cerebral cortex of white rat. The dendrite seen running upward and to the right from the

upper neurocyte is the continuation of the delicate cell process which is seen to the right of the heavy common dendrite. Golgi method.

Fig. 3. Anastomoses between five motor ganglion cells of the dorsal spinal cord of the white rat. Golgi method.

Fig. 4. The bodies of two pyramidal cells of the cortex connected by a common dendrite. Brain of white rat. Golgi method.

Fig. 5. Two nerve cells of basal ganglia connected by common dendrite. Golgi's method.

PLATE XXIV.

Fig. 6. Two motor spinal ganglion cells connected by short protoplasmic process. Methylene-blue staining.

Figs. 7 and 8. Motor spinal ganglion cells from cervical region of human spinal cord. Methylene-blue staining.

Fig. 9. A dendrite embedding itself in the wall of a capillary. Human spinal cord, anterior horn cell of cervical region. Methylene-blue staining.

REFERENCES CITED IN TEXT.

1. Gerlach, J.—The Spinal Cord, Stricker's Manual of Histology, Am. Ed., p. 623.
2. Held, H.—Beiträge zur Structur der Nervenzellen und ihrer Fortsätze, *Arch. f. Anat. u. Entwicklungsgesch.*, 1897, Suppl.-Bd., p. 273.
3. Bethe.—Die anatomischen Elemente des Nervensystems und ihre physiologische Bedeutung, *Biolog. Centralbl.*, 1898, xviii, 843.
4. Růžicka, V.—Untersuchungen über die feinere Structur der Nervenzellen und ihrer Fortsätze. *Arch. f. mikr. Anat. u. Entwicklungsgesch.*, 1899, liii, 485.
5. Sala, L.—Zur feineren Anatomie des grossen Seepferdenfusses, *Zeitschr. f. wiss. Zool.*, Bd. III., Taf. V., Fig. 6.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.

FIG. 9.

FIG. 8.