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Second.—Formaldehyde has an application in those methods used for tracing the course of medullated nerve fibers. All such methods, whether the original Weigert or some modification of it, are usually long and tedious, the time required frequently being some months. This length of time is often a very serious objection. Formaldehyde can be introduced in these methods for the purpose of rapidly giving firmness to the nervous tissue, and then subsequent steps may follow in quick succession. In this way the time may be reduced to ten days for the whole process.

Third.—In the study of nerve cells formaldehyde may now claim a place in the beautiful impregnation method of Golgi. The application is made in Golgi's "rapid" method, and consists in the substitution of pure formaldehyde for the 1 per cent osmic acid of the hardening mixture. The advantages resulting from this substitution may be an increased clearness of the subsequent silver impregnation, or in the slightly wider latitude of time during which hardening may occur. The physiological condition of the nervous tissue appears to be a very important factor in all Golgi work; and perhaps formaldehyde is less sensitive to these differences than osmic acid. However that may be, osmic acid in this method cannot be dispensed with. Workers should use both hardening mixtures side by side. The results attained by one will supplement those of the other in a most valuable way, thus virtually doubling the efficiency of the study as a whole.

THE NERVE CELLS OF THE SHARK'S BRAIN.*

BY GILBERT L. HOUSER.

The sharks are of the greatest interest to the morphologist on account of the many ancestral characters of their organization. The researches of recent years indicate that they represent quite well the primitive stem of the jaw-bearing vertebrates. With this fact in mind, the importance of the study of the shark's brain is at once apparent. For obvious

* The following brief notes are to be considered as in the nature of a mere preliminary communication on this subject.

reasons modern neurological investigation has been largely concerned with the mammalian brain in general and the human brain in particular. But the structures here are highly specialized, and their significance cannot always be thoroughly understood. In order to unravel the tangled threads of the complex neurological skein, the study of some primitive type of brain is an absolute necessity. The brain of the shark is the one to which we naturally turn for this purpose because of the morphological position which it occupies.

The several parts of the brain are arranged in almost perfect longitudinal series, and are well separated from each other. The *prosencephalon* is a relatively large, unpaired, globular mass. Its ventricle is imperfectly divided into lateral ventricles. A very prominent olfactory apparatus projects anteriorly. On the dorsal surface there are to be seen two slight swellings which may be taken as the anlages of the cerebral hemispheres of higher forms. The *thalamencephalon* is narrow, open dorsally, and the choroid plexus passes in to form a thin roof. The epiphysis arises just behind this point. It is long and slender, and ends in a dilation which is attached to the membranous roof of the skull. Both the *optic lobes* and the *cerebellum* retain the primitive condition of hollow outgrowths. The cerebellum is relatively quite large, and is thrown into transverse folds. The large size is evidently related to the swimming habits of the animal. The fourth ventricle of the *medulla oblongata* is widely open. Its sides are thickened, and project anteriorly as the restiform bodies.

The microscopic structure of the shark's brain was investigated by a few of the older workers, Viault, Rohon, and Sanders requiring especial mention here, The application of silver impregnation by Golgi to the study of nerve cells has, however, opened a new era in neurology, and has made necessary the reinvestigation of every species of nervous system. While the older methods of research had brought out certain general facts about the structure of the shark's brain, it is only through the application of the Golgi method that we can hope to acquire a thorough knowledge as to its ultimate cellular structure. I will enumerate briefly the most important results which I have already reached.

In the fore-brain the nerve cells are large and very conspicuous. They are not arranged in layers, neither do they have a pyramidal form. The prevailing type presents an oblong cell body from which three or four dendrites radiate indifferently in every direction. The dendrites do not branch very much, but there are so many of them that a very tangled complex is given.

In the mid-brain the ependyma cells are highly developed. Their processes run straight out through the whole of the nervous matter, giving a characteristic appearance to this part of the brain. The nerve cells appear to be somewhat better differentiated than in the fore-brain. Near the outer surface there are cells which send their dendrites in a tangential course. At a deeper level there are somewhat larger cells whose dendrites spread out in all directions. Still another type of cell may be found having long dendrites passing over the greater part of the distance between ependyma and outer surface.

The cerebellum has a structure which appears to foreshadow in its general plan the details of structure of a higher brain. It has a series of well defined layers, and the same layers are present in the same relations to each other as are found in the human cerebellum. There is a wide nuclear zone lying next the ependyma. A molecular layer lies next the outer surface. Between the two there is a crowded row of Purkinje cells. These cells have the familiar dendrites forming an arborization in the outer zone, but the degree of branching of the dendrites is far less marked than in the mammalian cerebellum.

The medulla oblongata exhibits a most beautifully reticulated system of fiber tracts. In this reticulum the microscope reveals neuroglia cells, processes of ependyma cells, and an occasional nerve cell. Whether the nerve cells are present except in connection with the nuclei of the cranial nerves which arise here is a fact which I have not yet determined.

Summarizing the above results, we see that mid-brain, cerebellum, and medulla oblongata foreshadow in organization the human type; but that the fore-brain does not. Coupling this fact with the suggestion to which I have already alluded as to the significance of the dorsal eminences of the fore-brain, and we have grounds for the hypothesis that the cerebral cortex proper is of secondary development.