# MORPHOLOGY AND PATHOMORPHOLOGY

## MORPHOLOGICAL INVESTIGATION OF THE DYNAMIC STRUCTURE OF THE OPTIC CORTEX IN THE CAT

E. L. Shul'ga

UDC 612.825.54-019 : 599.742.7

The complex mechanisms of interaction between various zones of the cortex have been investigated in considerable detail and from many different aspects. A special place in the study of this interaction is occupied by the study of the role of intercortical and cortico-subcortical pathways. Investigators using a combined morphological and physiological approach [3, 7-10, 12], have shown that transcortical pathways play the main role in the mechanism of complex forms of conditioned-reflex activity.

In continuing the study of this problem, the author used the possibility of recording optic evoked potentials far beyond the limits of the projection zone as an index of the dynamics of the cortical processes. These potentials differed from the primary optic responses in the duration of their latent periods [11].

During the investigations the pathways connecting the cortical regions over which the evoked potentials spread with the surrounding cortical zones and the subcortical structures were interrupted surgically. By the use of this method certain general principles were established, indicating that the movement of the optic evoked potentials from the projection zone along the intracortical connections possesses certain characteristics [14].

To obtain a correct interpretation of the absence of any marked effect of the operations of "undercutting" the cortex on the character of spread of the evoked potentials and of the disturbances arising after the operation of "cutting round" it was necessary to determine how completely the corresponding pathways had been interrupted and also to study the state of the nerve cells in the areas subjected to operation. The object of the present investigation was the morphological study of the somatosensory areas of the cortex in cats after isolation of parts of this area from the surrounding cortical zones and from the subcortical structures.

### EXPERIMENTAL METHOD

The operation of surgical isolation of part of the somatosensory area of the cortex from the surrounding cortical zones ("cutting round") was performed on 5 cats and the operation of isolation of an analogous part of the cortex from the subcortical structures ("undercutting") on 3 cats. The operative technique was described previously [14]. All the animals received a full preliminary electrophysiological examination. The chronic experiments on each animal lasted on the average about 6 months. The brain was fixed with 10% neutral formalin solution. A part of the brain containing traces of the wound incisions was excised from the cerebral hemisphere on the side of the operation, in the frontal plane (a corresponding part of the brain from the intact hemisphere served as the control). The pieces of brain tissue were embedded in celloidin; sections (18 $\mu$) were stained with hematoxylin-eosin (general survey), by Van Gieson's method (to determine the reaction of the connective tissue), and by Nissl's method (to study the state of the tigroid substance of the nerve cells). Some of the material was embedded in paraffin wax; sections (10 $\mu$) were stained with gallocyanin by Einarson's method and with methyl green – pyronine by Brachet's method (for nucleic acids).

Frozen sections were cut from another part of the material, and impregnated with silver by Campos's method [16] (to detect nerve cells and nerve fibers), by Aleksandrovskaya's method [1] (to detect microgalia) by Cajal's gold – mercuric chloride method (to detect astrocytes), and by Zolotova's method [6] (to detect medullated fibers).

### EXPERIMENTAL RESULTS

Isolation of the gray matter of part of the somatosensory area of the cortex from the surrounding cortical zones (operation of "cutting round"). After "cutting round" part of the brain to the depth of the cortex, in every case, the gray matter was completely divided and the encircling incision penetrated into the white matter (Fig. 1).

Department of Human and Animal Physiology, Rostov-on-Don University (Presented by Active Member of the Academy of Medical Sciences of the USSR S. A. Sarkisov). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 63, No. 4, pp. 105-109, April, 1967. Original article submitted June 19, 1965.

Fig. 1. Isolated area of the brain after the operation of "cutting round" the somatosensory area of the cortex. The arrows point to the position of the incisions. Zolotova's stain. Stereoscopic microscope (objective 2×, ocular 8×).

Fig. 2. Radial fibers entering the isolated part of the cortex. Zolotova's method. Objective 6.3×, ocular 8×.

The encircled part of the brain was still supplied by an adequate number of capillaries. The lumen of the capillaries was often dilated and distended with blood. The outlines of the vessels sometimes were tortuous, indicating dystonia of their walls. In the thickened meninges over the isolated part of the cortex and in the wound scars the walls of the blood vessels were thickened, and in some parts of the wound scars the development of a large amount of fibrous connective tissue could be seen. The nerve fibers were completely divided in the region of the wound scars which consisted mainly of a cluster of spherical granules and hypertrophied astrocytes. The medullated fibers passed from the white matter (of the "bridge" remaining between the wound incisions), and retained their radial arrangement (Fig. 2).

Horizontal fibers could not be seen inside the encircled area or they were irregular in configuration, consisting of separate fragments and containing droplets of modified myelin.

Disturbance of the normal layers of the cortex and death of the neurons (hyper- and hypochromia of their cytoplasm, tigrolysis, pycnosis, cell "ghosts") were observed only in those parts of the cortex next to the incision. In parts at a distance from the incision, inside the encircled area, above the "bridge" of intact white matter no disturbance of the normal layers of the cortex was observed. In individual cells partial tigrolysis and a decrease in the content of ribonucleic acid in the cytoplasm could be seen in some of the cells, but most neurons retained their normal structure. The integrity of the nerve cells in the encircled cortex was probably attributable to the afferent impulses which they received from below.

Interruption of direct connections between part of the somatosensory cortex and the subcortical structures (the operation of "undercutting"). In every case the incision passed beneath the cortex in the substance of the white matter; in the "undercut" area between $^1/_2$ and $^1/_3$ of the white matter remained (Fig. 3). The incision completely isolated the "undercut" part of the brain from its deeper portions. The scar at the site of the incision often possessed a cavity and was filled with large numbers of spherical granules, transitional forms of microglial cells, and astrocytes. The scar consisted mainly of hypertrophied and hyperplastic astrocytes. Proliferation of the fibrous connective tissue was rather more marked than after the "cutting round" operation. However, it proliferated only around the thickened blood vessels walls. The "undercut" part of the brain was well supplied with blood by capillaries, the connections of which with the pia mater could be clearly seen. Most capillaries contained blood in their lumen. The radial medullated nerve fibers in the deep layers of the cortex were in a state of disintegration: they were irregular in outline, the myelin spheres and breakdown products of myelin were seen along the course of the fiber. In the middle layers of the cortex the

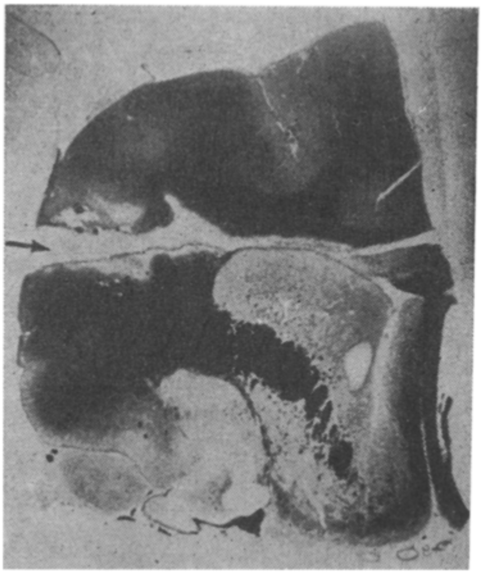

Fig. 3. Isolated part of the brain after the operation of "undercutting" of the somatosensory area of the cortex. The arrow points to the position of the incision. Zolotova's method. Stereoscopic microscope (objective 1×; ocular 8×).

radial fibers were fewer in number than in the control, they were most commonly thin, and evidently belonged to axons of association and commissural cells. Possibly some of the intact radial fibers belonged to arcuate axons of the association cells described previously [13].

In the plexiform layer of the "undercut" cortex, preservation of the normal configuration of the tangential medullated fibers could clearly be seen. This confirms the view [15] that most of the tangential fibers of the plexiform layer of the cortex belong to ascending axons of the Martinotti cells of layers V and VI.

The changes were also more marked in the nerve cells of the "undercut" cortex. Although the main arrangement of the cell layers of the cortex remained unaffected, various changes were observed in the individual cells. Some cells had evidently died, because extensive areas filled entirely with glial cells could be seen between them. The cells of layer II and VI of the cortex were preserved best of all. Among the cells of layers III and V, some of which showed only slight changes, were dark and hyperchromic cells, some of them almost undeformed, others considerably deformed (groups 2 and 3 in F. R. Dunaevskii's terminology [5]). In the large neurons of layer V the cells often had lost their tigroid substance and ribonucleic acid, they were palely stained, and many of the small cells were converted into ghosts. Small and large vacuoles were seen in the cytoplasm of the cells. Many basophilic chromatin granules were present in some nuclei, and ectopia of the nuclei was observed.

By comparing the morphological and functional indices it was possible to compare the role of the transcortical and cortico-subcortical connection in the spread of nervous processes such as evoked potentials. The results of the electrophysiological investigations showed that the "undercutting" operation did not affect the character of the evoked optic responses with a short latent period, recorded in this region, whereas after the operation of "cutting round" the somatosensory cortex, these potentials were seen to have disappeared in the isolated territory, despite the normal state of the cells of all the layers in this part of the brain, its good blood supply, and the integrity of the ascending radial fibers. These facts demonstrate the great functional importance of the horizontal and oblique connections of the cortex belonging to association and commissural neurons. However, before more accurate conclusions can be drawn, a special histochemical investigation of the nerve cells of this part of the cortex is necessary.

Hence, comparison of the results of morphological analysis with the electrophysiological findings suggests that the evoked optic potentials recorded outside the projection zone reflect nervous processes spreading mainly along intracortical pathways. These pathways evidently take part in the functional interconnection between different parts of the cortex in connection with its analytical and integrative activity.

## LITERATURE CITED


1. M. M. Aleksandrovskaya, Neuralgia in Various Psychoses [in Russian], Moscow (1950), p. 23.
2. M. M. Aleksandrovskaya, Doklady Akad. Nauk SSSR, 143, No. 6, 1442 (1962).
3. G. M. Glumov, Fiziol. Zh. SSSR, No. 12, 1437 (1962).
4. G. M. Glumov, The Role of Intracortical and Cortico-Subcortical Connections in the Mechanism of the Conditioned Reflex, Author's Abstract of Candidate Dissertation, Rostov-on-Don (1964).
5. F. R. Dunaevskii, in the book: Data on Evolutional Physiology [in Russian], 2, Moscow-Leningrad (1957), p. 137.
6. M. A. Zolotova, Lab. Practica, No. 3, 3 (1941).
7. A. B. Kogan, Abstracts of Proceedings of the Fourteenth Conference on Problems of Higher Nervous Activity to Commemorate the Fifteenth Anniversary of I. P. Pavlov's Death [in Russian], Moscow-Leningrad (1951), p. 20.
8. A. B. Kogan, Fiziol. Zh. SSSR, No. 9, 810 (1958).

9. A. B. Kogan, in the book: The Electroencephalographic Investigation of Higher Nervous Activity [in Russian], Moscow (1962), p. 42.
10. N. I. Nikolaeva, Changes in the Nervous Structures of the Brain during Conditioned Reflex Formation, Author's Abstract of Doctorate Dissertation, Moscow (1953).
11. N. N. Tkachenko, in the book: Electrophysiology of the Nervous System [in Russian], Rostov-on-Don (1963), p. 382.
12. M. M. Khananashvili, in the book: Structure and Function of the Nervous System [in Russian], Moscow (1962), p. 185.
13. E. G. Shkol'nik-Yarros, Zh. Vyssh. Nervn. Deyat., No. 1, 123 (1958).
14. E. L. Shul'ga, Fiziol. Zh. SSSR, No. 10, 1182 (1965).
15. J. Szentagothai, in the book: Structure and Function of the Nervous System [in Russian], Moscow (1962), p. 6.
16. R. Campos, Acta Anat. (Basel), 2, 75 (1946).