Degenerative and Compensatory changes in the basal amygdaloid neurons under cortical disorders

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Abstract

Experiments were conducted on 20 male rabbits. Gigantopyramidal and praeccntral regions of the neocortex were bilaterally ablated. After five weeks the neurons of the basal amygdaloid nucleus were classified into four types: large neurons of the dorsal portion; small neurons of the dorsal portion and within this group another type of neurons which were most affected by the ablations, and finally small neurons of the ventral portion. Golgi method of staining was used in this study. After the ablations following quantitative indices had undergone changes; number of primary dendrites, maximum radius of the dendritic field, length of the longest dendrite, length of all the dendrites of the neuron, number of spines in 100 urn of the dendritic length, branching of the dendrites, relative length of the dendrite and general ramification of the cell. Varying degree of the degenerative as well as compensatory changes were noted in all types of neurons. This study gave an idea about the degenerative as well as compansatory changes occurring in the neurons of amygdaloid complex and in other subc.ortical structures under the cortical disorders. (JPMA 32:56, 1982).

Introduction

Amygdaloid complex occupies a special position in the limbic system of the brain. On one hand it receives impulses from all the sensory systems e.g., from all modalities, and on the other hand its efferent output is projected to the hypothalamus and the central gray matter (the structures playing an important role in the genesis of emotional and motivational behavior). The amygdalar role in various functions of the organism has been reviewed in detail by Goddard (1964) and Fonberg (1974). Amygdaloid participation in the vegetative functions has been pointed out in several studies (Gallagher et al., 1979; Kapp et al., 1979; Stock et al., 1979). Its involvement in the memory processes has been studied by many authors (Chepurnov et al., 1977; Gallagher and Kapp, 1978; Halgrcn et al., 1978). The influence of amygdala on the regulation of complex forms of behavior, its vegetative and neuroendocrine control can be understood on the basis of afferent influences from the hypothalamus, subcortical and cortical structures. Direct anatomical connections of amygdala with hypothalamus (its ernotiogenic and neuroendocrine centrers) are well known (Ban and Omukai, 1959; Lammers, 1972; Kinoshita et al., 1979). In the amygdalar regulatory mechanisms a significant role is played by its interrelations and bilateral connections with neocortex (Egrova, 1974). Practically no information is available about the changes which occur in amygdala after its deafferentation from ncocortcx. Recently Shaikh and Basharat (1980), have studied the dcgeneratve changes in the cortical amygdaloid nucleus in rabbits after neocortical ablations. No data in available on the effects of chronic neocortical deafferentation on the phylogenetically younger part of amygdala the basolateral amygdala.
The aim of the present study was to investigate the pathological degenerative and compan satory changes which develop in a number of subcortical structures, especially in amygdala, (luring various cortical disorders. Our previous cytoarchitectonical studies on the basal amygdala and electrophysiological data on short-latency responses recorded from the basal nucleus after neocortical stimulations (Shaikh and Shaikh, 1977; 1980) served as the basis for this study.

Material and Methods

Experiments were conducted on 20 adult male rabbits (Weighing 2 to 2.5 kgs). Rostral parts of the neocortex were bilaterally ablated in all the animals.

Operation for ablations of neocortical areas:

The neocortical areas were ablated under nembutal narcosis (40 mg/kg of the body weight). The animals were kept for 5 weeks after the operation.

After 5 weeks anterior parts of both the, hemispheres (with ablated parts of the neocortex) were fixed after sacrificing the animals under nembutal narcosis. These portions of the hemispheres were stained with Golgi method. Serial sections were cut (100 um thick) and from the prepared slides drawings were made under photographic enlarger for the location of ablated areas. The ablated rostral regions of the neocortex were determined with the help of atlas of rabbit brain (Blinkov and Brazovskaya, 1973). It was noted that in all the rabbits ablations were fairly symmetrical and uniform. Area gigantopyramidalis and regio praecentralis had undergone ablations (Fig. 1).

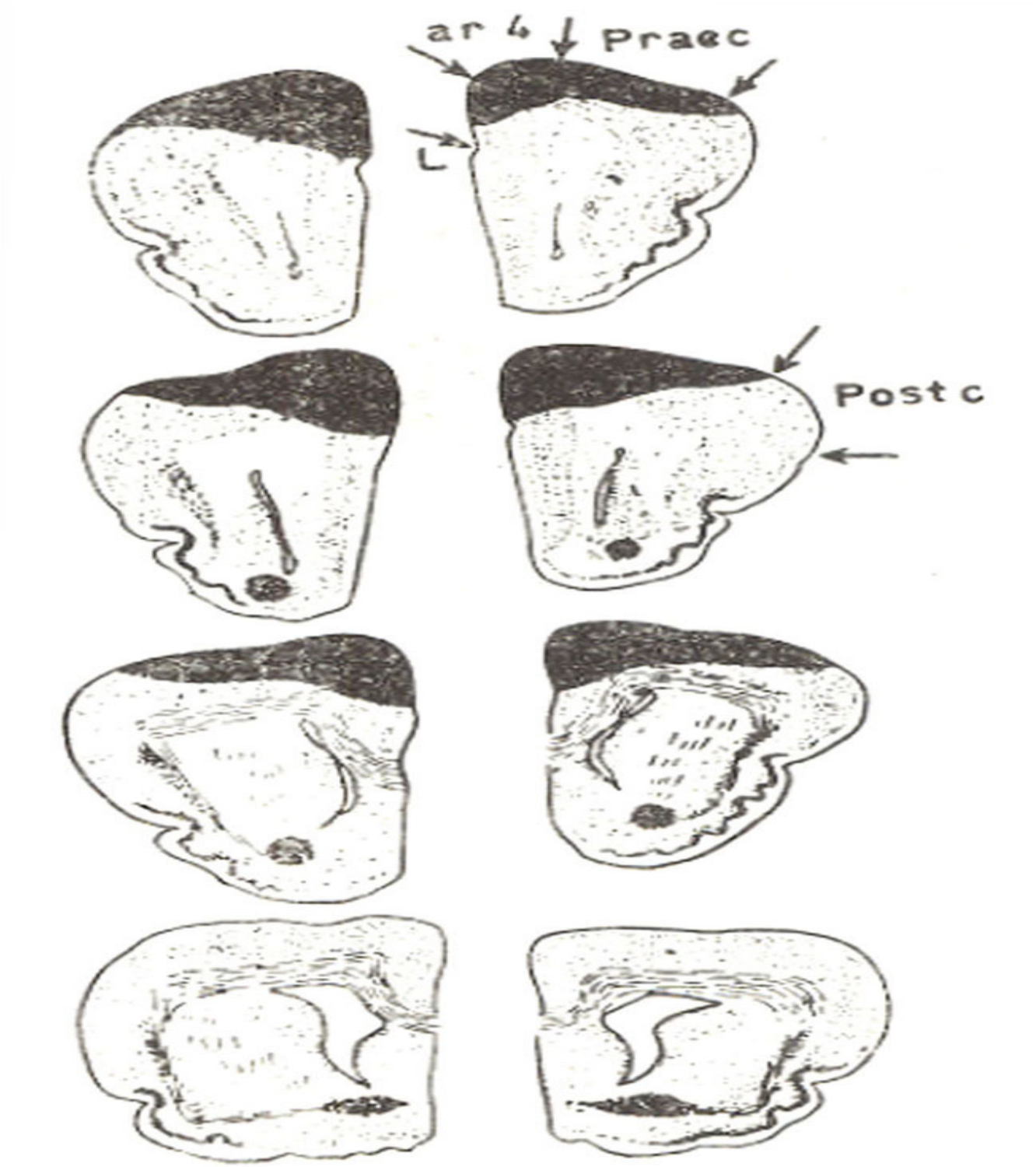


Fig. 1: Drawings of serial sections of rabbit brain. Dark areas indicate that the neocortical ablations involved area gigantopyramidalis and regio praecentralis.

Details of these methods are described elsewhere (Shaikh and Basharat, 1980).

Neurohistological Methods

Temporal lobes with amygdalae were also fixed and stained by the Golgi method along with the ablated regions of all the animals. Sections were serially cut (100-120 tim thick) along the frontal plane of the

brain. Camera lucida drawings were made under light microscope (x 400) from the prepared slides. Details are described elsewhere (Shaikh and Shaikh, 1980).

Methods of quantitative analysis of neurons:

Following parameters were measured from the camera lucida drawings of the neurons. Only those neurons were considered whose dendrites were not severely sectioned. 1. Length and width of the cell body. 2. Number of the primary dendrites (d). 3. Maximum radius of the dendritic field (Rcomp). 4. Length of the longest dendrite (R). 5. Number of the free ends of the dendrites (Bd). 6. Length of all the dendrites of the neuron (L). 7. Number of spines in 100 u of the dendrite length (T) .8. Branching of the dendrite (Ad). 9. Relative length of the dendrite (Ed). 10. General ramification of the cell (Ac).

The calculations of the derivative quantitative parameters are described elsewhere (Shaikh and Shaikh, 1980). The neurons are classified into large and small neurons in the dorsal part of the basal nucleus and into small neurons in the ventral portion of the basal nucleus. This classification is in conformity with our previous

Abbreviations: ar 4-area gigantopyrampidalis; Praecregio praecentralis; Postcregio postecntralis; L-regio limbica superior.study in which the neuronal coposition of the basal amygdaloid nucleus of rabbit brain was described (Shaikh and Shaikh, 1980). The results obtained were compared with the normal neuronal composition described by Shaikh and Shaikh (1980).

Observations and Results

These observations are based on the study of 142 neurons of the basal amygdaloid nucleus.

Neurons of the dorsal portion of basal amygdala:

Neurons were grouped into large and small neurons depending upon their body size.

Large Neurons:

Fifty two large neurons were studied. These neurons have a large body size (15 x 42.5 um). These are polygonal, oval or rectangular in shape. In all directions from the soma, several thick dendrite trunks arise breaking up into thin branches near the cell body (Fig. 2).

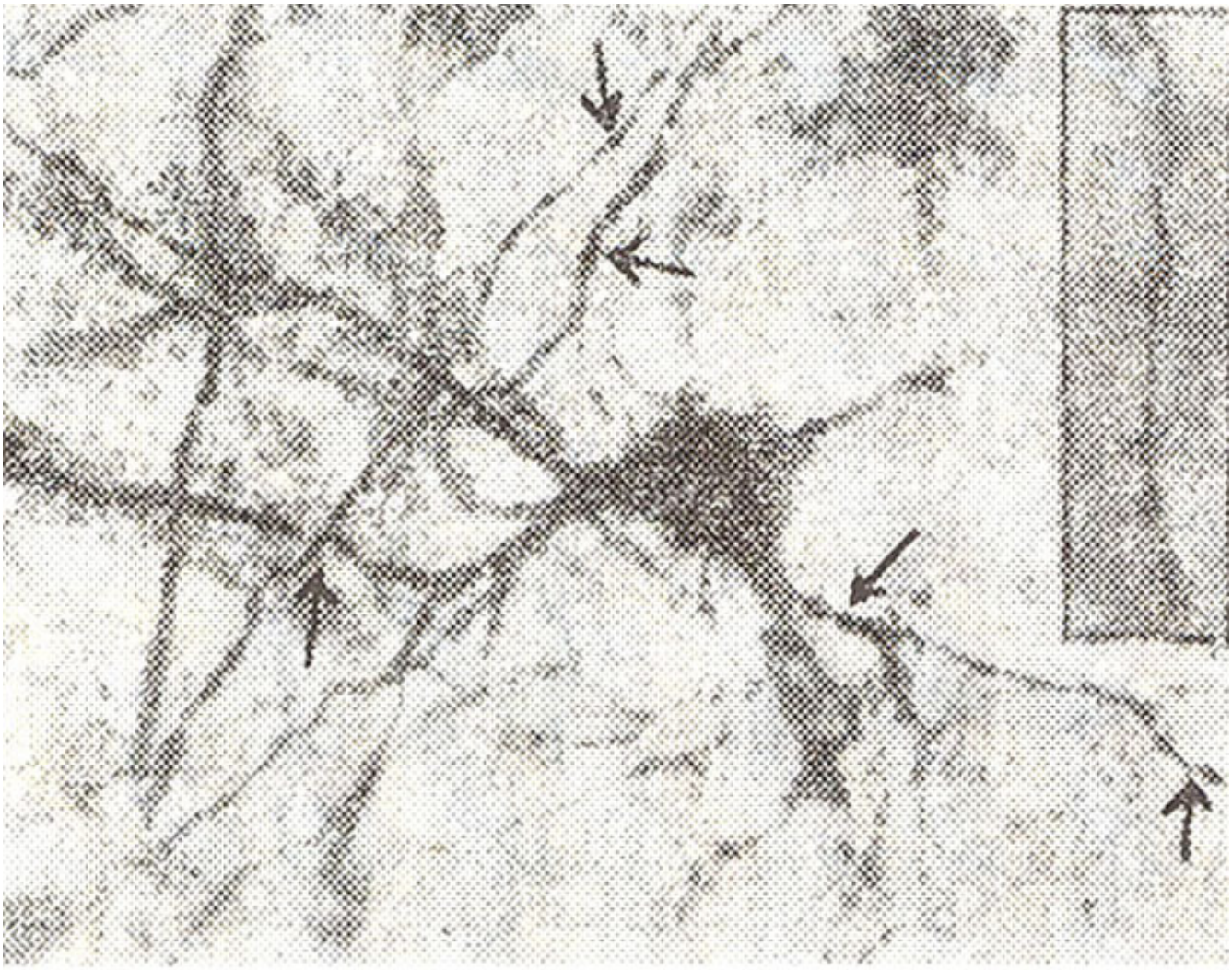


Fig. 2

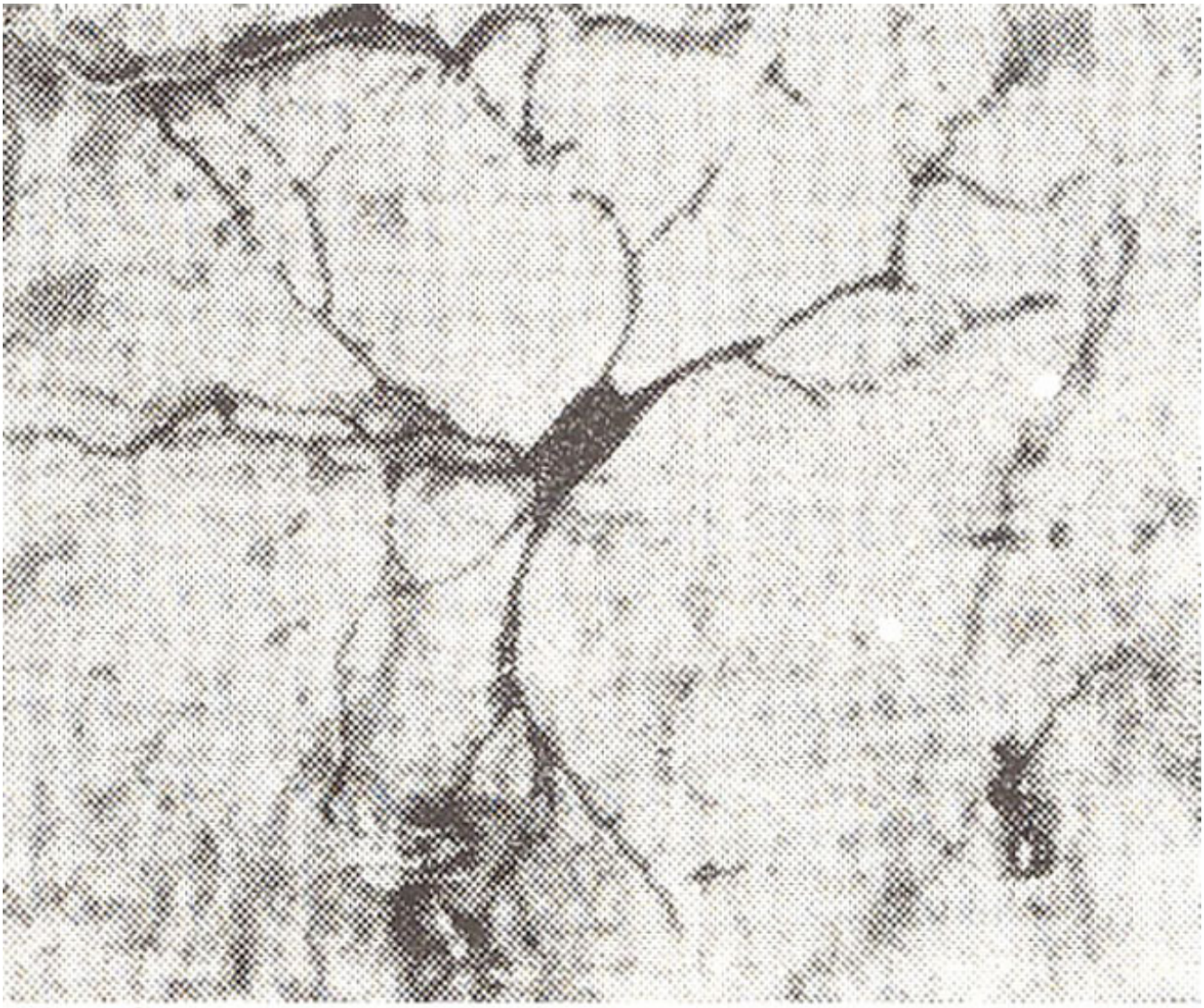


Fig. 3

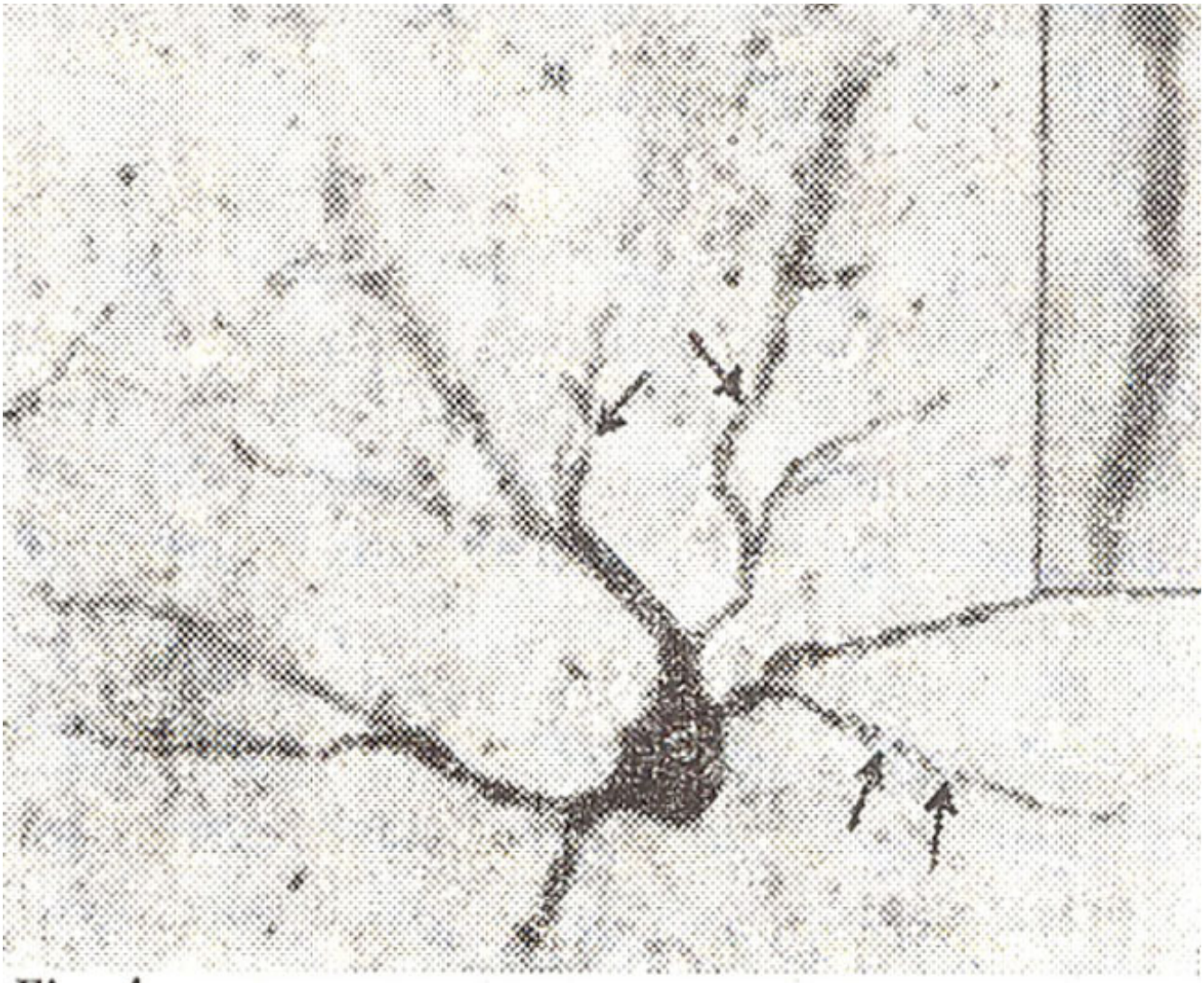


Fig. 4

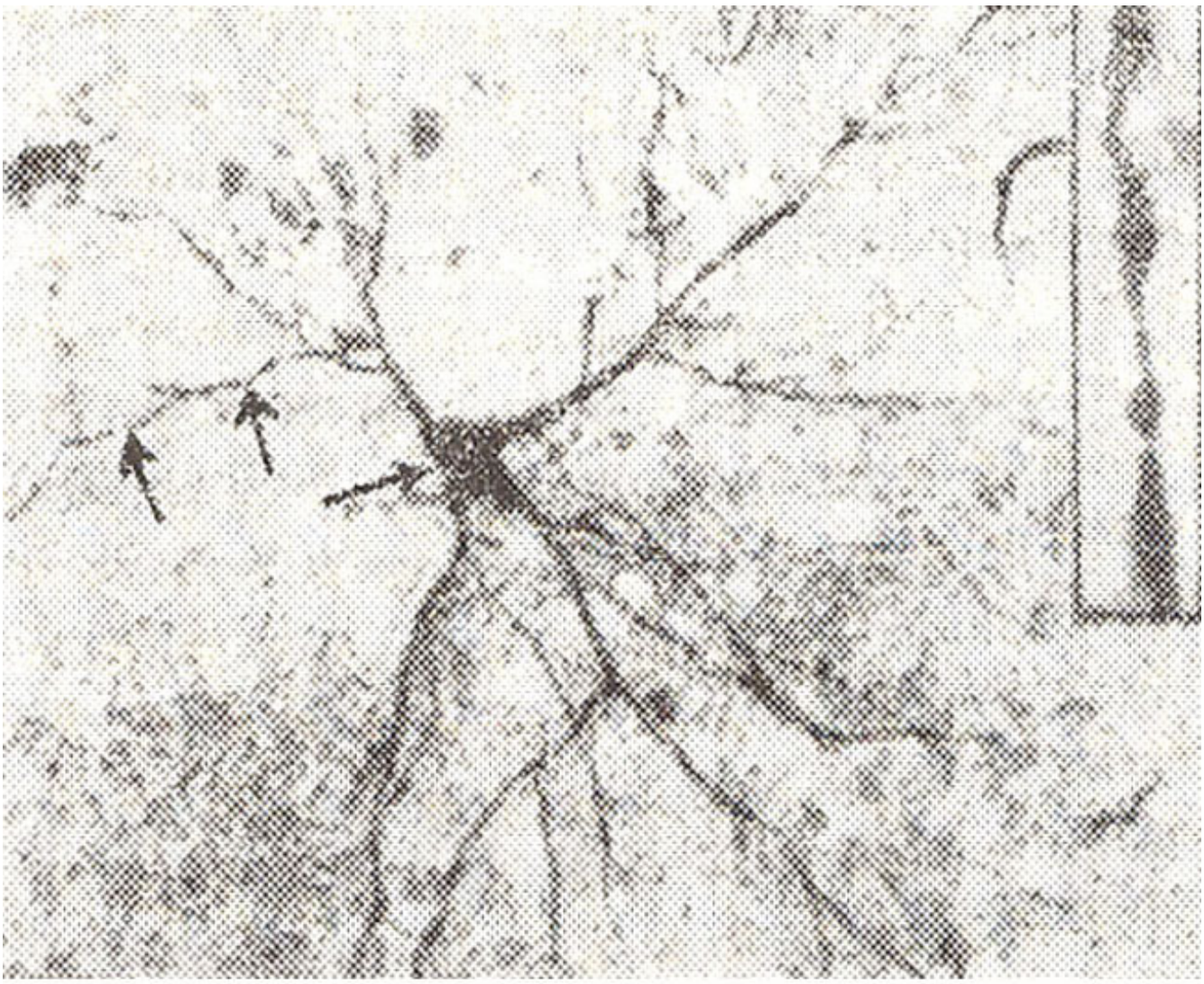
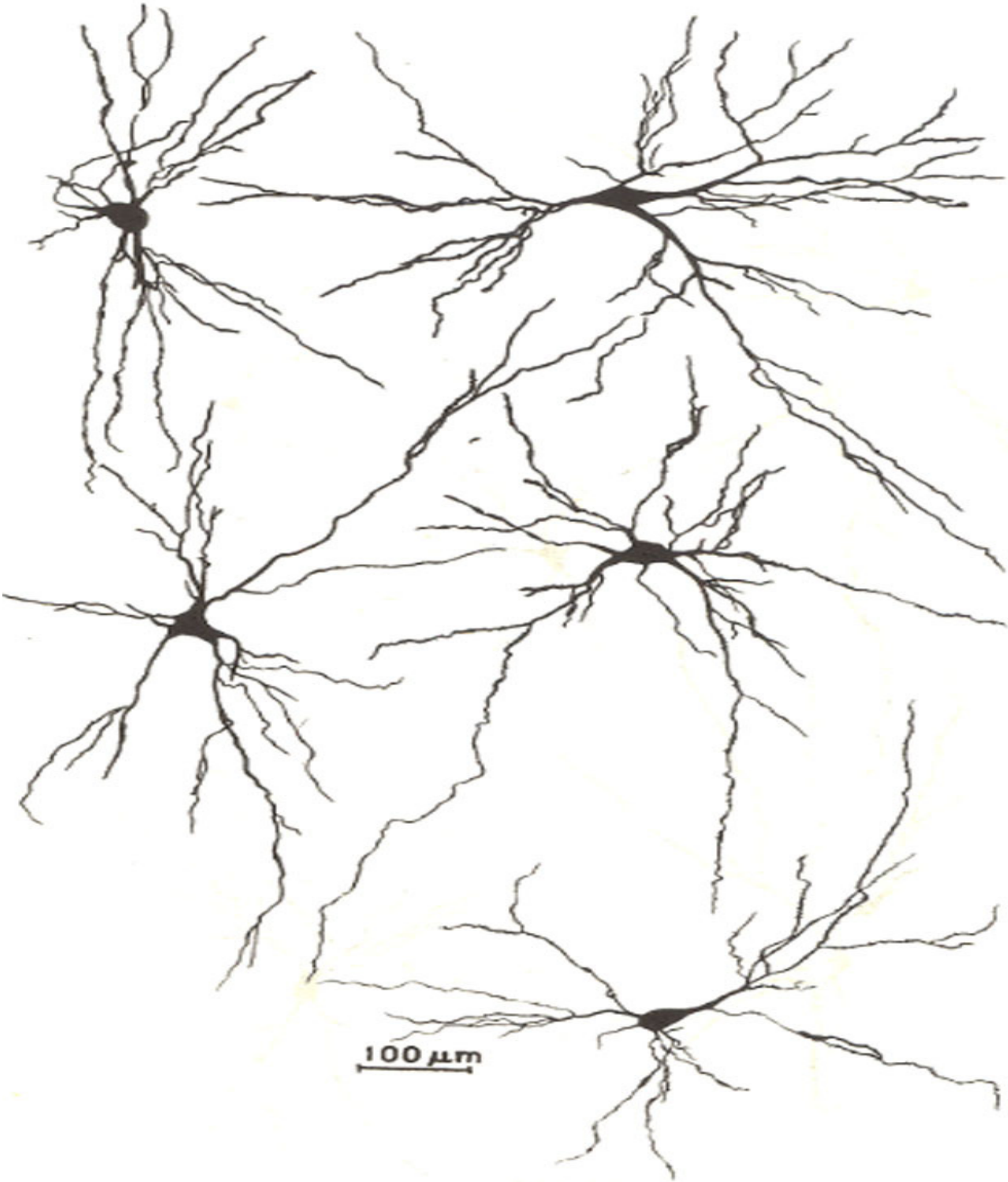


Fig. 5

Fig. 2-5: Photomicrographs of neurons of basal amygda-. loid nucleus after neocortical ablations; 2, large neuron of the dorsal portion; 3, small neuron of the dorsal portion; 4, small neuron of the dorsal portion; 5, small neuron of the ventral portion. Arrows indicate varicose swelling and fragmentation of the degenerated dendrites. Golgi; x 400. Insets: portions of the degenerated dendrites and loss of spines, x 1500.

occupied by the branching dendrites is 463 um. The length of the dendrites is 500 um. Branching of a dendrite is 4 to 7 and the general ramification of the entire cell is 26. Number of spines in 100 wn length of the dendrite is 34. Some portions of the dendrite branches have varicose swellings in the form of beads throughout their length (Fig. 6).



Figs. 6–9: Camera lucida drawings of neurons of basal amygdaloid neurons; 6, large neurons of the dorsal portion; 7, small neurons of the dorsal portion; 8, small neurons of the dorsal portion; 9, small neurons of the ventral portion.

Almost half of the studied cells showed these signs of degeneration; the neurons which had not undergone varicose changes had a few spines or were without spines.

Forty nine small neurons were studied these neurons have a small bod.y size (7.5 x 25 urn) and thin dendirtes ramifying near the cell body. The dendrites are covered over by numerous spnes, 98 in 100 un

of the dendrite length (Fig. 3, 7).

Fig. 7

Maximum radius of the dendritic field is 387.5 um. The length of the dendrites on average is 400 um. Branching of the dendites is 4.5 and general ramification of the ccli is 16.98. These indices show that majority of these neurons seem to be normal without noticeable signs of degeneration. Only some

individual neurons had degenerative signs.
Within this group of small neurons a “peculiar” type of cells was noticed. Their body size is 12.5 x 35 t.tm. This type of neurons was not observed in the classification of the normal neurons of the dorsal part of the basaltamygdaloid nucleus described by Shaikh and Shaikh (1980). These neurons are oval or oblong in shape. Dendrites in these neurons have numerous spines or are without spines (Fig. 4, 8). Total length of the dendrites is 350 um. The number of dendrites leaving the soma is 5. Average ramification of the dendrite is 4.2 and that of the entire cell is 19. Relative length of the dendrites is 15.7 um. A marked decrease in the number of spines was noticed as compared to the I dendrites of ‘less changea’ small neurons.
In this “peculiar” type of neurons further two types of neurons could be distinguished; severely changed cells and less changed cells (Fig. 8).

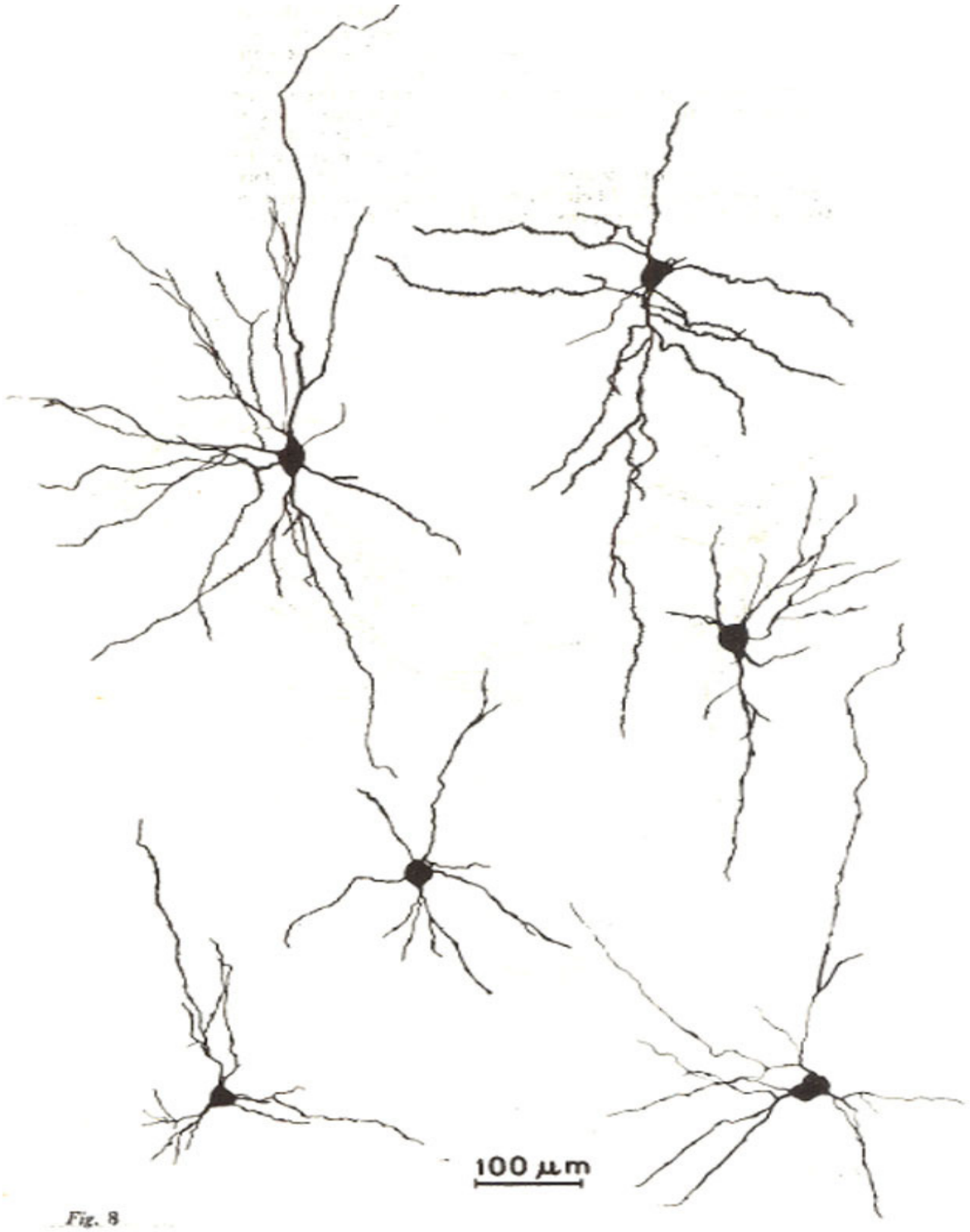


Fig. 8

As far as the reason for the presence of this "peculiar" type of neurons is concerned it may be due to the swelling of the cell body. Such changes can be expected in the cells having signs of degeneration on their dendrites.

Neurons of the ventral portion of basal amygdala

In the ventral part of the basal nucleus neurons were grouped into small neurons.

Small Neurons

Forty one small neurons were studied. They are mainly oval in shape. Part of the neurons showed signs of degeneration. Swelling of some portions of the dendrites was observed with less frequent spines. Some of the dendrites had varicose swellings in the form of dendrites and were without spines. Radius of the dendritic field is 365 ELm. Maximum length of the dendrites is 377.5 um and the average length of a dendrite is 18.3 um. The number of dendrites arising from the soma is 5. Ramification of the dendrite is 5.2 and of the entire cell is 18.75 .In these neurons a great variability was noticed in the number of their spines. Denirites of some neurons retained their spines and some of them lost the spines (Fig. 5, 9).

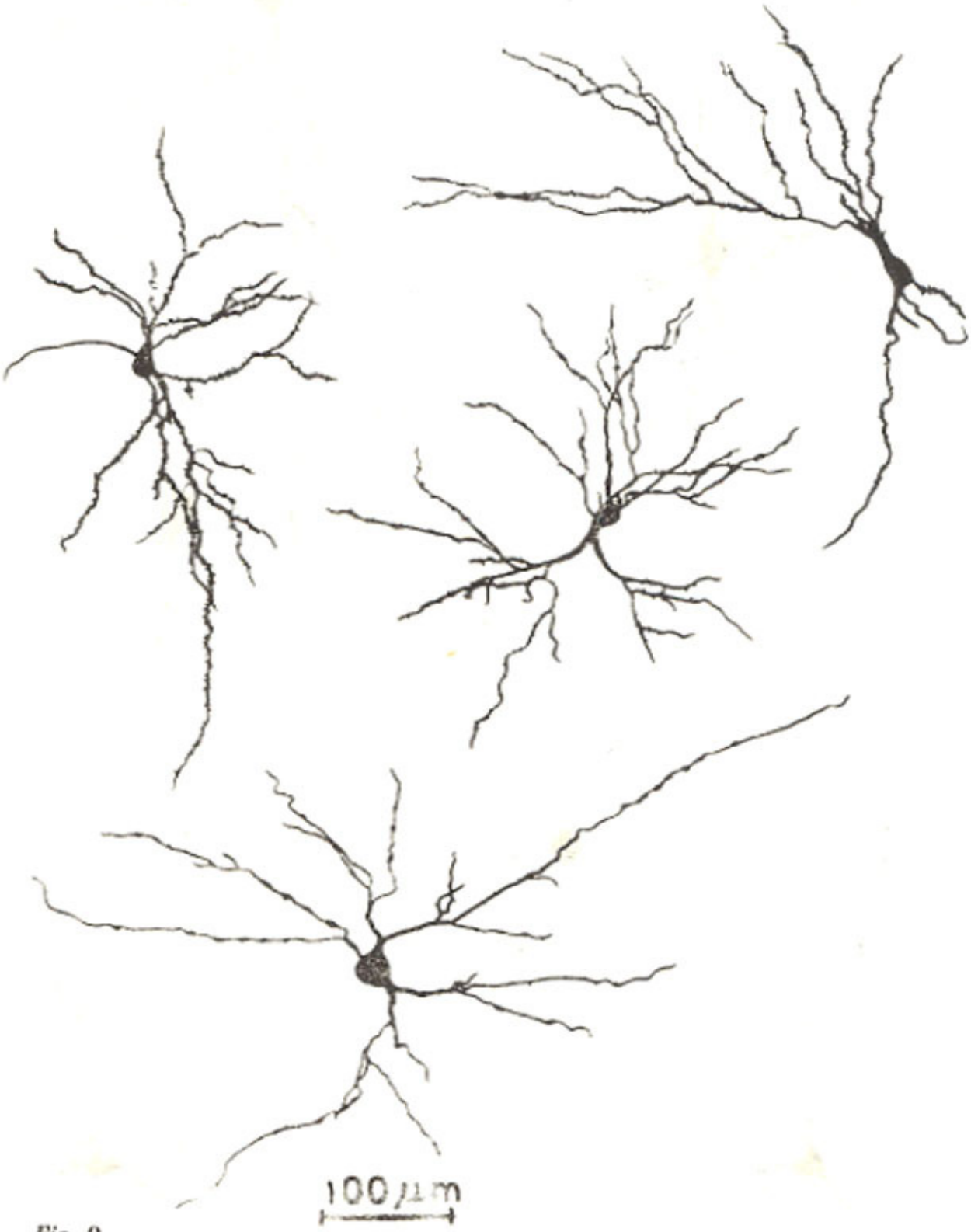


Fig. 9

Discussion

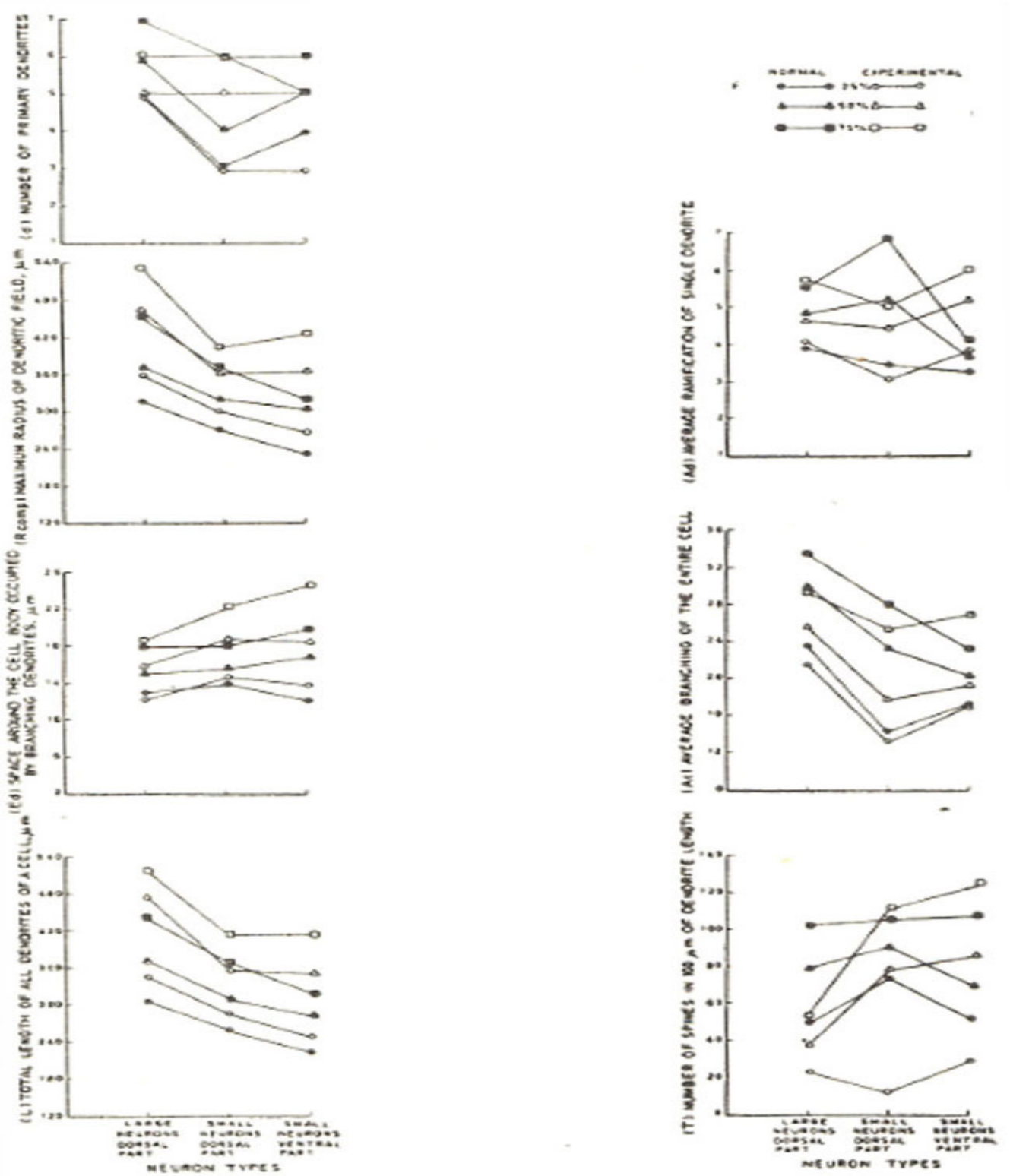


Fig. 10: Comparison of quantitative indices of experimental neurons with the normal neurons.

As shown in figure 10, different types of neurons have reacted differently to the neocortical ablations. It was interesting to note that the severely affected cells were the small neurons although some changes were noted in the large neurons too. The small neurons showed marked structural changes such as decrease in the number of spines on their dendrites, fragmentation and varicose swelling of the

dendrites. The profound changes in these neurons indicate their close interrelation with the neocortical structures. These results are also in agreement with the general idea that these neurons play a thief role in the mtranuclear activity of the basolateral part of amygdala. Probably the afferent signals coming to this nucleus are analysed in the small neurons. In this connection it should be pointed out that in small neurons the length of the dendrites is certainly changed after neocortical deafferentation (Fig. 10).
The large neurons which accomplish the basic effector-integrative functions (Leontovich, 1975) had undergone changes only in the number of dendritic spines and the dendritic length (Fig. 10).
In all the animals ablations were symmetrical in the rostrocaudal direction as far as the area involved and the depth was concerned. The ablations did not touch the white matter and did not exceed the medial surface of the hemisphere (Fig. 1). However, it is not excluded that the marginal areas of precentral gyrus had undergone degenerative changes. On this basis the medical part of the praecentral region was also included in the ablated areas.
The anterior portion of the limbic area lies more caudally to the anterior ablated areas. In rabbits anterior limbic region sends its eflérent connections to the precentral granular and agranular fields, postcentral, parietal and temporal regions. So these transcortically passing connections were undoubtedly aamaged after carrying out these ablations in all the animals. Thus the changes noted in the amygdala neurons can be considered to be due to the destruction of neocortical connections with amygdala and other subcortical structures (including direct amygdalopetal pathways).
Valverde (1967; 1968) studied structural changes in the cortex of mouse after deprivation of light and enucleation. In another study conducted by Benhamida (1970), a significant decrease in the number of spines on apical and basal dendrites was noted in all the cortical layers following cortical isolation. Loss of spines in the cortical neurons was also reported after visual deprivation (Globus and Scheibel, 1967). Lynch and co-workers (1975) studied the effects of partial deaflérentation on dentate gyrus. They have shown that sectioning of entorhinal cortical connections leads to a number of degenerative changes-morphological and biochemical.
Recent studies on the structural changes after deprivation or deafferentation have shown dendritic changes and phenomenon of reinnervation. In these studies phenomenon of ‘sprouting’ has also been indicated (Lynch et al., 1975; Tsukahara et al., 1975 and Woodward, 1975). Shaikh and Basharat (1980) have studied the changes in the neuronal structure of cortical amygdala in rabbit following rzeocortical ablations. In this study compansatory as well as degenerative changes have been reported in the dendritic tree of the neurons. These compansatory changes characterize the neuronal plasticity of the adult brain determining the maintenance and conservation of the deudritic spines or their renewal after chronic deafferentation.
Our results may serve to supplimeut our knowledge of the pathological degenerative and compansatory processes which occur in a number of subeortical structures during various cortical disorders.

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