Differential telencephalic projections of the medial and ventral divisions of the medial geniculate body of the rat

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The medial geniculate body of mammals is not a homogeneous structure, and has thus been subdivided into a varying number of component nuclei. On the basis of cytoarchitectonics and Golgi analysis, Cajal subdivided the medial geniculate body of a number of mammals into ventral, medial, and dorsal divisions and, more recently, Morest has confirmed and extended these observations. Morest reports that the cells which make up the ventral division of the medial geniculate body (MGv) are characterized by tufted dendrites, while those that compose the medial division (MGm) are characterized by radiate dendrites. It has been suggested that cells with tufted dendrites are characteristic of thalamic relay nuclei related to a specific sensory system with a relatively homogeneous type of input, while cells with radiate dendrites are characteristic of multiple input systems, such as the brain stem reticular system. This difference in cell type raises the question of whether or not each cell group projects to the telencephalon in a distinct fashion.

On the basis of Golgi material, Lorente de Nó described two types of thalamocortical projections to neocortex. First, a ‘specific’ afferent which was thought to originate in a primary thalamic relay nucleus and ascend unbranched through layers VI and V and then end in a dense plexus chiefly in layer IV and second, an ‘unspecific’ afferent which was a fine caliber fiber of unknown origin that branched repeatedly in all cortical layers up to and including layer I. Using anterograde degeneration techniques, Killackey and Ebner have recently described two types of thalamocortical projections from different thalamic regions to the same portion of somatic sensory cortex in the opossum and the hedgehog, and other investigators have published preliminary reports suggesting differing projections from various subdivisions of the medial geniculate of the hedgehog and the tree shrew.

For the present study, discrete unilateral and bilateral lesions were stereotaxically placed in the ventral or medial subdivisions of the medial geniculate in 20 female Sprague–Dawley albino rats. Two large unilateral lesions of the medial geniculate body were employed to ascertain that the medial geniculate body projections were restricted to the telencephalon of the same side. All lesions were made with a posterior horizontal approach in order to avoid cortical damage. After a 7-day survival, the
animals were perfused, their brains fixed in 10% formalin and then stored in 30% sucrose-formalin until ready for sectioning. The brains were cut coronally into 40 μm sections on a freezing microtome and every fifth and sixth section stained with the Fink–Heimer procedure (see ref. 1) for degenerating axoplasm and cresyl violet, respectively.

If a large lesion is made which encroaches on both the medial and ventral subdivisions of the medial geniculate body the following distribution of degeneration is

Fig. 1. Photomicrographs of coronal sections of the caudoputamen at the level of the internal capsule. A: following a lesion of the ventral division of the medial geniculate body (MGv), degenerating fibers can be traced through the caudoputamen but there is no evidence of terminal degeneration. B: the same region of the caudoputamen following a lesion of the medial division of the medial geniculate body (MGm). Following such a lesion, dense fiber and terminal degeneration is evident.
observed. Degenerating fibers course rostrally through the nucleus and run along the lateral edge of the ventral posterior nucleus before entering the internal capsule. At the level of the internal capsule, a region of dense terminal degeneration similar to that illustrated in Fig. 1B is found in a restricted portion of the caudoputamen. However, the majority of degenerating elements continue up and into the neocortex where dense fiber degeneration is evident in the deeper layers. Dense terminal degeneration is found in layers IV and III, and moderate to light fiber and terminal degeneration can be traced out to layer I. This pattern of degeneration is illustrated in Fig. 2B.

The question now arises whether this is a unitary pattern of degeneration or whether it can be further subdivided. The results of discrete lesions suggest that the latter is the case. Figs. 1A and 2C illustrate the results of a lesion, restricted to MGv. Following such a lesion, large caliber fibers can be traced up and through the internal capsule. However, there is no evidence of terminal degeneration in the caudoputamen (Fig. 1A). The large caliber fibers enter neocortex and terminate densely in restricted portions of layers IV and III (Fig. 2C). There is no evidence of fiber or terminal degeneration in layers II and I. In contrast a lesion of MGm results in a projection of small caliber fibers which terminate densely in the caudoputamen (Fig. 1B) and in addition continue to neocortex where they distribute in a more widespread fashion in all cortical layers (Fig. 2A).

The above data make several points which deserve particular emphasis. First, the degeneration in the caudoputamen is equally dense following a large lesion of MGv and MGm or a smaller lesion restricted to MGm, suggesting that MGm alone projects to this basal telencephalic nucleus. Second, the degeneration in layers IV and III following a lesion of MGv or the degeneration in all layers following a lesion of MGm is less dense than that observed after a large lesion which destroys many fibers as well as cell bodies from both subdivisions. This indicates that there is some overlap in the topographical projection of each nucleus. However, the areal extent and overlap of MGm projections are much greater than MGv, suggesting a less highly organized topographical projection from MGm than from MGv. Third, both MGv and MGm project to the same cortical area and the projections overlap within this cortical area. However, the pattern of laminar separation of the terminal degeneration suggests that each input may influence different cortical cells, or at least different portions of the same cells. This is a question which can only be resolved by the electron microscope.

A final point is the bearing of our data on the concept of 'essential' and 'sustaining' thalamocortical projections proposed by Rose and Woolsey on the basis of retrograde cell changes following cortical lesions. The present results suggest that a restricted lesion of auditory cortex would result in severe retrograde cell changes in MGv and this would be interpreted as an 'essential' projection. However, from the same cortical lesion one would expect only slight retrograde changes in MGm, because of its wider cortical distribution and its major projection to the basal telencephalon which would serve to 'sustain' these thalamic cells. Killackey and Ebner have made a similar point with regard to the somatic sensory system of the opossum and hedgehog.

In conclusion, this study demonstrates two discrete types of thalamic projections.
to rat auditory cortex, each of which arises from thalamic cells with distinctly different dendritic arborizations. Similar interpretations have been advanced for the auditory and somatic sensory thalamus of other species. The identification of separate, specific and unspecific projections from the dorsal thalamus to the neocortex suggests that dual processing systems may be a fundamental principle of thalamocortical sensory organization.

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Fig. 2. Photomicrographic montages of auditory neocortex. A: following a restricted lesion of MGm, sparse small-caliber degenerating fibers can be seen to enter layer VI and run vertically through other cortical layers to layer I. B: following a combined lesion of MGm–MGv dense fiber degeneration is found in the deeper layers and dense terminal degeneration is evident in layers IV and III. In addition, fine degenerating elements are found in layers II and I. C: following a lesion restricted to MGv fiber degeneration is found in the deeper layers and a restricted terminal field is found in layers IV and III. There is no evidence of degeneration in layers II and I. Scale bar = 50 mm.