The University of Connecticut
Schools of Medicine and Dental Medicine
MEDS 370, Introductory Neuroscience
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Lecture

Anatomy of the Visual System

GOALS

Understand the **optics of the eye**. Know the cellular connections between the **retina** (especially the ganglion cell), the **lateral geniculate body, and the visual cortex**. Become familiar with the concepts of **retinotopic organization, visual fields, lamination** in the lateral geniculate and cortex. Relate the **basic cell types in the neocortex** to the functional columns for orientation and ocular dominance. Identify the cortical pegs as sites of color processing neurons in the cortex. Finally, use the **lesions** of the visual pathway to help you remember the functional organization.

INTRODUCTION

The retina projects to the lateral geniculate body and the hypothalamus in the diencephalon and to the superior colliculus in the midbrain. Of these, the pathways via the lateral geniculate body to the cortex are most involved in the perception of visual stimuli. Thus, the basic circuit for this system is the **retino-geniculo-striate pathway**. The superior colliculus will be discussed in lectures on eye movements (CNS, module II), and the hypothalamus will be discussed in CNS module III.

VISUAL FIELDS (Fig. 1)

Each eye sees a monocular visual field. This is like the field of view for a camera with an optical lens. The visual fields of both eyes combine to form a binocular visual field. Visual fields are divided into four quadrants: nasal, temporal, superior, and inferior. Each visual field consists of an area of central vision and more peripheral areas. Like the camera, the optical components of the eye (the cornea and lens) invert and reverse the image that enters the eye. Thus, on the retina, the image is upside down and backwards. The image on the retina is the retinal field. Anatomically, the area of central vision in the retina is the macula lutea, and it has the densest concentration of receptors. In the center of the macula is the fovea, an area seen as a depression in the retinal layers.

ORGANIZATION AND PROJECTIONS OF RETINAL GANGLION CELLS

Ganglion cells in the retina project to the brain. All axons from the ganglion cells of one eye form the **optic nerve**. At the **optic chiasm**, axons from the nasal retina (temporal visual field) cross to the opposite side. Axons from the temporal retina (nasal visual field) are uncrossed. The redistribution of the axons at the chiasm produces an important reorganization of visual information. After the chiasm, information from the left half of the visual field of both eyes is transmitted to the right side of the brain and vise versa. After the chiasm, the axons continue as the **optic tract** until they reach the thalamus. There, many synapse in the lateral geniculate body. The remainder of the axons continue into the midbrain as the **brachium of the superior colliculus** until they synapse in the **tectum** (superior colliculus) or **pretectum**.

ORGANIZATION AND PROJECTIONS OF THE LATERAL GENICULATE BODY.

Although the lateral geniculate receives axons from both eyes, these axons do not overlap. Axons from the two eyes terminate in separate layers of the LGB. In primates, the lateral geniculate contains 6 layers that contain separate populations of neurons. Neurons in one layer tend not to extendtheirdendrites into adjacent layers. Each layer contains a complete re-representation of the 1/2 of the retinal field. However, the retinotopic maps in each layer are superimposed, so that the same point in the retinal field is lined up in each layer at the same point. Thus, a point in the visual field is represented as a **line of projection** perpendicular to the geniculate layers. Since each layer receives input from one eye only, cells in the LGB are monocular. There is also an anatomical segregation of other functional properties. Separate ganglion cells in the

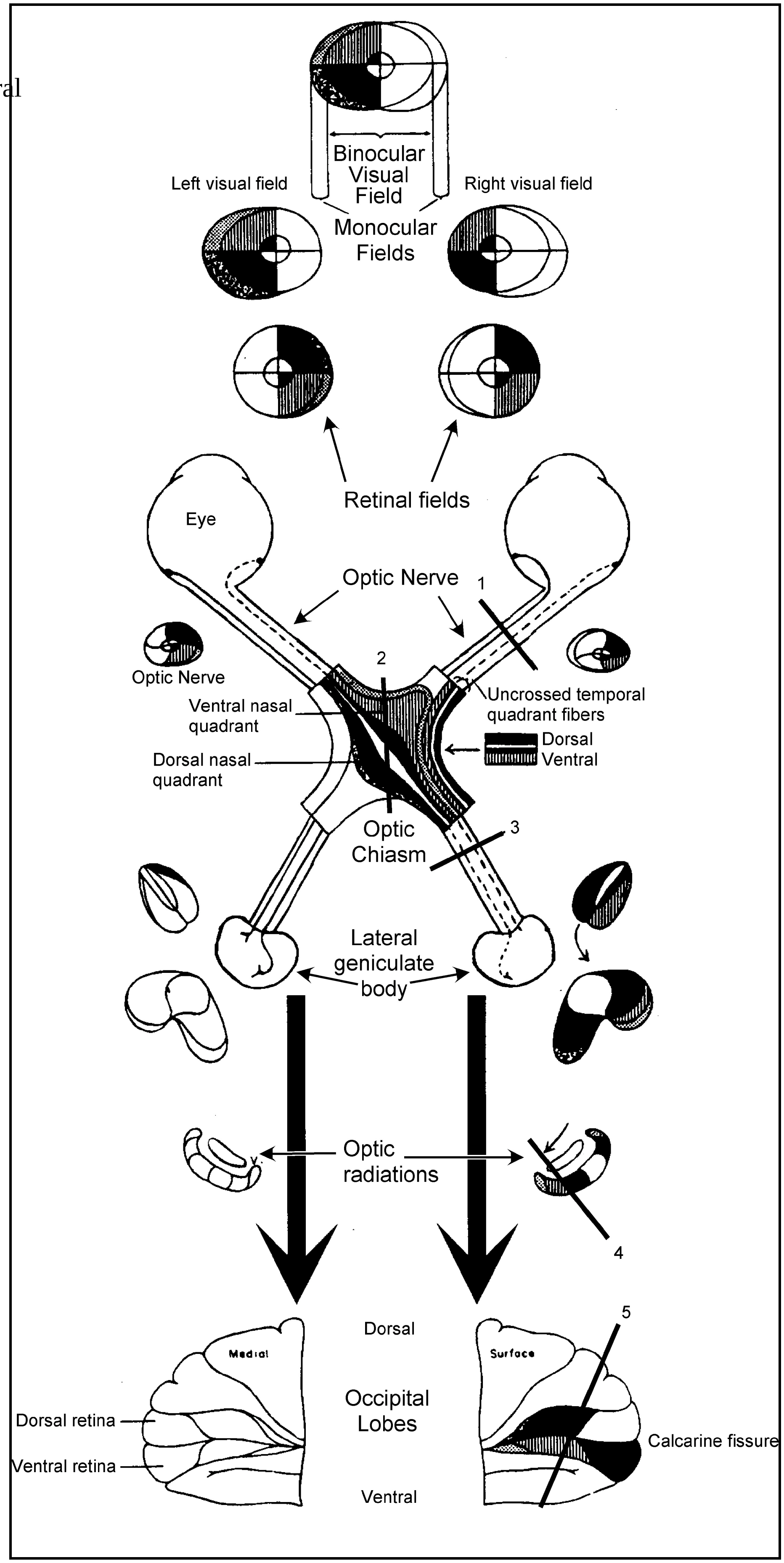

Figure 1

retina project to parvicellular layers and the magnocellular layers in the lateral geniculate.

The neurons of the lateral geniculate body send their axons to the ipsilateral neocortex (telencephalon) via the **optic radiations**. Fibers in the optic radiations that represent the inferior retina course beneath the temporal lobes. Fibers from the superior retina travel beneath the parietal lobes. The optic radiations terminate in the occipital lobe.

ORGANIZATION OF THE VISUAL CORTEX

The primary target of the axons from the lateral geniculate body is the **striate cortex, area 17** in the occipital lobe. This area is **primary visual cortex** (see syllabus on thalamus and cortex). Striate cortex derives its name from the thick stripe of myelinated fibers also found in layer IV (the line of Gennari). These are the axons from the lateral geniculate. There also are heavily myelinated fibers in layer VI. These two bands of fibers are also called the inner and outer bands of Baillarger.

The vertical meridian of the visual field is represented along the border of areas 17 and 18 (Fig. 2). The area of central vision terminates most caudally in the striate cortex. So, the small part of the striate cortex that wraps around to the lateral surface also contains the middle of the area of central vision.

Striate cortex is surrounded by **peristriate cortex** (areas 18, 19) which occupies much of the remainder of the occipital lobe (Fig. 2). **Extrastriate cortex** surrounds the peristriate cortex includes parts of the inferior parietal lobe and the inferior and middle temporal lobes. Cortical areas receive inputs from each other and also receive inputs from the pulvinar in the thalamus. There is a serial order to the cortical projections: striate cortex projects to area 18, 18 to 19, etc. Except for area 17, the peristriate and extrastriate cortex contain more than one area, and each area contains a complete retinotopic map.

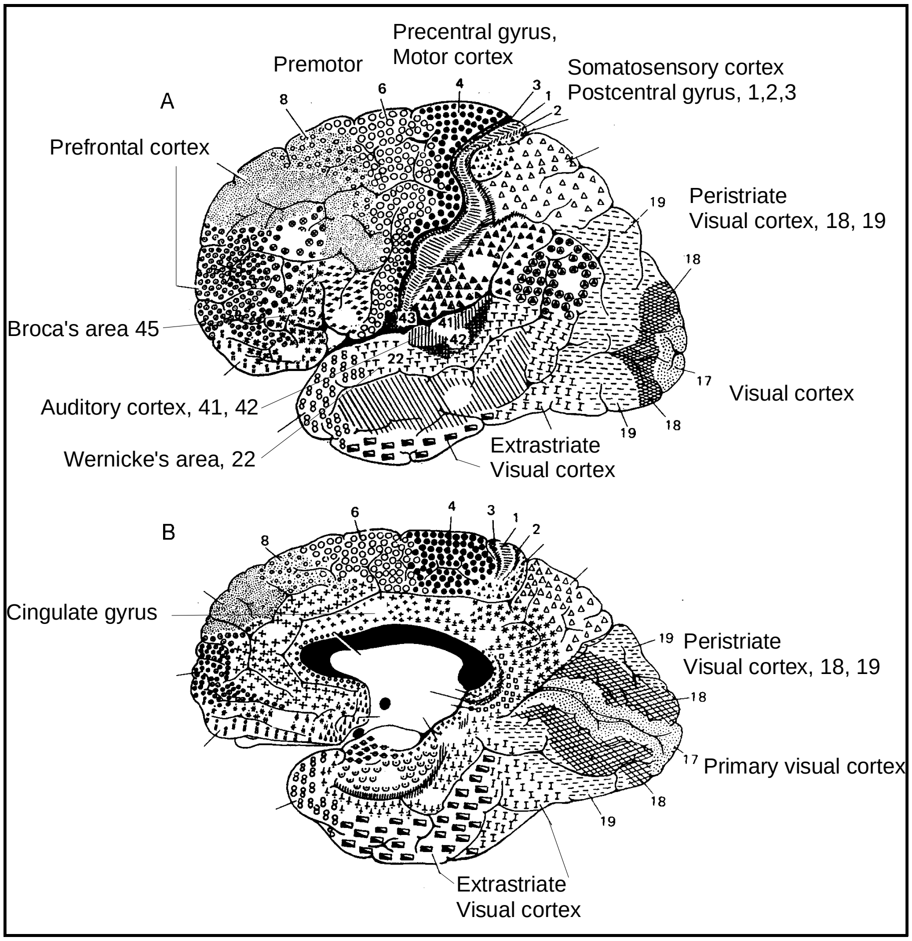

Figure 2

STRUCTURAL BASIS OF CORTICAL PHYSIOLOGY

Visual cortex, as in all neocortex, contains six layers. There are two main neuron types, stellate and pyramidal neurons. Stellate neurons tend to confine their dendrites to one layer. In contrast, pyramidal cells have dendrites that can extended perpendicular to the layers and receive inputs from 4 or 5 separate layers. Pyramidal cells form the structural basis for functional columns in the cortex.

Ocular dominance columns Layer IV is the main termination for axons from the lateral geniculate. In the primate, axons from the lateral geniculate terminate as patches in layer IV. Stellate cells within these patches receive inputs from only one or two layers of the lateral geniculate and are monocular (respond to stimuli in one eye only). The pyramidal cells outside of layer IV are usually binocular, that is they respond to visual stimuli in either eye.

Form sensitive cells are found in orientation columns. Outside of layer IV, pyramidal cells dominate. Because the integrate inputs from several layers, their responses are different from stellate cells. For example, their receptive fields are no longer round like those of the ganglion cells, the geniculate cells, and the stellate cells. They respond to stimuli with a specific orientation, e.g., slits, edges. Cells with oriented receptive fields form columns. Cells with similar orientations are in the same column. Orientation columns are perpendicular to ocular dominance columns.

Color sensitive cells are found in layer IV and in cortical blobs (pegs) Color responsive cells are at least partially segregated from form sensitive cells. Color sensitive cells are found in the parts of layer IV that receive inputs from the parvocellular lateral geniculate body. These cells have round receptive fields and are not sensitive to form. Similar cells are found in cortical pegs (also called blobs). Cortical pegs may represent part of an anatomically separate system for processing color.

Both form (orientation) and color sensitive cells are found outside of striate cortex in the peristriate and extrastriate cortex. Current evidence suggests that some of these cortical regions are more or less specialized for form or color vision.

LESIONS OF THE VISUAL PATHWAY (Fig. 3)

Blindness (anopsia) is associated with lesions of specific parts of the visual pathway. The type of blindness is described by the visual field defect. Monocular blindness *(1)* results from a lesion of the optic nerve. Heteronymous hemianopsia is blindness in the opposite visual fields and can be produced by a lesion of the optic chiasm that involves the crossing fibers *(2)*. Homonymous hemianopsia is blindness in the same half of the visual field *(e.g., a lesion of the optic tract, 3)*. Lesions of the optic radiations in the cortex often cut fibers in the temporal lobe or the parietal lobe on their way to the occipital lobe. This will produce a bilateral quadrant anopsia *(4)* since only part of the optic radiations are damaged. Finally, a lesion in the striate cortex on the medial surface may produce a hemianopsia with macular sparing *(5)* since the area of central vision may not be completely damaged.

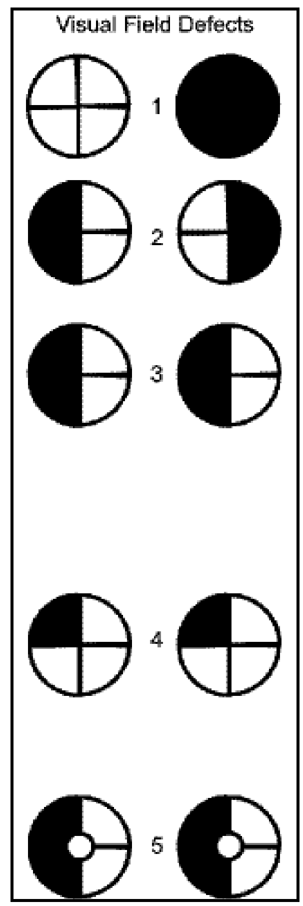

Figure 3