

Vision

Objective

- To understand the functional organization of the visual pathways.
- To learn the key visual field defects and to be able to use visual field impairments to localize the site of CNS damage
To understand the neural circuitry underlying pupillary reflexes
NTA Ch 6
- Key Figs: 6-1, 6-2; 6-5; 6-19; 6-21; 6-22; 6-23
Table 6-1
- Clinical Cases
#6 Homonymous hemianopsia; CC6-1

Self Evaluation

- Be able to identify all structures listed in key terms and describe briefly their principal functions
- Know the visual field defects
- Use neuroanatomy on the web to test your understanding

List of media

B-1 The retina, H and E stain

The mammalian retina contains neurons that are densely packed into six layers (NTA Fig. 6-2). There are three classes of retinal neurons: receptors, interneurons, and projection neurons. The outermost retinal layer (adjacent to the pigment epithelium) contains two types of photoreceptors, rods and cones. Photoreceptors synapse onto interneurons, the most important of which are the bipolar cells which, in turn, synapse on ganglion cells, the retinal projection neurons. Ganglion cells are the only neurons located in the innermost retinal layer. On their way to the thalamus, ganglion cell axons pass over the inner surface of the retina, converge toward the posterior pole of the eyeball, and exit as the optic nerve (NTA Fig. 6-5). The region where ganglion cell axons exit the eyeball is devoid of photoreceptors; this region is called the optic disc and causes a blind spot in the visual field.

Identify the layers in which photoreceptors, interneurons, and ganglion cells are located. (See NTA Fig. 6-3)

B-2 Organization of the visual system

The optic nerves from each eye meet at the midline to form the optic chiasm. The optic chiasm is located at the base of the brain, ventral to the hypothalamus and dorsal to the pituitary gland. Here, a partial decussation of retinal ganglion cell axons takes place; fibers from the nasal half of each retina cross to the opposite side, but those from the temporal half remain uncrossed. The fiber bundles from each eye then recombine posterior to the chiasm to form the optic tracts.

Most of the optic tract fibers terminate in the lateral geniculate nucleus of the thalamus, which relays to the cerebral cortex; this projection (geniculo-calcarine path) mediates visual perception. The efferent projections from the lateral geniculate nucleus are called the optic radiations (NTA Fig. 6-10) and terminate in the occipital lobe of the cerebral cortex, in the region of the calcarine fissure. This area is called the primary visual cortex and corresponds to Brodmann's area 17. Information from the primary visual cortex projects to adjacent cortical areas, which constitute the higher order visual areas. Note that the ventral fibers of the optic radiations pass rostrally for a short distance into the temporal lobe (Meyer's loop; NTA Fig. 6-10) before they turn caudal to join the remaining fibers of the optic radiations. These travel through the parietal lobe adjacent to the posterior limb of the internal capsule. Most of the remaining fibers that do not synapse in the lateral geniculate nucleus pass along the lateral and inferior surface of the diencephalon. They form a surface landmark called the brachium of the superior colliculus. These retinal axons project to the midbrain (retino-tectal path) and are important in the control of pupil diameter (for example, the light reflex) and eye movement. In addition, there is a direct retinal projection to the hypothalamus that is important in regulating circadian rhythms. This projection will be considered in the laboratory on the hypothalamus.

opticrodiats Optic radiations (movie)

Key:

Optic nerve, chiasm, tract, and radiations=gray

Thalamus=purple

Lateral geniculate nucleus=aqua

Optic radiations, cerebral peduncle (flys away), and subcortical white matter=white

X-50 Transverse section through the midbrain-diencephalic juncture.

This and the next slide are roughly in orthogonal planes. Note the position of the lateral geniculate nucleus lateral to the medial geniculate nucleus on both slides. Identify the position of the optic tract and the lateral geniculate nucleus on the brain stem model and in this slide.

X-65 Coronal section through the caudal diencephalon.

As for the previous slide, note the position of the lateral geniculate nucleus lateral to the medial geniculate nucleus on both slides. Identify the position of the

optic tract and the lateral geniculate nucleus on the brain stem model and in this slide.

AN01 Thalamo-cortical relations (animations)

The lateral geniculate nucleus has six cell layers (NTA Fig. 6-9). Three of these layers receive input from the ipsilateral eye, and three receive input from the contralateral eye. Within a single layer, the location of the ganglion cell terminals in the lateral geniculate nucleus is related to the retinal area from which they receive photoreceptor input. Adjacent areas on the retina project to adjacent areas in the lateral geniculate nucleus. This organization is termed retinotopy and is another example of the systematic mapping of a receptive surface on to a central neural structure. The retinotopic organization of the visual system will be discussed further in the next subsection of this lab.

Observe the region of the occipital lobe to which the lateral geniculate nucleus projects.

X-120 Optic radiations

On the brain stem model, determine the approximate plane of section. First identify the atrium and posterior horns of the lateral ventricle. Next follow the paths of the optic radiations from the thalamus anteriorly to the primary visual cortex, which is located in occipital pole, posteriorly. Also identify the: 1) the thalamus, 2) the various limbs of the internal capsule, 3) the corpus callosum, and 4) other components of the ventricular system.

M-2 An MRI scan, same level as X120

An MRI scan (T2), in the horizontal plane, through approximately the same level of the brain as shown in X120. In general, white matter appears darker than gray matter on this scan. However, certain structures appear darker for a variety of reasons. It is the case that the visual radiations give a very weak signal on MRI. As a consequence, the path of the visual radiations can be followed lateral to the atrium and posterior horns of the lateral ventricle.

B-5 Visual cortex - Myelin stain

This slide illustrates a section through the cortex of the occipital lobe. The white matter of the cortex is stained black! Most of the tissue on this section is the primary visual cortex (area 17), which is distinguished by the prominent stria of Genari, hence the name striate cortex. This is a band of myelinated axons of cortico-cortical association neurons. These axons are located in layer IVb. Area 18, the secondary visual cortex, can be distinguished by the lack of the stria of Genari. On the basis of the "myeloarchitecture" of the cortex, three prominent layers can be identified. In contrast, by examining the "cytoarchitecture" of the cortex, six or more layers are observed (see next slide).

B-5a Visual cortex - Nissl stain

This section is stained for the presence of Nissl substance and therefore reveals the locations of neuronal cell bodies. For orientation purposes, the large band with a low cell density corresponds to the stria of Genari – layer IVb (slide B005) and in the midst of the tissue, the cell-free white matter. Now proceeding from the pial surface, layer I contains few cells. Layers II and III have a high density of cell bodies. Layer IVa is actually the deepest portion of the superficial thick cell band. Layer IVb has few cells but many axons – the stria of Genari. Layer IVc is thick, has a high cell density and actually consists of two sublaminae. Layer V is the next deeper band, with a low cell body density, followed by layer VI, and then the white matter. In which layers do most axons from the lateral geniculate nucleus terminate? What are the connections of neurons in layers II and III? How about layers V and VI?

B-6 Visual cortex - Anterograde labeling of layer IV of ocular dominance columns (see Figure 6-15A in NTA)

This slide demonstrates that the projection to layer IV of the visual cortex from one retina does not overlap with the projection of the other retina. This is demonstrated by injecting radiolabeled amino acid into one eye of a Rhesus monkey and following the transport of proteins that incorporate the label. Initially, the label is taken up by ganglion cells and incorporated into protein. A small amount of labeled protein is transported to the synaptic terminals and released with neurotransmitter. The labeled protein is taken up by postsynaptic neurons, in this case lateral geniculate neurons, and transported to the synaptic terminals in the visual cortex. This slide is a radiograph showing the distribution of label in the cortex. Labeled material is lightly colored on this slide. Note that ocular dominance columns demonstrated anatomically (i.e., regions of cortex that receive a projection from one eye only) are observed in layer IV only. (see NTA Fig. 6.11)

B-7 Visual cortex - Anatomical reconstruction of distribution of radioactive label in layer IV (see Figure 6-15B in NTA)

Similar to B007 but plane of section is through layer IV only. Note that the pattern of ocular dominance columns resembles a fingerprint.

B-8 ¹⁵O-labeled water positron emission tomography (PET) scan – visual stimulation.

This slide illustrates a PET scan of a midsagittal “slice” through the human brain while the subject viewed three different visual stimuli: A. Macular stimulation, B. Perimacular, and C. Peripheral. The stimulus is shown above the PET scan. The distribution of ¹⁵O water approximates cerebral blood flow. There is a correlation between neuronal activity and local cerebral blood flow since neurons rely on blood for nutrition. Therefore the PET scan presents an image of cerebral activity (See PNS Chapter 22 for a discussion of PET.) Cerebral blood flow not

related to visual stimulation has been subtracted from the images (i.e., the images reflect the difference between the distribution of resting cerebral blood flow with subject in the dark and cerebral blood flow during visual stimulation), clearly revealing the activation of the primary visual cortex. The retinotopic organization is also revealed with this technique. Higher order visual areas can also be identified with PET (see next slide). (Courtesy of Dr. Peter Fox, Washington University, Fox, et al., Journal of Neuroscience (7): 913-922, 1987) .)

B-16 Higher-order visual cortical areas

Whereas the primary visual cortex (abbreviated V1) is located in cytoarchitectonic area 17, the secondary (V2) and higher-order visual areas (V3-V5) are located in areas 18 and 19 of the occipital. The function of several of these higher-order areas has been somewhat characterized, based on neuronal recordings in monkeys and functional imaging studies in humans. In particular, V4 is thought to play a key role in color vision and V5, in visual motion. These 2 visual areas, in turn, give rise to two distinct pathways for processing visual information. In one, which streams ventrally and rostrally into the temporal lobe, is important for identifying objects. The second pathway, which streams dorsally and rostrally into the parietal lobe, is important for spatial vision (including both stimulus location and information about stimulus motion). These two pathways are sometimes called the “what” and “where” pathways.

B-10 Visual field deficits

This slide illustrates classical and common visual field deficits resulting from lesions at various sites in the visual pathways. Be sure to study these field cuts carefully and understand the anatomy underlying them.

Visual pathway to midbrain

X-45 Midbrain

Identify the superior colliculus and the Edinger-Westphal nucleus. In this section you should also observe the red nucleus, substantia nigra, and the cerebral peduncles. These latter three structures are important in the control of body and limb movement.

X-50 Pretectal area

On this slide identify the Edinger-Westphal nucleus and the region called the pretectal area. In addition, identify the posterior commissure and the oculomotor nucleus. The pretectal area serves visual reflex functions. You should be able to describe the pathway for pupillary light reflexes. Anisocoria is the term used to describe pupillary asymmetry. In humans, anisocoria occurs with lesions of the motor projection to the periphery only. Why?

X-100 Sagittal section - close to the midline.

Identify the posterior commissure. What axons decussate through the commissure? Because this section is located close to the midline, the superior and inferior colliculi are not clearly distinguished. What other visual decussation is located on this slide?

Key Structures and Terms

Rods

Cones

Bipolar cells

Ganglion cells

Optic nerve

Optic tract

Blind spot

Optic chiasm

Lateral geniculate nucleus

Optic radiations (Meyer's loop)

Primary visual cortex (Brodmann's area 17)

Retinotopic organization of area 17

Visual association cortex

Superior colliculus and brachium

Pretectal area

Posterior commissure

Nucleus of Edinger-Westphal

Ciliary ganglion

"What" pathway

"Where" pathway