# Medical Neuroscience | Tutorial Notes

## Visual System: Central Visual Pathways

### *MAP TO NEUROSCIENCE CORE CONCEPTS*[1]

NCC1. The brain is the body's most complex organ.

NCC3. Genetically determined circuits are the foundation of the nervous system.

### *LEARNING OBJECTIVES*

After study of the assigned learning materials, the student will:

1. Describe the distribution of the axons of retinal ganglion cells to major processing centers in the forebrain and brainstem.
2. Discuss the topographic representation of visual space in the primary visual cortex (V1) and its anatomical basis in the organization of visual projections.
3. Discuss the distribution and functions of parietal and temporal "extrastriate" visual pathways.

### *TUTORIAL OUTLINE*

I. Overview of Central Visual Pathways

- A. central projections of the retina arise from retinal ganglion cells
- B. projections terminate on a variety of structures in the diencephalon and midbrain (see **Figure 12.1**[2] for gross overview)
  1. diencephalic targets
     - a. dorsal **lateral geniculate nucleus** (LGN)
       - (i) principal target of retinal ganglion cells
       - (ii) relays visual signals to the **primary visual cortex** (**V1**)
       - (iii) this pathway, is responsible for most aspects of what we know as visual perception
     - b. **suprachiasmatic nucleus** of the hypothalamus
       - (i) responsible for entraining endogenous circadian (daily) rhythms to natural day-night cycle

[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience ) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

(ii) the light-sensing elements in this visual projection are a special class of photosensitive ganglion cells that contain another photopigment, melanopsin

2. midbrain targets

**a. superior colliculus**

(i) involved in coordinating orienting movements of the head and eyes to a visual stimulus (and other sensory stimuli)

**b. pretectum**

(i) involved in pupillary light reflex (see **Figure 12.2**)

**See tutorial on "Visual System – Pupillary Light Reflex".**

**Be sure that you know the neuroanatomical basis of the pupillary light reflex and what can be learned about the integrity of the nervous system as you consider the possible outcomes of this test (e.g., constriction of the left eye, but not the right eye, when light is presented to the right eye, vice versa, etc.)**

(ii) pretectum is also involved in coordinating the activities of the preganglionic neurons that innervate the ciliary muscles and allow for accommodation

C. **parallel processing** in visual pathways begins with distinct anatomical and physiological classes of retinal ganglion cells and continues into the array of cortical areas that process different aspects of visual information

II. The pathway from the retina to V1 in more detail

A. from retina to brain (see **Figure 12.1**)

1. ganglion cell axons leave the retina at the optic disk and project centrally in the optic nerve ("CN" II—not really a nerve, but an extension of the brain)

2. about 55% of the optic nerve axons cross the midline (i.e., decussate) in the **optic chiasm** and project to the contralateral hemisphere; the other 45% remain ipsilateral (see below for consideration of retinotopy)

3. central to the optic chiasm, ganglion cell axons form the **optic tract**, which is simply the central continuation of optic chiasm

4. axons (and branches of axons) exit the optic tract and terminate in central targets in the diencephalon and/or midbrain

5. the principle projection to the visual parts of the cerebral cortex originates in the LGN and terminates in **V1**, **Brodmann's Area 17** (also called the "striate cortex", for its prominent striation in the human brain), which is located in the banks of the **calcarine fissure** on the medial aspect of the occipital lobe

B. retinotopic organization of the visual field projections

1. general principles

a. the nearest neighbor relationships within each half-retina are maintained throughout the projections to the LGN and primary visual cortex; this is termed "**visuotopy**" or "**visual topography**"

*b.* however, *each hemisphere* (LGN and V1) *represents the CONTRALATERAL visual hemifield*

2. anatomical basis in the retina for visuotopy

a. some important conventions (see **Figure 12.3A**)

a. the **point of fixation** is in the center of the visual field

b. the **vertical meridian** projects as a vertical line that passes through the fovea of each retina

c. similarly, the **horizontal meridian** projects as a horizontal line that also passes through the fovea

d. **temporal** refers to the half of the retina (or visual space) that is **lateral** to the fovea (or vertical meridian)

e. **nasal** refers to the half of the retina (or visual space) that is **medial** to the fovea (near the vertical meridian)

b. each retina sees overlapping regions of visual space that includes portions of both visual hemifields (see **Figure 12.3B**)

(i) **binocular visual field** is seen by nasal and temporal parts of both retinas

(ii) **monocular crescents** of visual space (far temporal in visual space) are seen only by the extreme medial portion of the nasal retina (the nose gets in the way!)

c. the lens inverts and reverses the optical image: the superior part of the visual field is seen by the inferior part of the retina, and the temporal half of the visual field is seen by the nasal half of the retina

d. how are the central projections from "corresponding" points in each retina that see the same position in visual space brought together in the brain? (see **Figure 12.4**)

a. axons of ganglion cells in the **nasal** retina **decussate** in the optic chiasm and project to the **contralateral hemisphere**

b. the axons of ganglion cells in the **temporal** retina **do not cross** and remain **ipsilateral**

c. the **line of decussation** in the retina runs through the fovea

3. in the LGN

a. each optic tract terminates in an orderly fashion, so that each LGN contains an orderly map of the **contralateral visual hemifield**

b. however, the axons from each retina terminate in distinct layers

4. in V1

a. the projections of the LGN to V1 terminate in proper topographic order in cortical layer 4 (see **Figure 12.5**)

b. the fovea is represented in the posterior part of the calcarine sulcus, with more peripheral parts of the contralateral visual hemifield represented in progressively more anterior locations

c. the upper visual field is represented in the inferior bank of the calcarine sulcus, while the lower visual field is represented in its superior bank

d. the representation of the fovea is disproportionately large (like the "over-representation" of the hand in S1)

e. on the way to V1, the projection of the LGN is called the **optic radiation** (see **Figure 12.7**)

(i) the lateral-inferior part, called **Meyer's loop**, "loops" into the white matter of the temporal lobe before projecting onto the inferior bank of the calcarine sulcus (terminating in the lingual gyrus)

(ii) the more medial-superior fibers course through the white matter of the parietal lobe before projecting onto the superior bank of the calcarine sulcus (terminating in the cuneus gyrus)

III. Extrastriate Visual Cortex

A. beyond V1 (= "striate cortex"), there are multiple areas in the occipital, parietal and temporal lobes that process visual information (see **Figure 12.16-12.18**)

B. these areas are arranged into two broad functional pathways that feed visual information from V1 into associational cortical areas in the parietal and temporal lobes (see **Figure 12.18**):

1. **dorsal** or **lateral parietal pathway**: responsible for spatial aspects of vision, such as the relationships between objects and ourselves and the movements of objects (including ourselves) through the environment (i.e., "**where?**")

2. **ventral** or **inferior temporal pathway**: responsible for high-resolution form vision, color processing and object recognition (i.e., "**what?**")

## *STUDY QUESTIONS*

Q1. Where are the cell bodies that grew their axons into the right optic tract?

A. left nasal retina
B. right nasal retina
C. left temporal retina
D. right temporal retina
E. A & D
F. B & C
G. A & B
H. C & D

Q2. There is a female patient who happens to enjoy a hot cup of tea most days at about 4:00 PM. Her problem is that she frequently spills her tea. The reason she spills her tea is that she does not appreciate the movement of tea filling her tea cup as she pours it out. She also has great difficulty judging the movement of traffic when she crosses a street at a crosswalk. Which of the following best explains her visual impairment?

A. She is blind in her non-dominant eye.
B. She is blind in her dominant eye.
C. She has torn the center of her optic chiasm.
D. She has a lesion in her inferior occipitotemporal association cortex in her non-dominant hemisphere.
E. She has a lesion in her lateral parieto-occipital associational cortex in her dominant hemisphere.