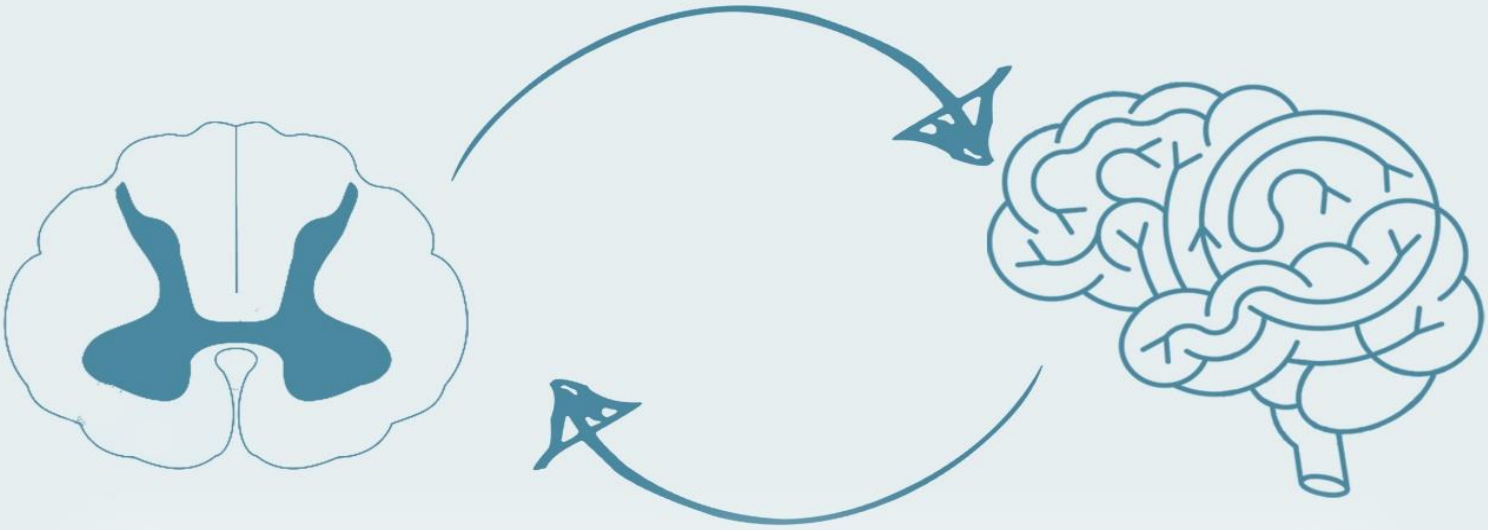

CNS

physiology

slides | sheets

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Introduction

Last lecture, we discussed the anatomy of the eye. We also explored the function of the retina in detecting and processing the perceived light.

Ganglion cells axons converge on the optic disc and form the optic nerve. They carry the information from the retina towards the central nervous system via several pathways. In this lecture we generally review these pathways. (please refer to the slides for figures.)

First Pathway*; To The Primary Visual Area*

The cortex is the target for the information that we experience consciously. And before reaching the cortex, the pathway must pass through the thalamus, as we discussed previously.

In this pathway, the axons of the optic nerve reach the lateral geniculate nucleus in the thalamus, where they synapse, and the pathway proceeds towards the primary visual are in the occipital lobe of the cortex.

The Distribution

We discovered how in some sensory pathways a complete crossing of fibers occurs (PCML, ALS), whereas other pathways proceed ipsilaterally (taste), and others contain crossing and non-crossing fibers (auditory pathway). For this pathway, visual sensation from a side of the visual field is perceived by the cortex of the contralateral side (tracts from the right visual field reach the left cortex, and vice versa).

Since the retina is semicircular, each eye has parts that collect light waves from the same side of the visual field, and other parts that collect the waves from

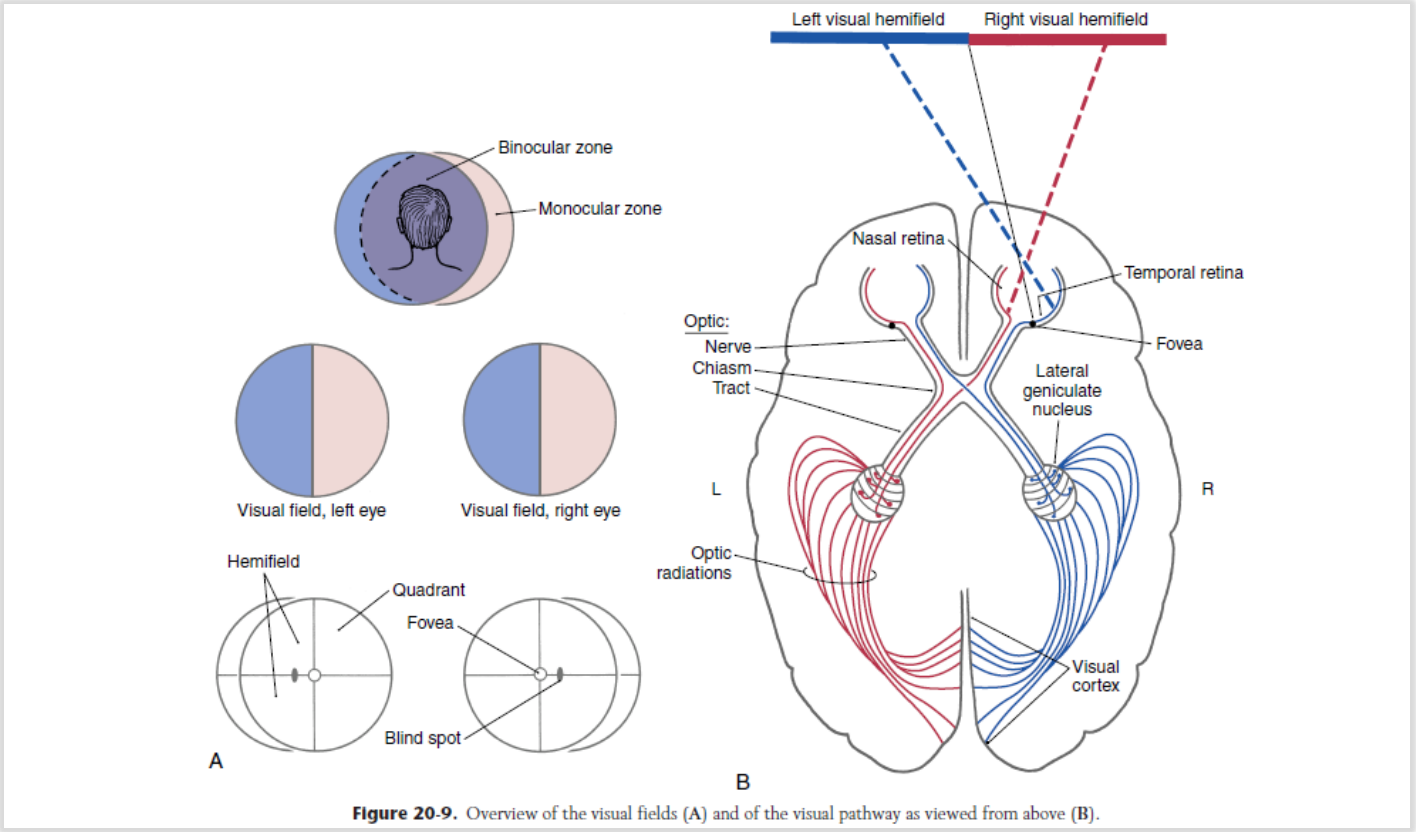


Figure 20-9. Overview of the visual fields (A) and of the visual pathway as viewed from above (B).

the contralateral side. Notice that in the following figure, the nasal part of each eye collects light from the same side of the visual field, whereas the temporal part of each eye collects light from the contralateral side. Moreover, the nasal part is associated with the of the peripheral parts visual field; however, the temporal part is associated with the central parts. So, the left visual hemi-field is projected on the nasal part of the left eye and the temporal part of the right eye. (Notice that the central area of the visual field is seen with both eyes "binocular zone", but the peripheral areas are seen by on eye "monocular zone.")

And since visual sensation from a side of the visual field is perceived by the cortex of the contralateral side, then the fibers from the **nasal part** of each eye (collects light ipsilaterally) cross to the other side, and proceed towards the **contralateral cortex**, and the fibers from the **temporal part** of each eye do not cross and continue towards the cortex **on the same side**. So, for the right eye, the nasal part sends axons that cross to the left side, and their path continues towards the left cortex, and the temporal part sends axons that travel on the right side without crossing, and end up being projected on the right cortex. Remember that the crossing of the nasal parts occurs at the **optic chiasm**.

After this stage, the pathway continues towards the thalamus, specifically to the lateral geniculate nuclei. This path is called the optic tract (till reaching the thalamus). From the lateral geniculate nuclei, the fibers go to the visual cortex in the occipital lobe. This path is called the optic radiation (from the lateral geniculate to the cortex).

The Visual Cortex

The visual cortex (Bradman's area 17) lies on either bank of the calcarine sulcus in the occipital lobe. The **superior** bank of the calcarine sulcus, on the cuneus, receives input from the inferior part of the contralateral hemifields (i.e. **superior** part of retina), whereas the **inferior** bank of the sulcus, on the lingual gyrus, receives input from the superior part of the hemifields (**inferior** part of retina). (remember that the inferior part of the retina receives light from the superior part of the visual field, and vice versa.)

00:00 – 10:00

We said in the previous lecture that the macula lutea, which is specialized with detailed vision, is a high-density area of photoreceptors. Consequently, it has a wide representation on the cortex. Macula lutea presentation is in the caudal portions of the visual cortex, whereas the peripheral areas of the retina are presented anteriorly. (Area of representation of central retina to that of peripheral retina = 2:1; from posterior to anterior.)

Lesions and Associated Symptoms

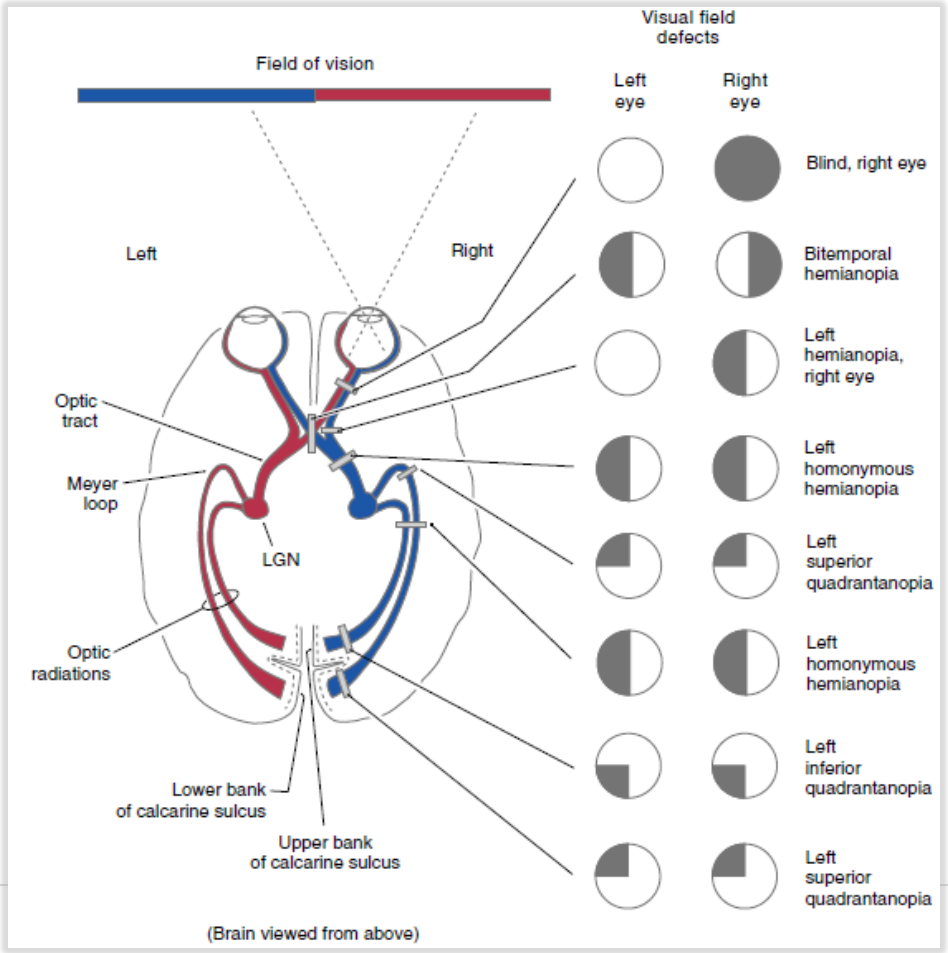
According to what we have discussed, we can summarize the lesions along the visual pathway and their symptoms in the following table.

Note: the fibers of optic radiations have a complex path; they go anteriorly and inferiorly, and then they curve back again. This "sweeping" part of the optic radiation is called Meyer loop.

	Name of defect	Lesion part	Consequences and symptoms
1	One-eye blind	One optic nerve	Loss of vision in monocular zone on one side (ipsilateral)
	Example: in blind right eye, right optic nerve lesion results with loss in the right monocular zone.  *1		
2	Bitemporal hemianopia*2	Optic chiasm	In optic chiasm, nasal fibers cross; so the results here are: loss in nasal fibers vision (peripheral vision) 
3	One-eye hemianopia (rare)	Non-crossing temporal fibers on one side (not seen in thrombosis; can be due to tumor or mass)	The lost area is covered by the other eye (loss in binocular area)
	Example: in left hemianopia (right eye), defect occurs temporal fibers on the right side. 		
4	Homonymous*3 hemianopia	Optic radiation or optic tract at one side	contralateral visual field loss (half loss) (vision of both eyes is affected; after optic chiasm, the fibers mix from both eyes)
	Example: in left homonymous hemianopia, right optic radiation defects lead to left visual field loss. 		
	See Figure: T1 in Appendix		
5	Superior quadrantanopia*4	Inferior part of optic radiation "Meyer loop" (on one side); or lower bank of calcarine sulcus " Lingual	Loss of superior quadrant contra-laterally (vision of both eyes is affected)

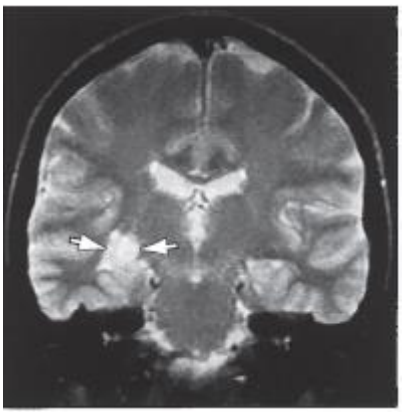
		gyrus " (on one side)	
	Example: in left superior quadrantanopia, defect in the inferior part of the right optic radiation; or defect in the lower part of calcarine sulcus on the right side lead to loss of the left superior quadrant. 		
	See Figure: T2 in Appendix		
6	Inferior quadrantanopia	Upper bank of calcarine sulcus "cuneus " (on one side)	Loss of inferior quadrant contra-laterally (vision of both sides is affected)
	Example: in left inferior quadrantanopia, defect in the right cuneus results with loss of the left in inferior quadrant. 		
	See Figure: T3 in Appendix		

*1: the presentation refers to the visual field and not the retinal receptors.
*2:Hemianopia:blindness over half the vision field
*3: Homonymous: in both eyes
*4: quadrantanopia: blindness over quarter the vision field



10:00 – 20:00

MRI Sections



In this section, a lesion in the right Meyer loop can be seen. The resultant symptoms include left superior homonymous quadrantanopia. (notice the proximity of the optic radiation to the hippocampus.)

Note: in MRI section, the patient's right is your left. Also note that cerebellum indicates the posterior part of the section; and so it helps you in analyzing the section.

“Final note about Meyer’s loop : the lower fibers of the optic raditions that go first anteriorly and inferiorly then backwards extend over a large part of the temporal lobe, so a stroke affects **that** part of temporal lobe will cause superior quadrantanopia. In conclusion, even optic raditions are considered one unit, but Meyer’s loop can be damaged alone.”

Ganglion Cells; *Types and Functions*

By now, we knew that a lot of processing occurs in the retina, and so we can say that the retina sends already processed information, via ganglion cells. According to the information they receive, ganglion cells have several subtypes; including X, Y, W and melanopsin-containing ganglion cells. Melanopsin-containing ganglion cells are discussed in the next section.

Ganglion cell X

These cells are small in size. They have not-so-widely distributed dendrites and, accordingly, connect to small number of bipolar cells. This means that each of these cells is responsible for a small area on the retina. These cells are present in the central areas of the retina, and they are responsible for high-resolution detailed vision. Also note that these cells convey colored vision.

Ganglion cell Y

In contrast to X cells, Y ganglion cells are large in size that have large axons and widely distributed dendrites (less resolution). These cells are present more on the periphery of the retina, and they are connected to the quicker optic receptors, rods. They are responsible for quickly-moving objects (movement in the visual field).

Ganglion cell W

These cells are similar to Y cells in anatomy and distribution (large cells with widely distributed dendrites). Functionally, they are more specialized with movement and directions; because they are not only connected to bipolar cells, but also to Amacrine cells.

Because they carry different modalities, ganglionic cells differ from each other in the pathways they travel through. So, from the optic nerve, the different fibers reach the thalamus, where they separate.

In the lateral geniculate, the superficial two layers contain cells with large size and are called the magnocellular (M) layers. The remaining 4 layers contain small cells and are therefore termed the parvocellular (P) layers. The Y fibers terminate in the magnocellular layers, whereas the X fibers terminate in the parvocellular layers. Recall that the Y ganglion cells receive their input mainly from rods, have larger receptive fields and thick, rapidly conducting axons, and are particularly sensitive to moving stimuli. The X ganglion cells receive input mainly from cones, have small receptive fields and slower conducting axons, and they arise mainly in the central retina and are responsible for high-acuity color

vision. The ganglion cells of the remaining W class terminate on small cells scattered between the main layers.

Both X and Y fibers reach area 17 on the cortex, but X fibers are represented more superficially, whereas Y fibers are represented more deeply in the cortex. This is consistent with the fact that they convey different modalities, and it is also consistent with the labeled line principle.

Notice that 4 layers in the lateral geniculate connect to X fibers (from both eyes; 2 ipsilateral and 2 contralateral); in comparison to only 2 layers for Y fibers (from both eyes; contralateral and ipsilateral). (Again, after optic chiasm, the fibers mix from both eyes.)

20:00 – 30:00

Second Pathway*; To Hypothalamus*

To organize the body circadian and seasonal rhythms, the body depends on light that is sensed by our eyes. Melanopsin-containing ganglion cells are the principal ganglion cells for this function.

Despite having connections with bipolar cells and photoreceptors, melanopsin-containing ganglion cells can detect light on their own. That is done by the melanopsin they contain, which is melanin-based in structure (in contrast to the structures in photoreceptors, which are vitamin-A-based). After detecting light, these cells initiate action potentials that help in organizing the body "internal-clock".

<u>Lesions and Body Rhythms</u>

When lesions result with photoreceptors degeneration (Macular degeneration and retinitis pigmentosa), the body can still have normal circadian and seasonal rhythms; since melanopsin-containing ganglion cells are still intact.

On the other hand, lesions that cause general cell damage in the eye, such as vascular lesions and glaucoma, result with defects in circadian and seasonal rhythms of the body.

Third Pathway*; To Superior Colliculus*

This pathway enables visual processing in terms of movement and directionality. In this pathway, fibers reach the superior colliculus of the mid brain. From there, fibers emerge and descend in the tectospinal tract to perform reflexes.

To be experienced consciously, the pathway should reach the cortex. And since this pathway carries already processed information, it does not project to the primary visual cortex, but rather to the parieto-temporal association cortex (posterior insular area). This cortex is responsible for the perception of movement and directions (vestibular pathway also reaches this cortex). Some fibers also go to area 5 and 7, which are associated with attention and movement.

As in any other pathway, fibers should pass the thalamus before reaching the neocortex. Fibers of this pathway synapse in the pulvinar nucleus not through LGN (pulvinar nucleus also shared with the vestibular pathway).

<u>Lesions: Blind Vision</u>

This pathway is responsible for the so-called "blind vision" phenomenon. Here, the patient gets blind because of damage to area 17. The patient cannot see, but can feel moving objects and can train to walk without a stick if the previous pathway is preserved.

(Notice: these are not visual hallucinations, which can happen in other diseases in a similar manner to the other sensory hallucinations (phantom limb, auditory hallucinations.))

NOTE

- X and Y fibers participate in cortex pathway (first discussed).
- W and Y fibers participate in the pathway to superior colliculus

Forth Pathway*; To Pre-tectum*

This pathway transmits the afferent fibers of the papillary light reflex; it gives information about the amount of light that falls on the retina. According to that, the pupil acquires the suitable constriction.

The steps of papillary light reflex happen in the following arrangement:

1- From the retina, the afferent fibers emerge, and after the optic chiasm, branching of tracts
2- The branches head towards the pretectum in both sides; so the right tract goes to the right and the left pretectum. (This step happens before the thalamus.)
3- They synapse in the olivary pretectal nucleus (in both sides).
4- Interneurons from the olivary pretectal nucleus emerge, and synapse in the Edinger-Westphal nucleus, which is a parasympathetic nucleus.
5- Presynaptic fibers go through the oculomotor nerves of both sides to synapse in the two ciliary ganglia.
6- Postsynaptic fibers innervate the constrictor muscles of the eyes

So, when light exposure increases, firing rate increases in the afferent fibers. Consequently, this leads to pupil constriction in both eyes.

“If you are interested “ https://www.youtube.com/watch?v=Gmt44ikiZwU

<u>Lesions in This Pathway</u>

According to what we discussed earlier, fibers go to both sides in this pathway; and so increasing light exposure on the right eye leads to constriction in both eyes. This notion is essential to predict the symptoms associated with the lesions of this pathway.

In this table, several lesions of this pathway are differentiated according to the responses of the papillary light reflex:

Part defected	Test	Constriction in
Right optic nerve	Light on right eye Light on left eye	No constriction Both eyes
Right oculomotor nerve	Light on right eye Light on left eye	Left eye Left eye
Right optic tract	Light on right eye Light on left eye	Both eyes Both eyes

(This table is important for the next lecture.)

30:00 – 45:00

Appendix

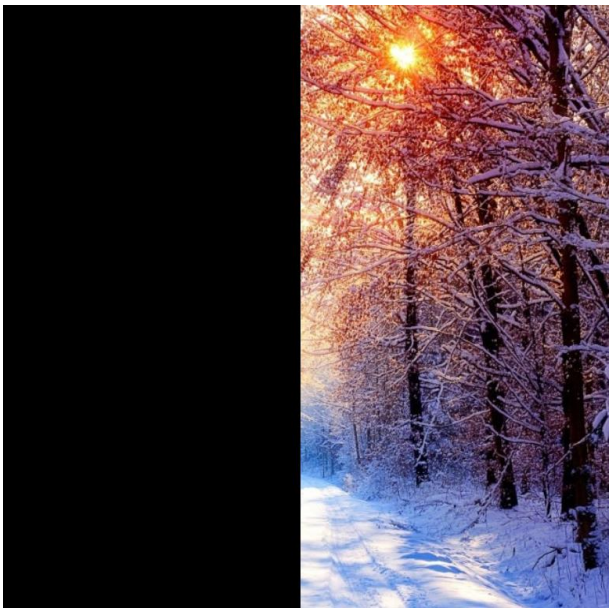


Figure: T1

Figure: T2

Figure: T3