The Visual System

The Lateral Geniculate Nucleus

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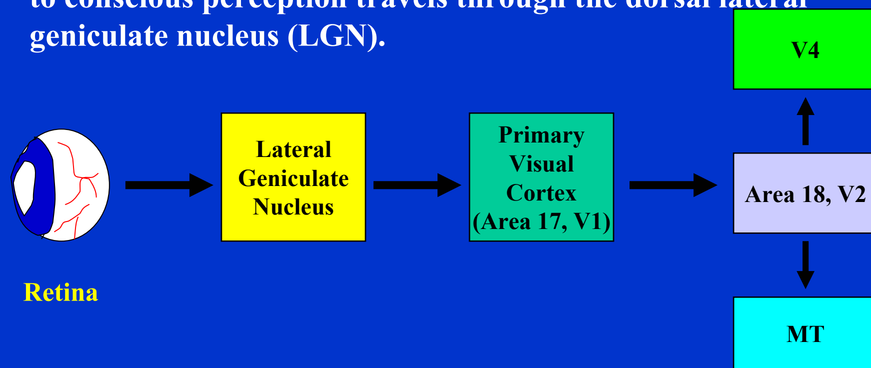
- Required Reading

- 2/20/04 LGN *Adler's Physiology of the Eye Chapter 28*

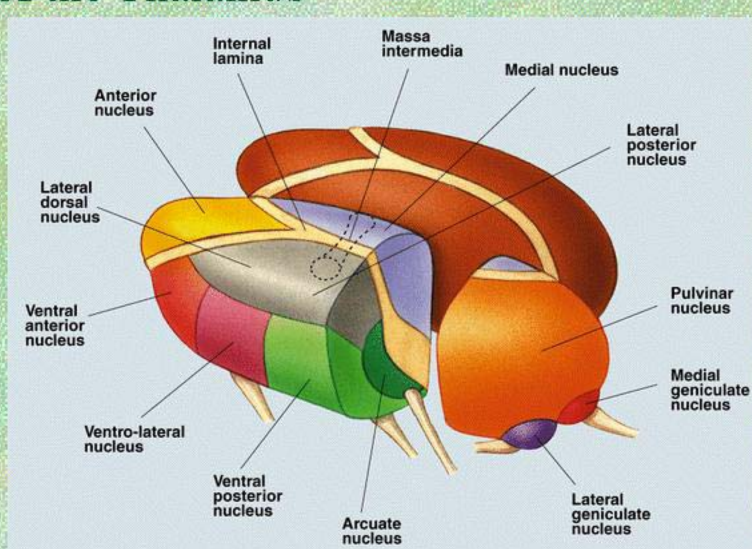
- 2/23/04 *Cortical Architecture Adler's Physiology of the Eye Chapter 29*

Primary Visual Pathway

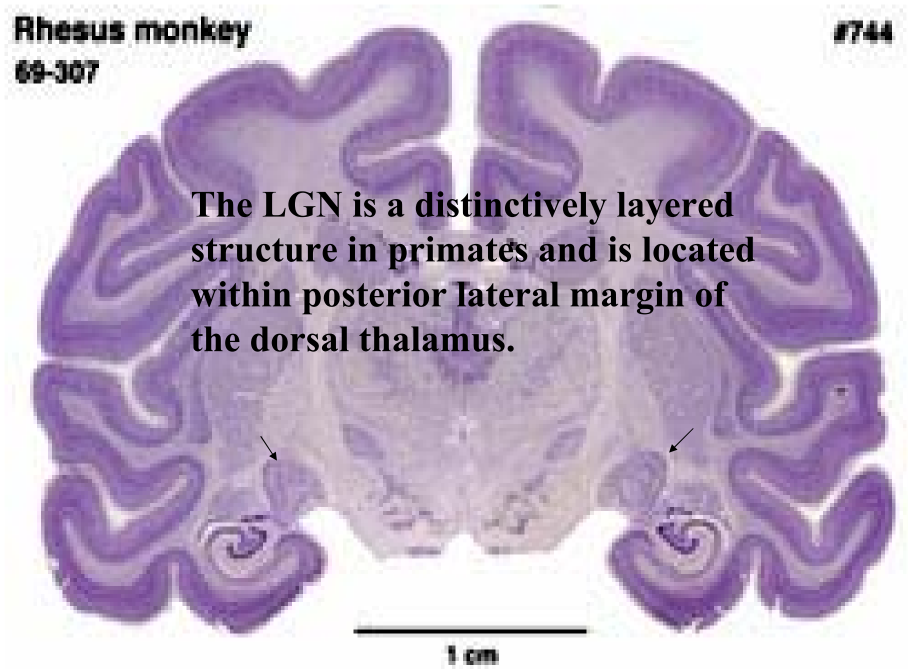
In primates all visual information from the retina critical to conscious perception travels through the dorsal lateral geniculate nucleus (LGN).



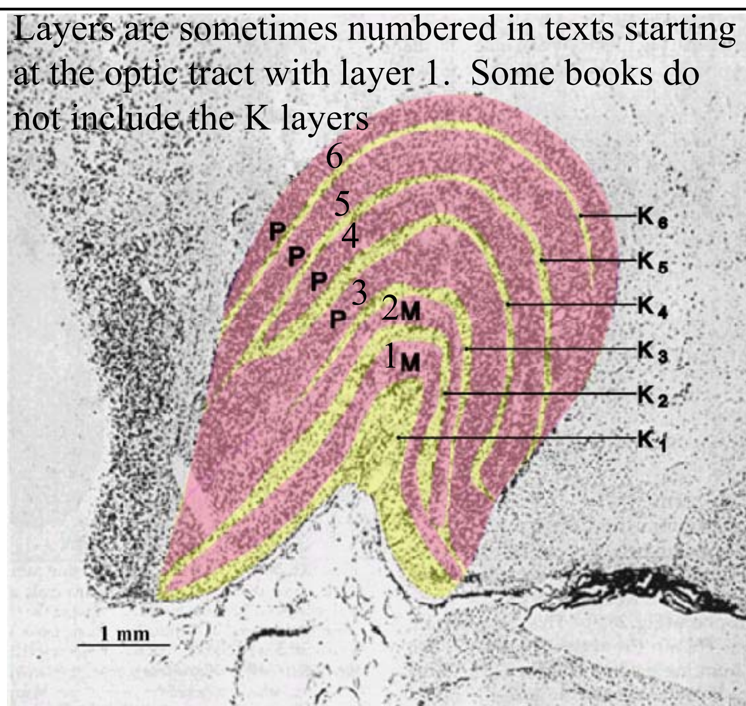
The Lateral Geniculate Nucleus (LGN) of the Thalamus



The LGN is a distinctively layered structure in primates and is located within posterior lateral margin of the dorsal thalamus.



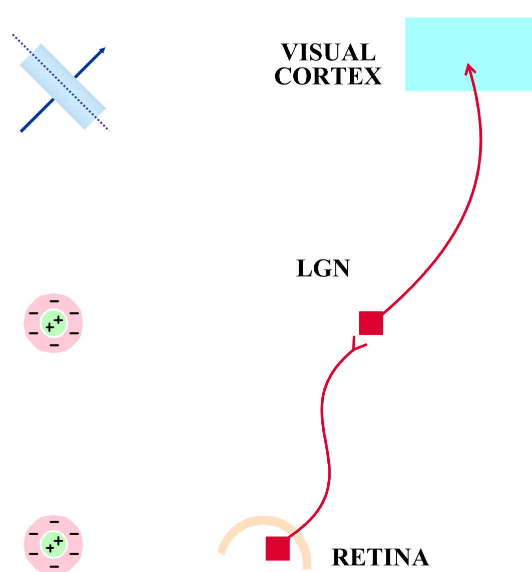
Layers are sometimes numbered in texts starting at the optic tract with layer 1. Some books do not include the K layers



Question

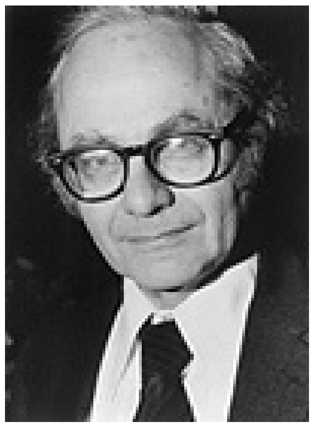
- How similar or different are the receptive fields in the LGN from those in the retina?

Answer: retinal ganglion cell and LGN cell receptive fields are very similar.

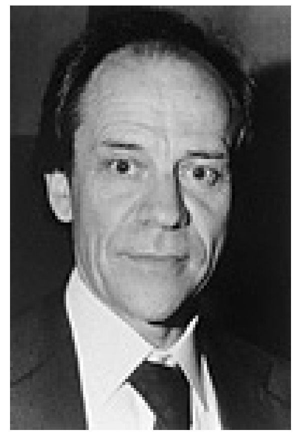


Nobel Prize 1981

Hubel



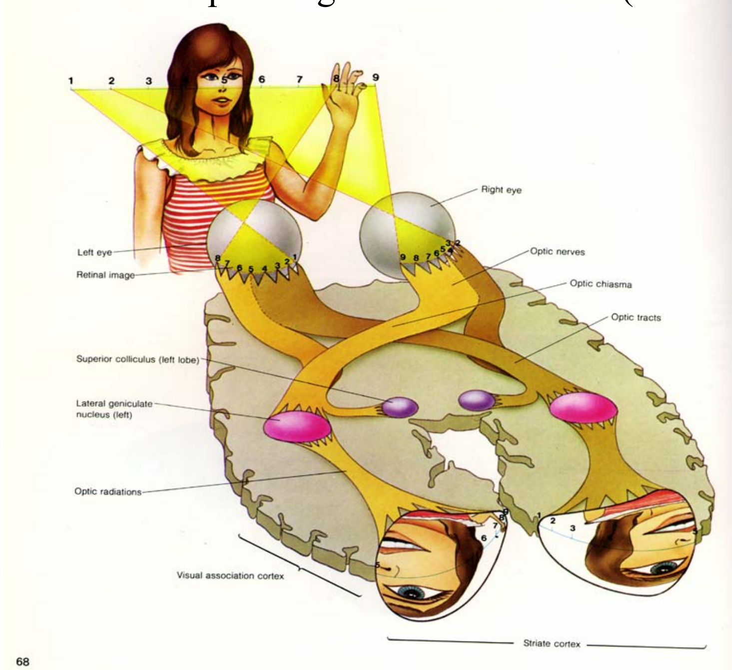
Wiesel



Movies

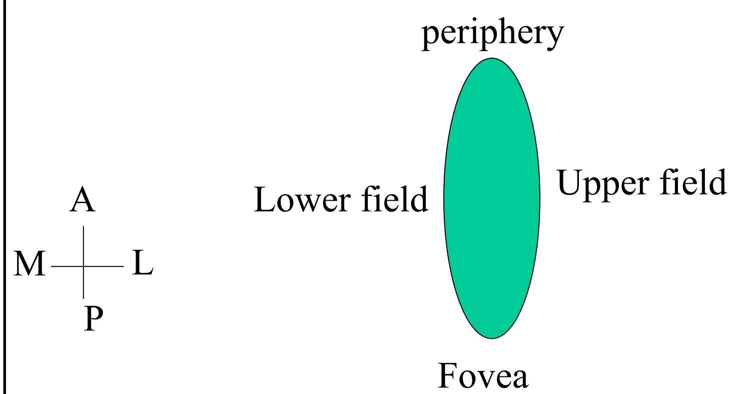
- Hubel plotting ON center LGN cell
- Responses of a K cell to a yellow/blue isoluminant grating
- Responses of a P cell not sensitive to Yellow verses blue

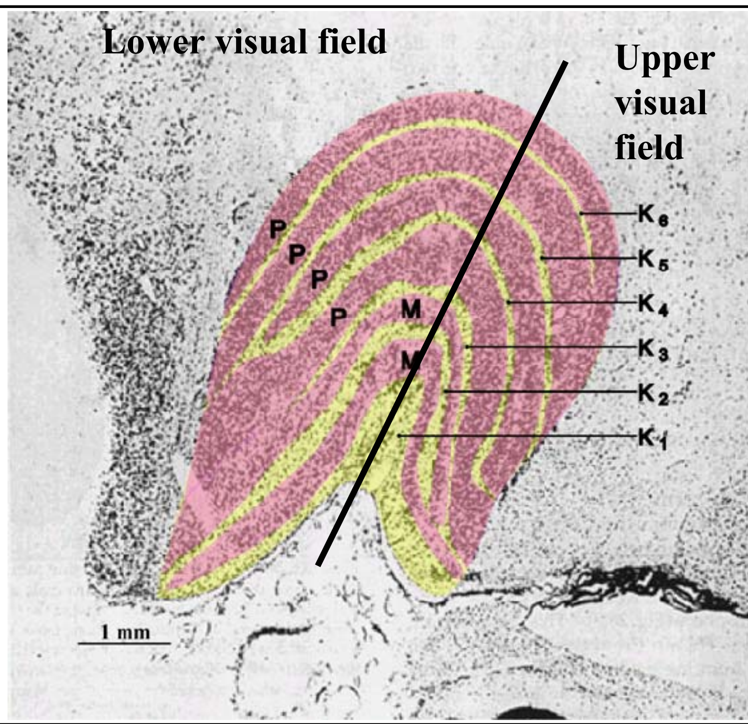
How is visual space organized in the LGN (MAPS)



Question: which would you prefer to lose one eye or one LGN? Why?

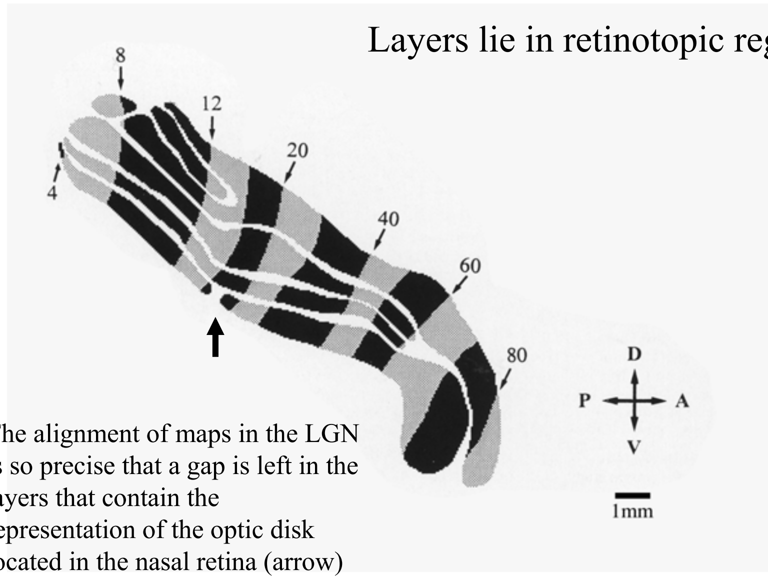
Within each LGN layer the opposite hemifield is represented such that the superior and inferior visual fields are located toward the lateral and medial zones of the layer, respectively and the central (toward the fovea) and peripheral visual fields are located, respectively, at the posterior and anterior zones of the layer.



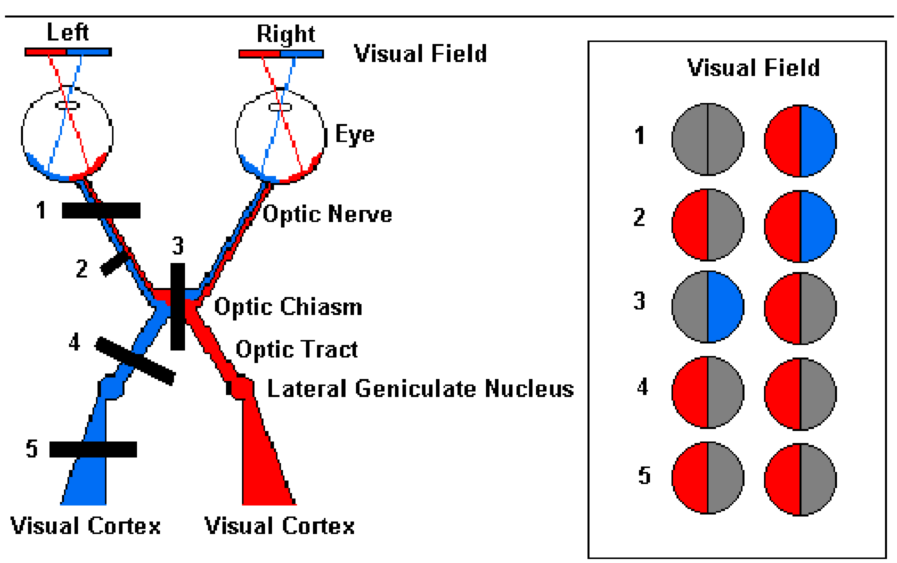


More tissue is devoted to central vision in the LGN

Layers lie in retinotopic register



The alignment of maps in the LGN is so precise that a gap is left in the layers that contain the representation of the optic disk located in the nasal retina (arrow)



What is being segregated by the layers of the LGN?

Left and right eye input
P, M, K
ON and OFF ?

Two P layers get input from the ipsilateral (same side of the brain) eye and two P layers get input from the contralateral (opposite side of the brain) eye. Each M layer gets input from one eye. Retinal input to K layers (yellow) has not been worked out.

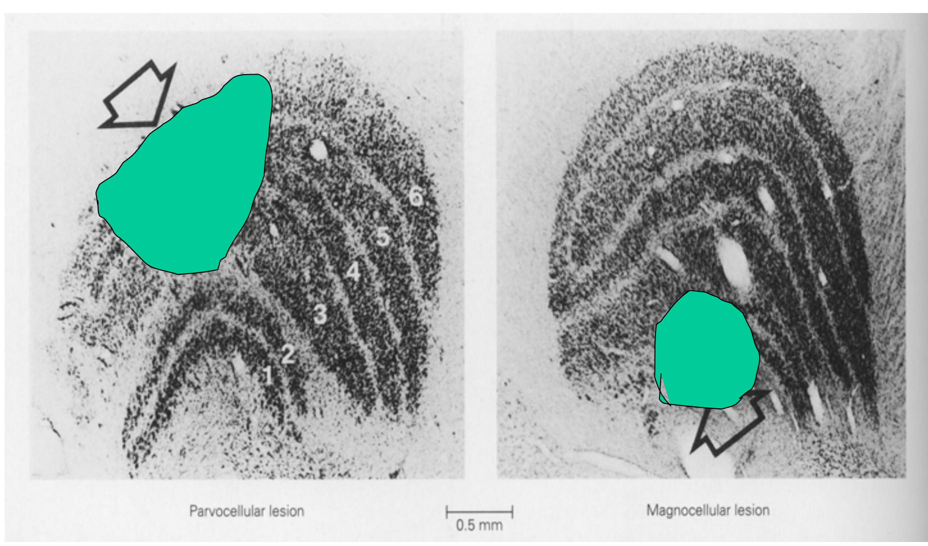
Classes of Primate Retinal Ganglion Cells projecting to the LGN

Property	M cell (7-10%)	P cell (80%)	K cell (7-10%
Morphology	Parasol	midget	variable
Soma size	large	medium	small
Receptive field Dendritic field	Center/surround medium	Center/surround small	Variable Avg. large
Spatial freq	low	high	low
Wavelength selective	no	yes	Some blue-on
Contrast sensitivity	high	low	Intermediate
Temporal freq. Sustained/transient	High transient	Low sustained	Intermediate/variabl e Both types
Axon speed	High (2.0msec)	Medium (4.0)	Low (>5.0)

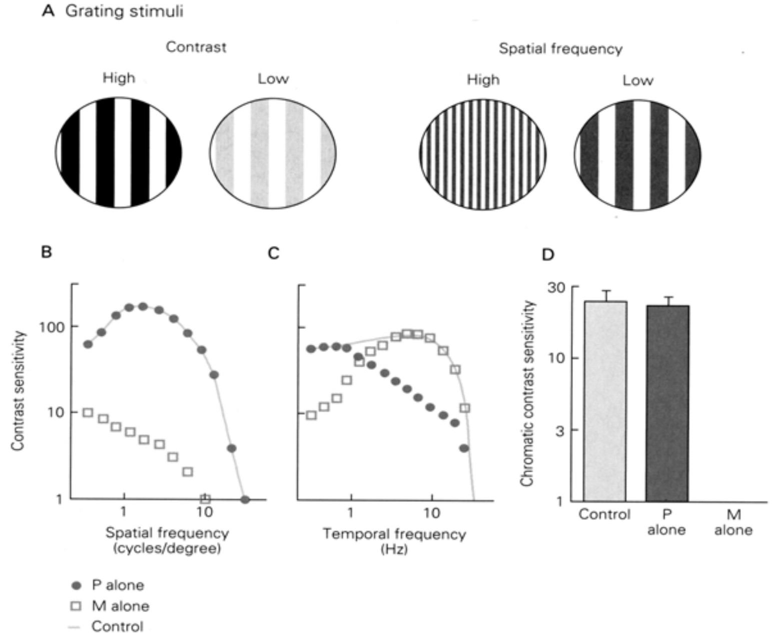
How does parallel pathway organization relate to visual perception?

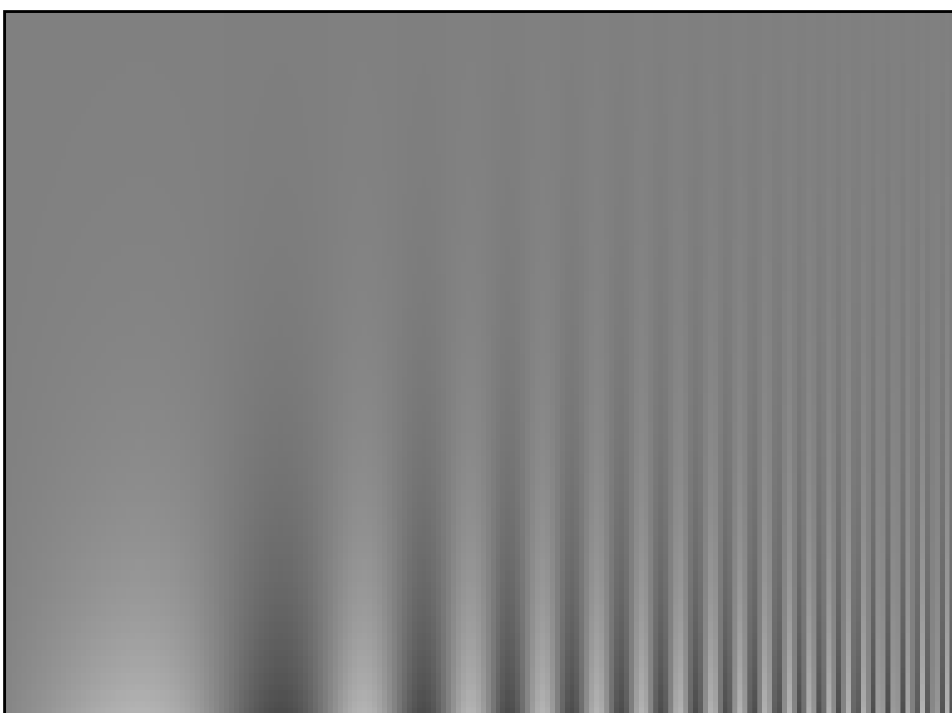
The properties of P cells suggest that they are useful for color and detail vision. The properties of M cells suggest that these cells contribute more to motion vision.

Do we require P cells to see visual objects (forms)? Do we require M cells to see movement?



Changes after lesions of M or P LGN layers





Lesions of M and P LGN layers in macaque monkeys result in visual deficits that can mainly (although not exclusively) be predicted by the wavelength, spatial and temporal thresholds of the most sensitive cells in each pathway.

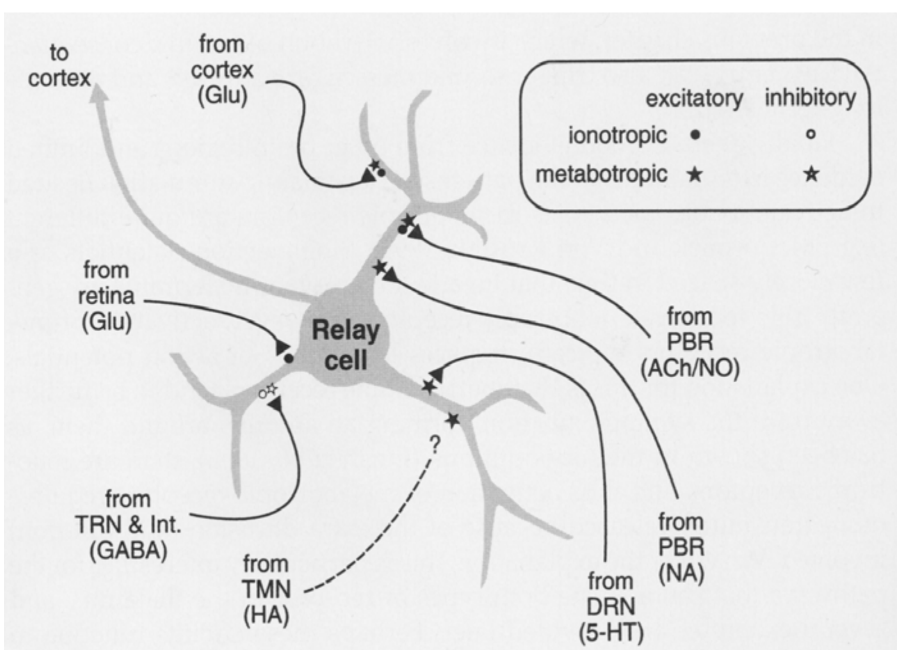
Monkeys can see form and motion with *either* pathway as long as the stimulus content presented is within the range of the remaining pathway.

What is the LGN really doing?

Question from assigned readings

- Does the LGN receive inputs from any other sources besides the retina? If so name one.

Yes, visual cortex



So what happens in the LGN anyway?

The changes seen in receptive field structure between retina and LGN are subtle and are best thought of as adjustments necessary to efficiently transfer relevant information to cortex. When the input from the retina is measured within a LGN relay cell in form of synaptic or S-potentials and these S-potentials compared to the output of that same cell recorded as action potentials the ratio of S potentials that result in action potentials (the transfer ratio) has been found to be less than 1.0, typically around 0.3-0.5 in an anesthetized preparation (Kaplan et al., 1987).

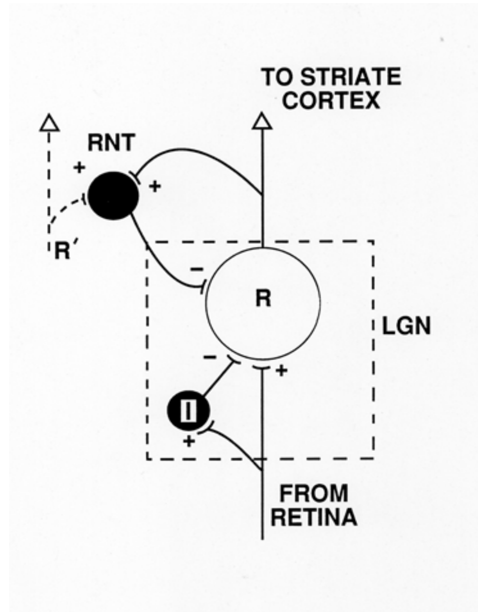
The regulation of the flow of visual signals from the retina to the cortex means that only certain visual signals are allowed to pass on to cortex

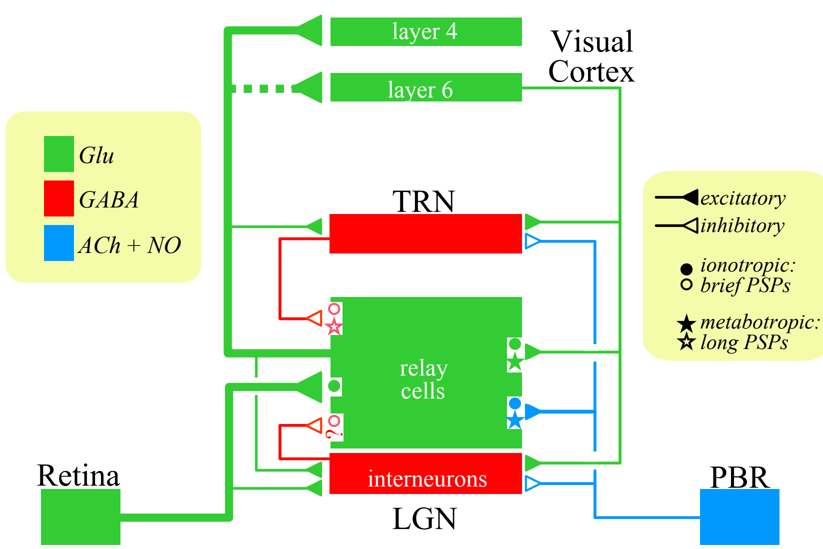
There are two main types of cells that exist in the LGN, relay cells and interneurons.

LGN cells can be grouped into two principal cell classes, *relay* cells that send an axon to visual cortex and *interneurons* whose axons remain within the LGN.

LGN relay cells use the transmitter glutamic acid (glutamate) whereas interneurons use the transmitter (-amino butyric acid (GABA).

Signals relayed to cortex by relay cells (R) are regulated by input from two inhibitory neurons, interneurons (I) and thalamic reticular neurons (RNT). Information is regulated by feedforward and feedback loops. These circuits control the transfer ratio of information that gets through to cortex

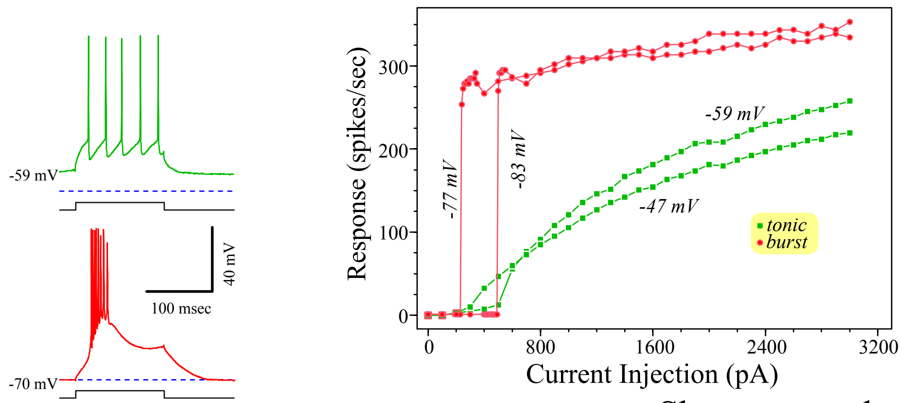




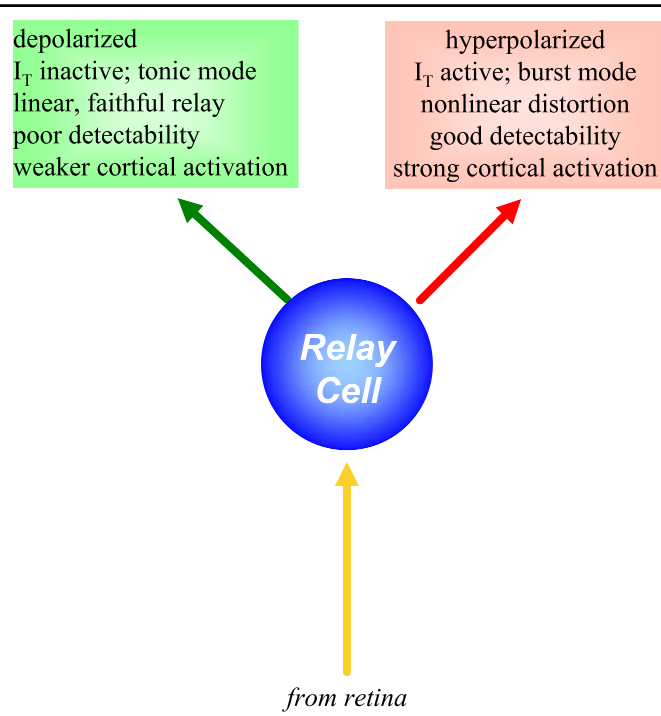
Tonic and Burst Response Modes:

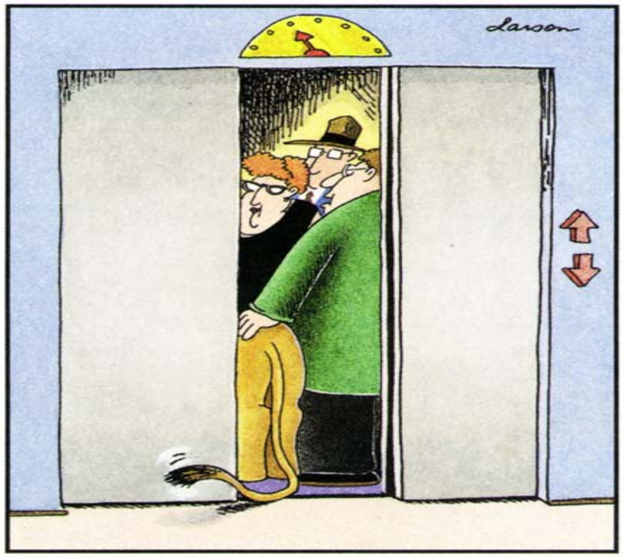
Determined by voltage- and time-dependent state of I_T

- If cell is relatively depolarized for roughly 100 msec or more, I_T is *inactivated* and response is *tonic mode*: sustained firing of unitary action potentials with no role for I_T
- If cell is relatively hyperpolarized for roughly 100 msec or more, I_T is *de-inactivated* and response is *burst mode*: I_T is activated, leading to all-or-none Ca^{2+} spike and burst of action potentials



Sherman et al.





"Don't be alarmed, folks. ... He's completely harmless unless something startles him."

Key Points

- Each LGN has a map of the opposite hemifield
- Receptive field properties of LGN cells are similar to their retinal inputs.
- M, P, K and left and right eye retinal inputs to LGN are segregated into different layers.
- The LGN regulates visual signals via feedback and feedforward inhibitory pathways and specialized circuitry.
- Visual information sent from the LGN to cortex reflects not only retinal input but modulatory input from many other brain areas that send axons to the LGN.