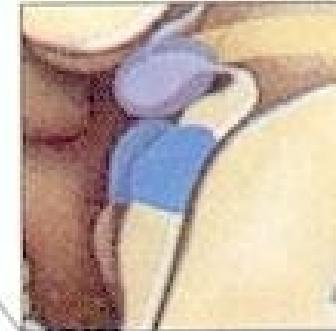
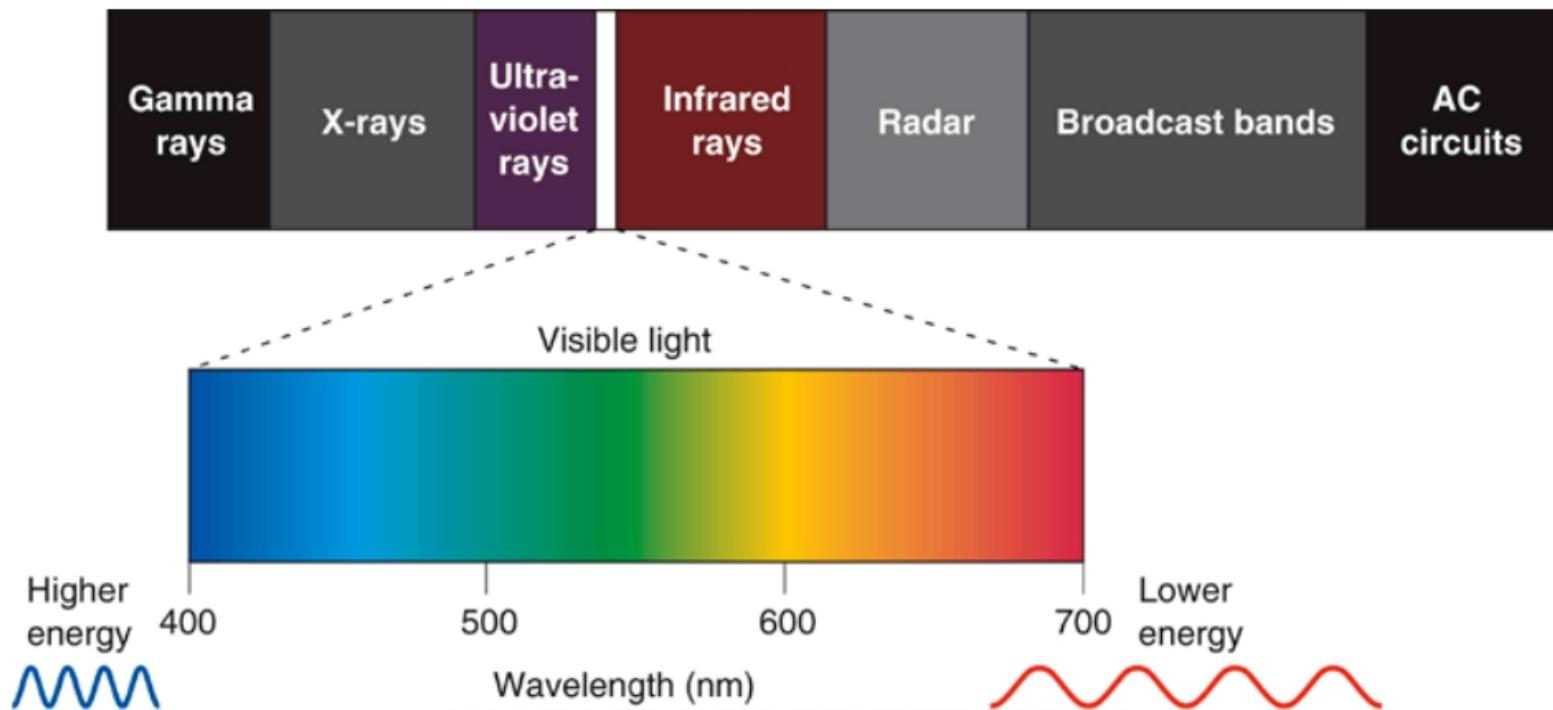


# Sub-cortical Vision

NAIL088  
Ján Antolík  
MFF UK, 2019

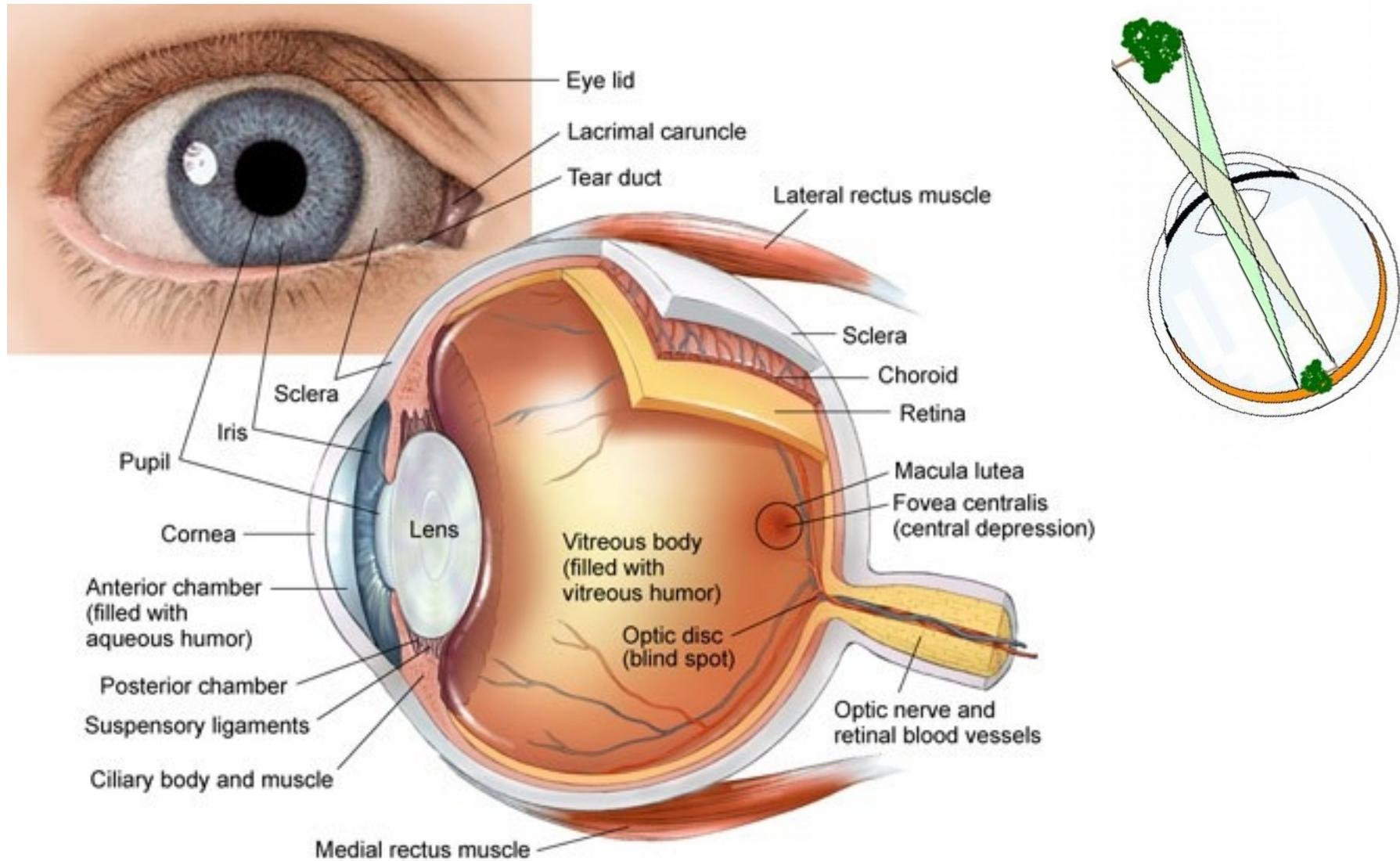


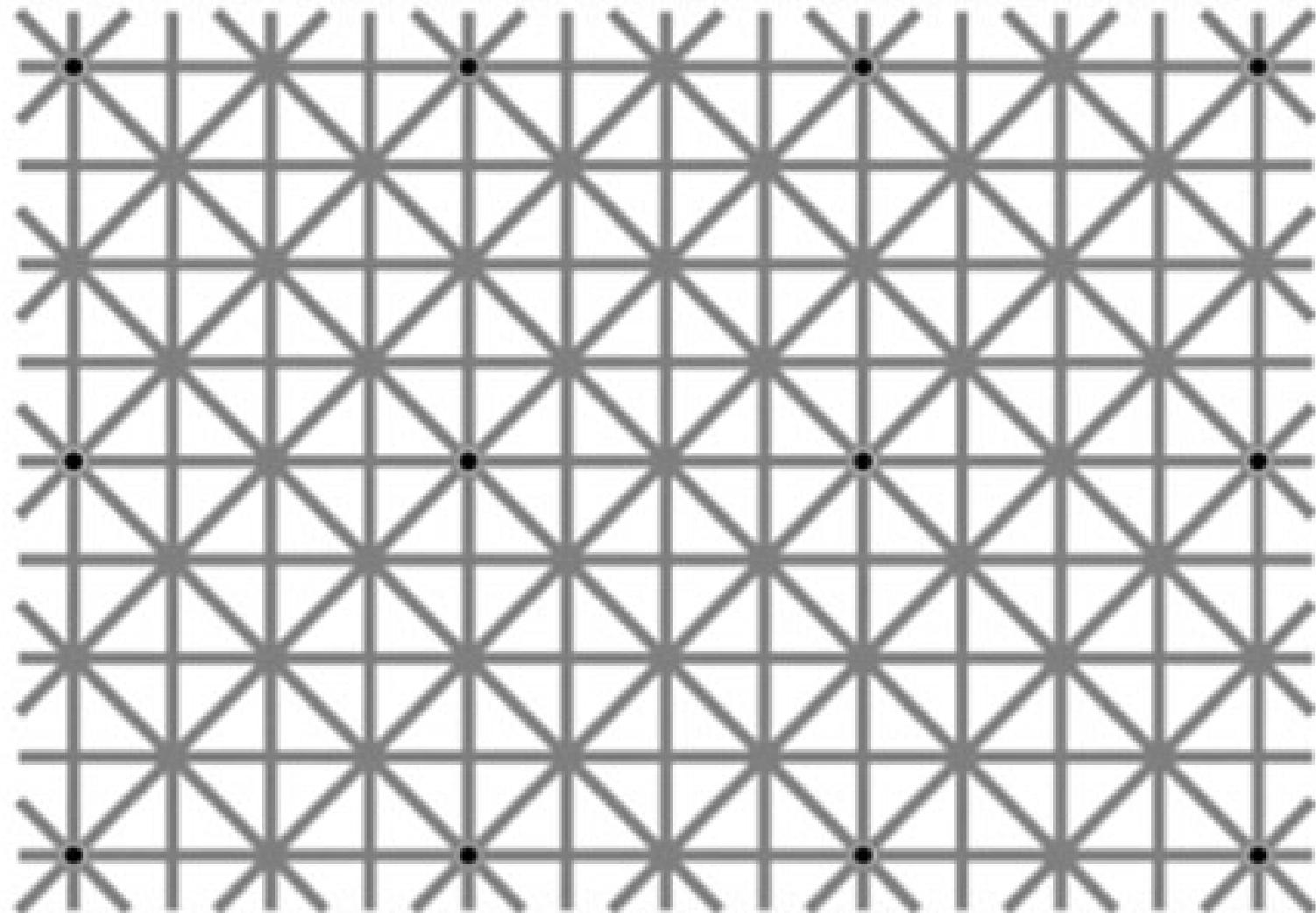
# Light

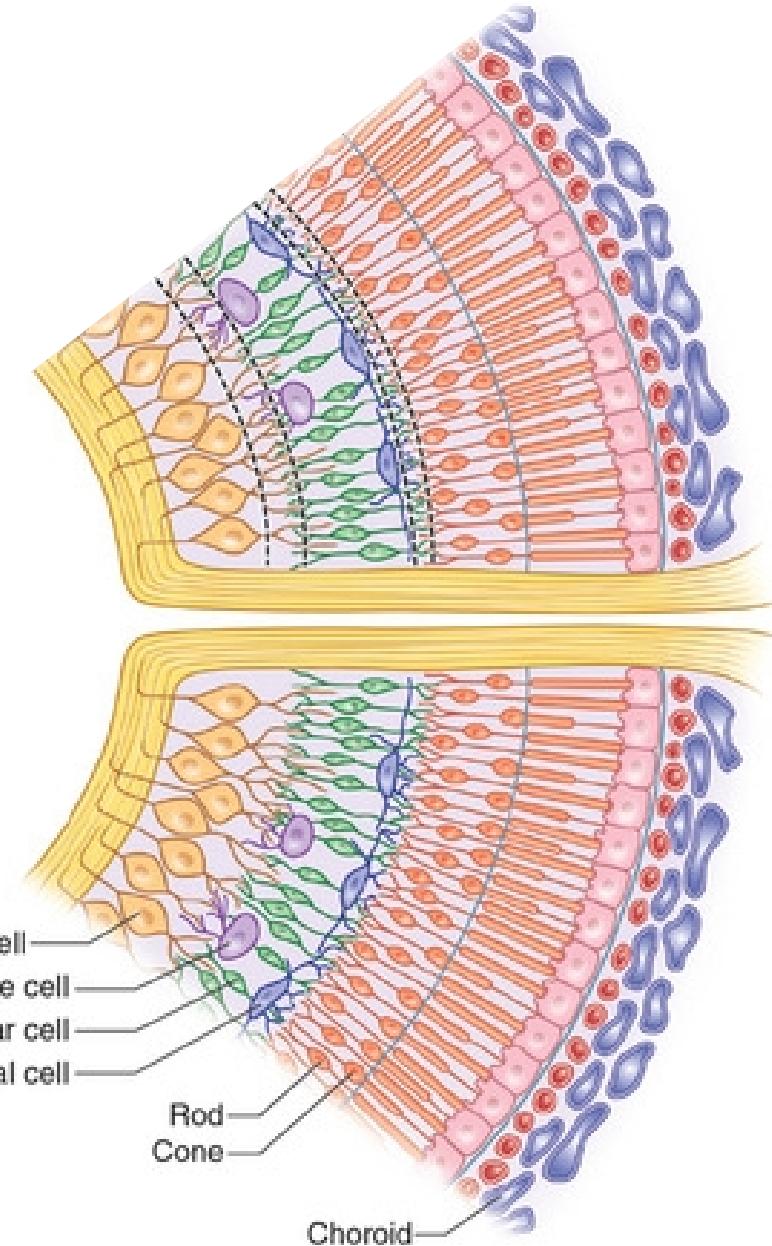
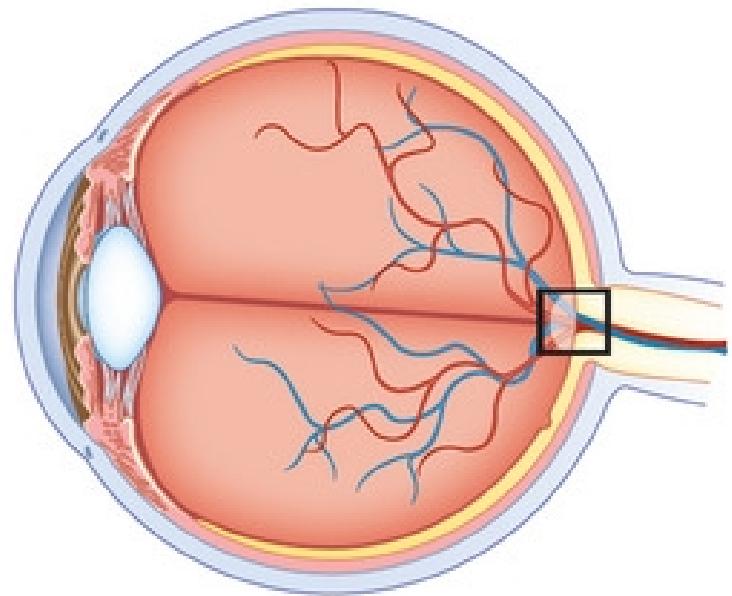


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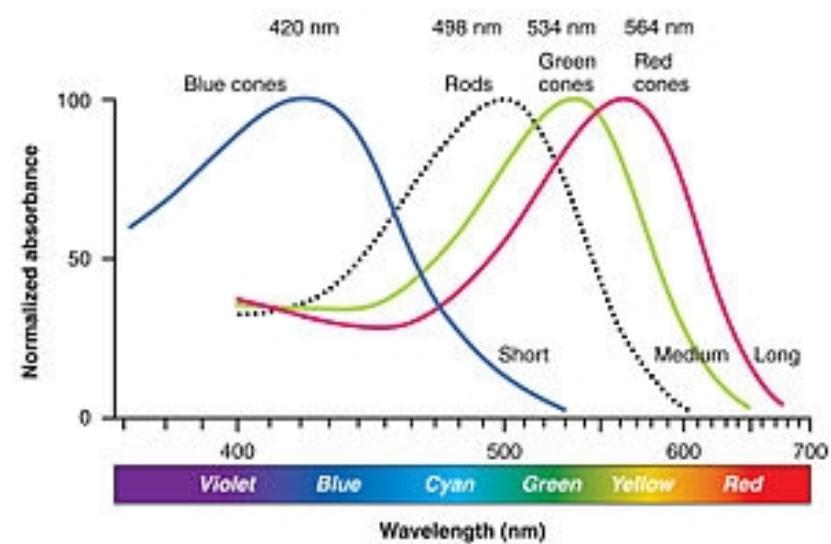
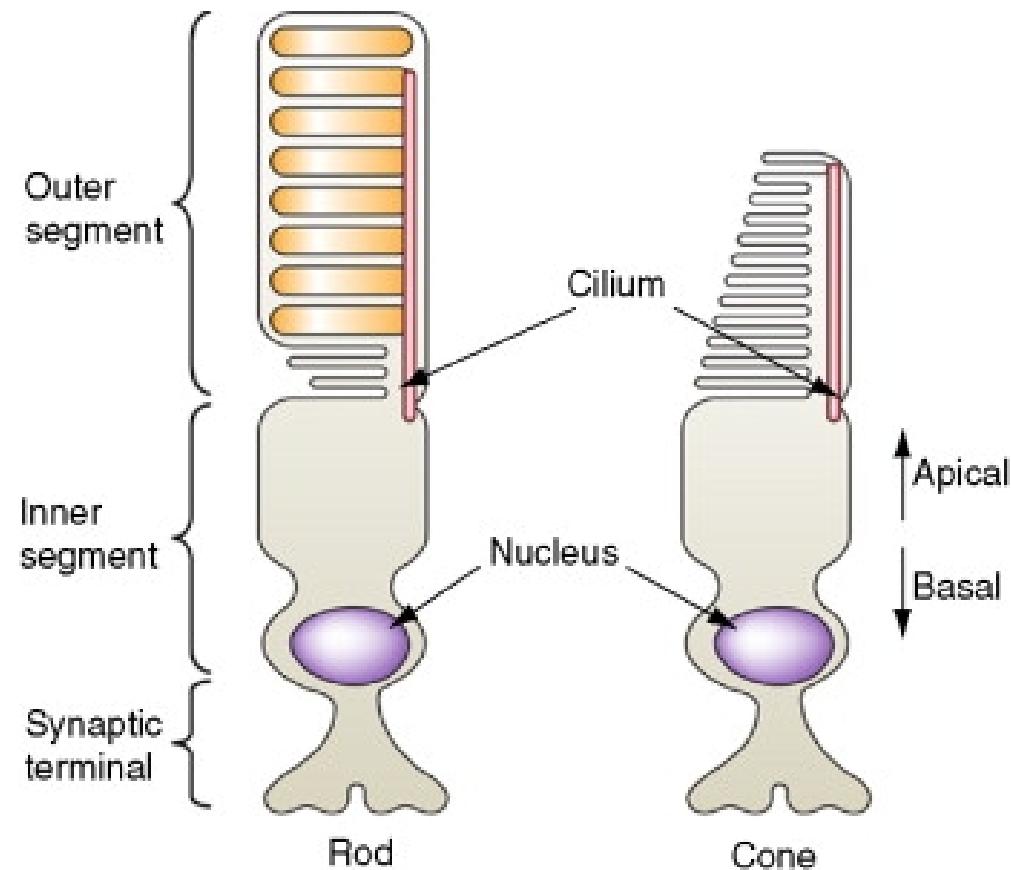
# The Eye

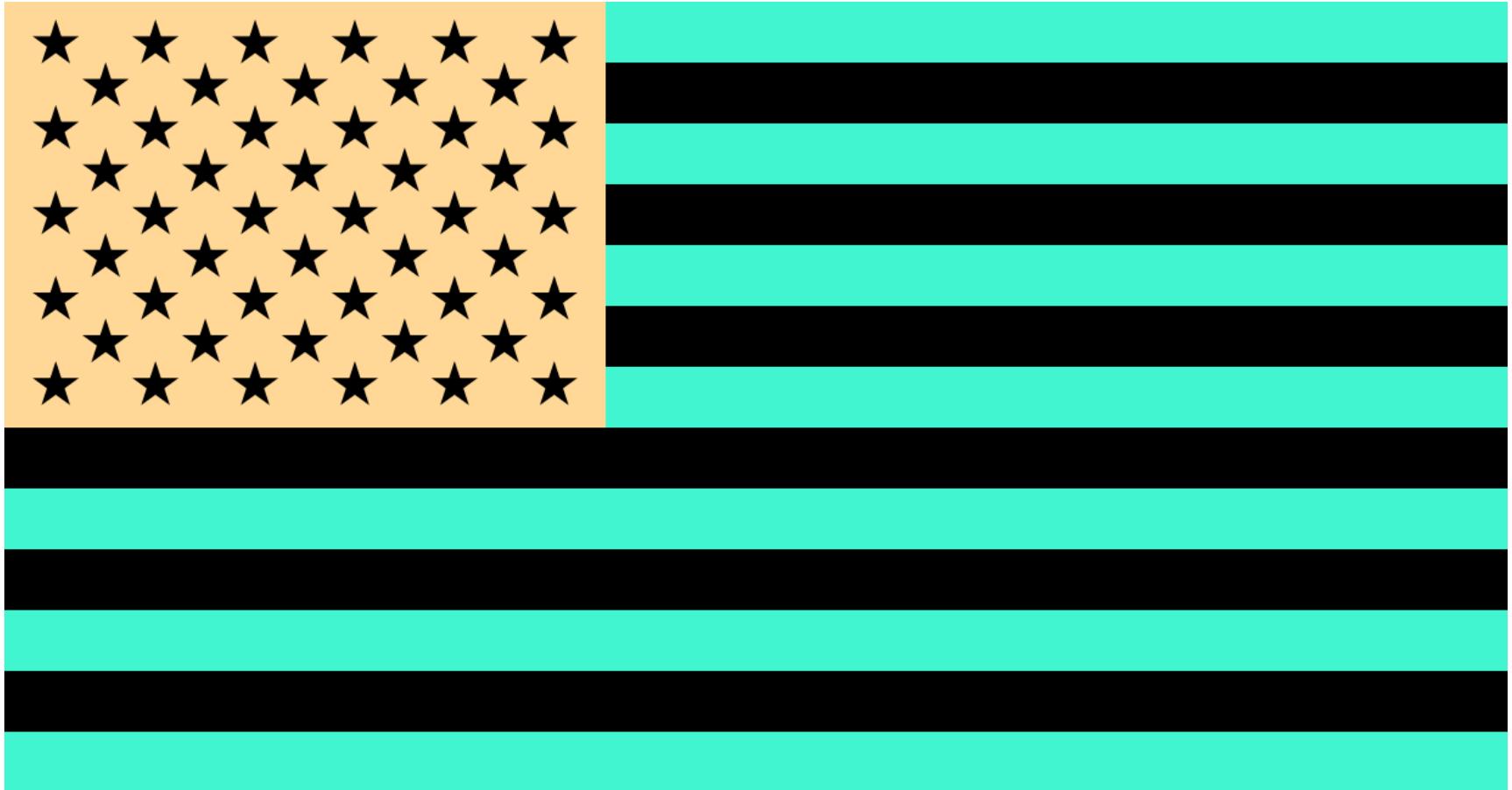




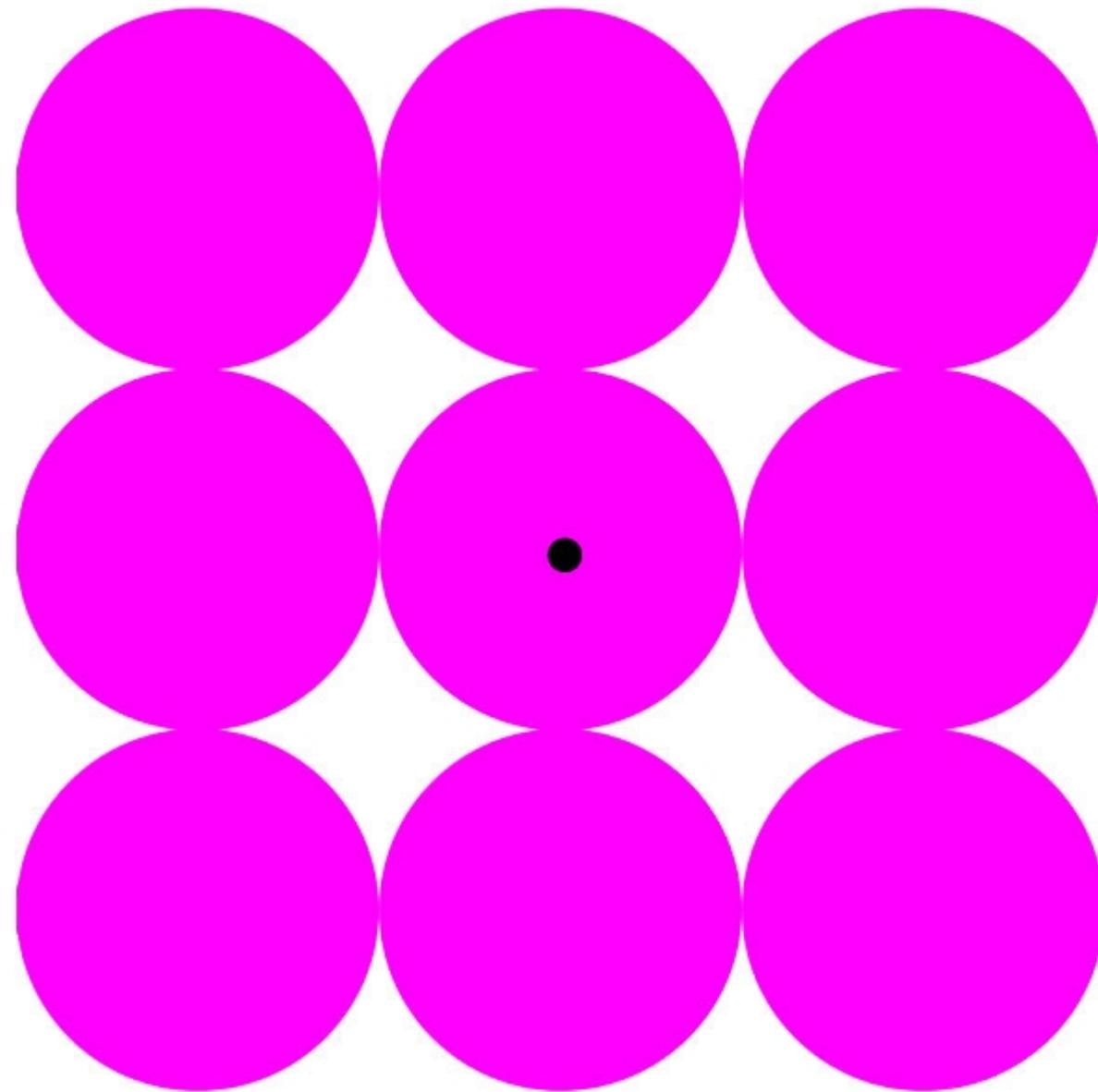


# Photo-receptors & color vision



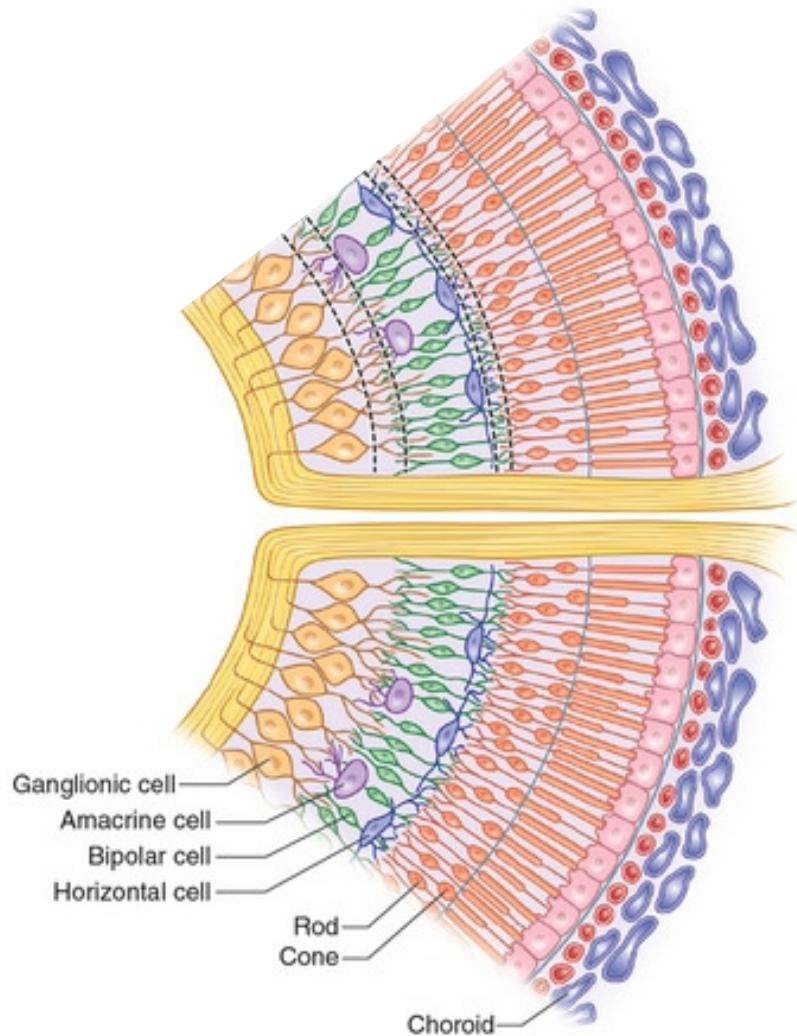




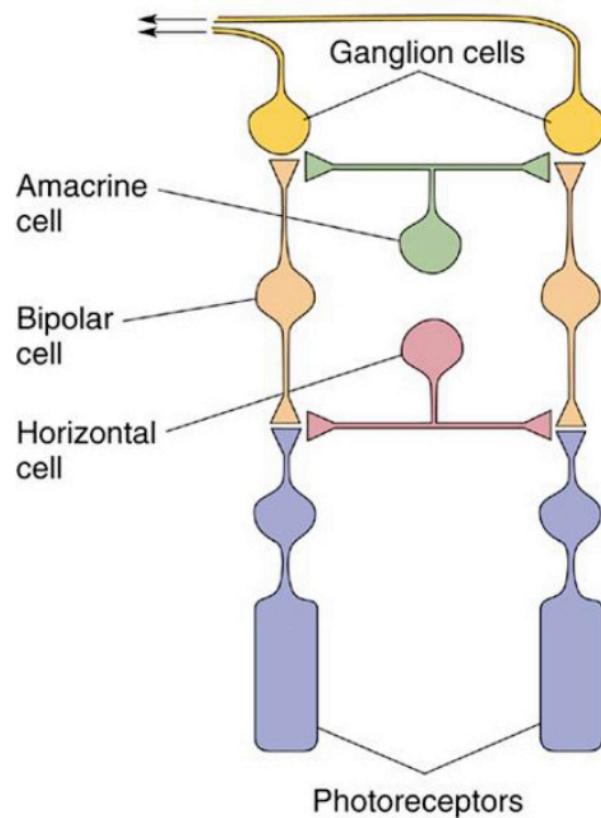




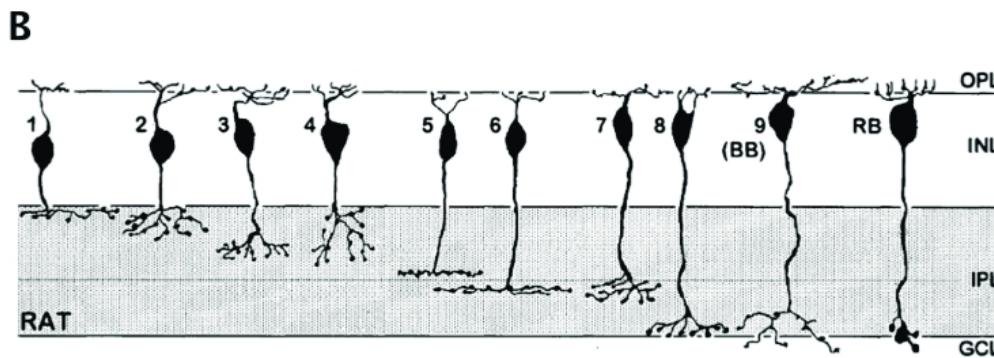
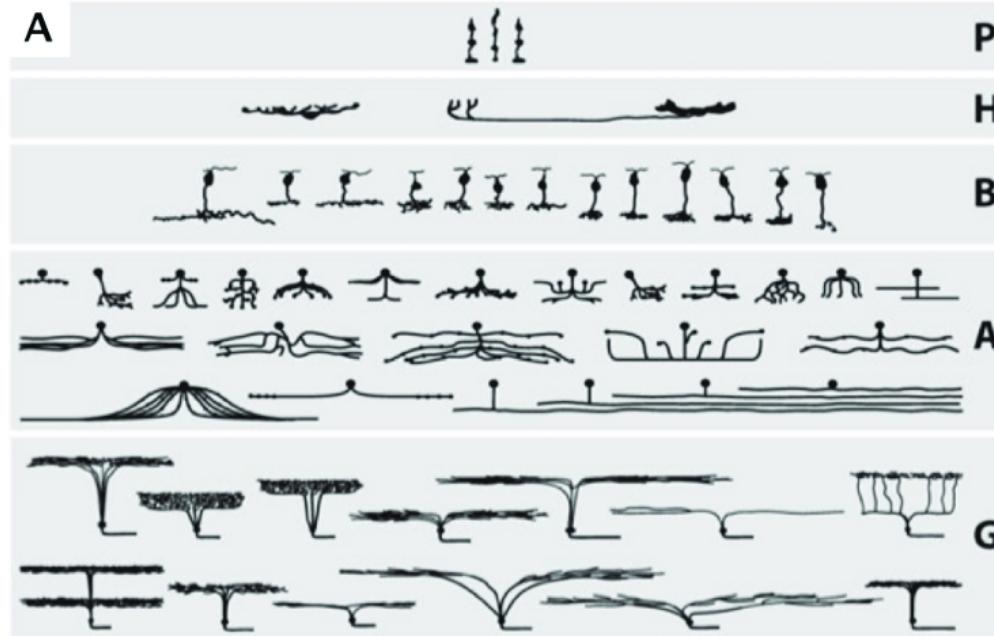
# Retina as layered computation



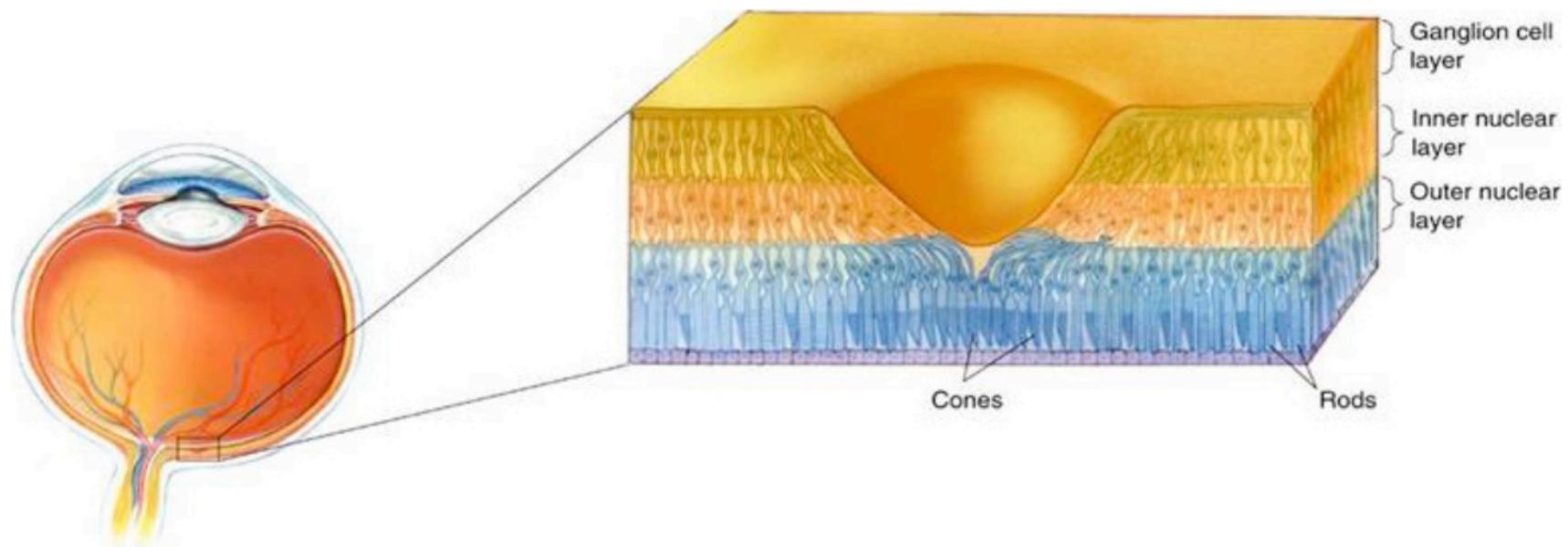
Ganglion cell axons  
projecting to forebrain



# More than 80 retinal cell types

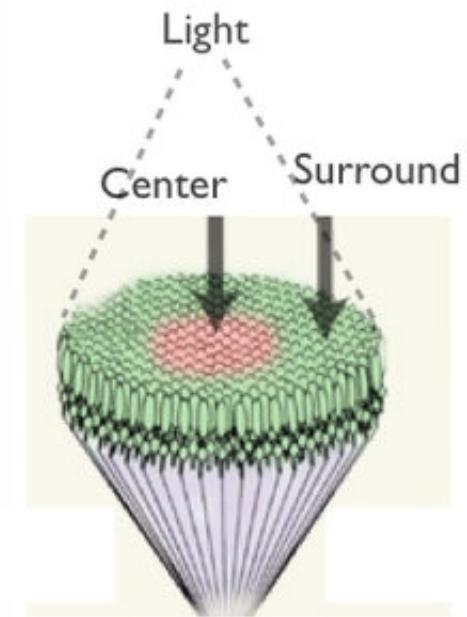
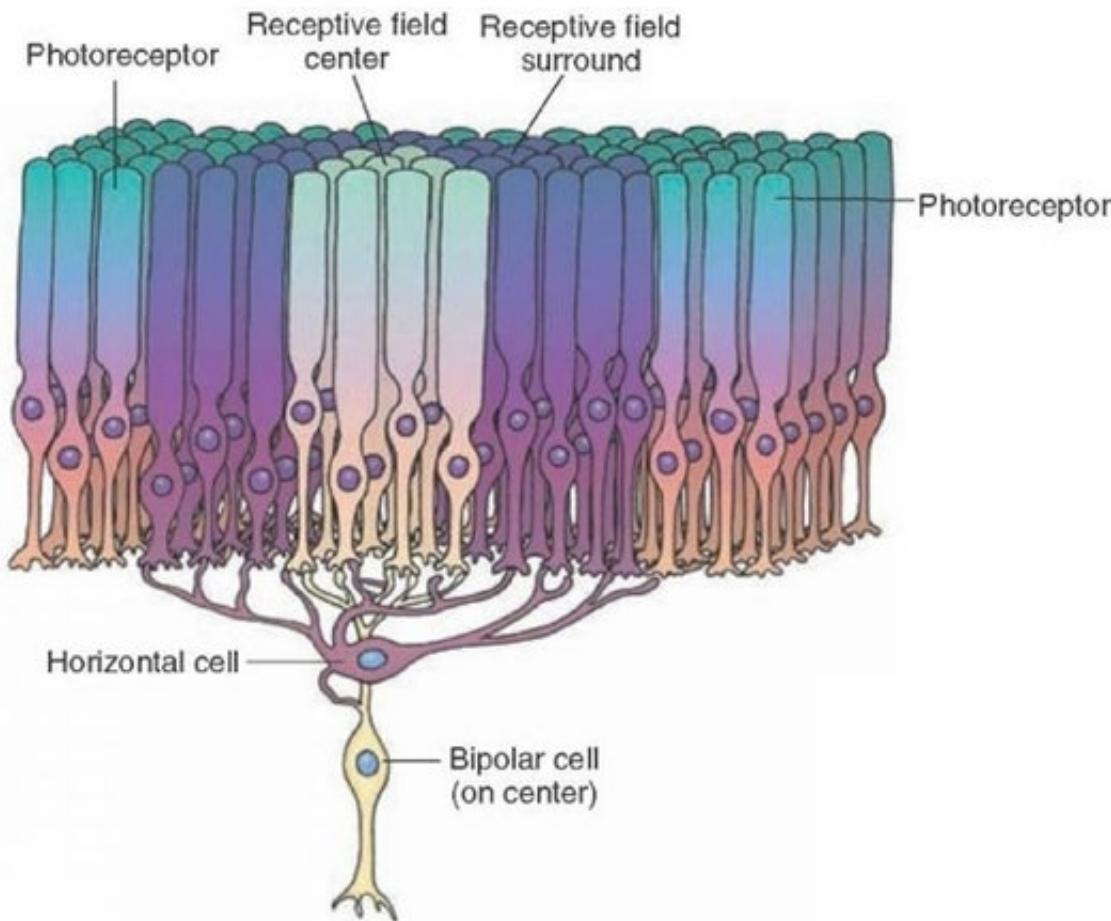


# Fovea – macular pit

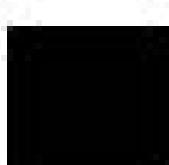
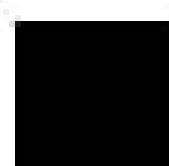
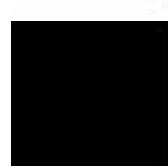
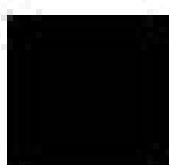
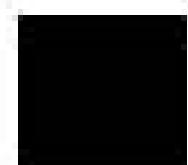
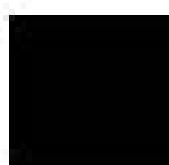
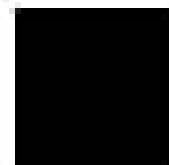
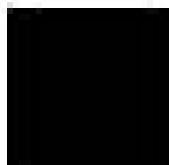
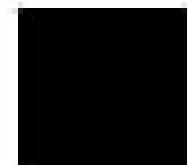
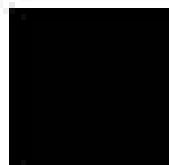


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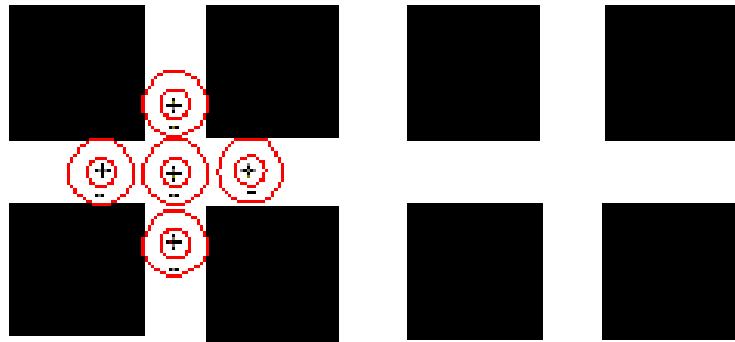
# Retinal receptive fields



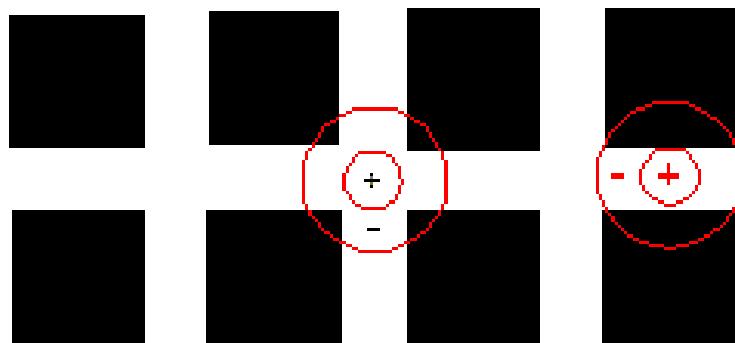
Retinal ganglion cell



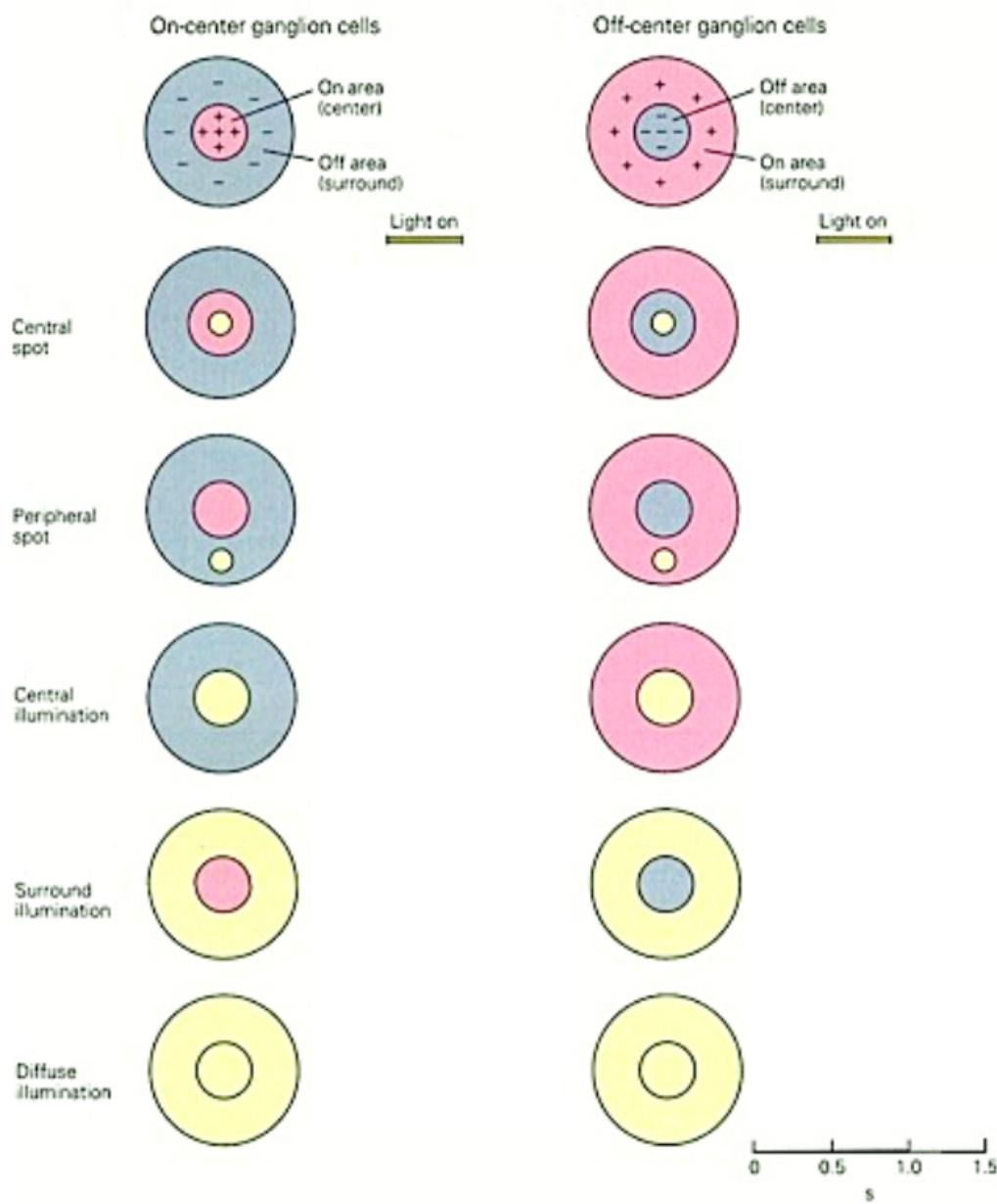
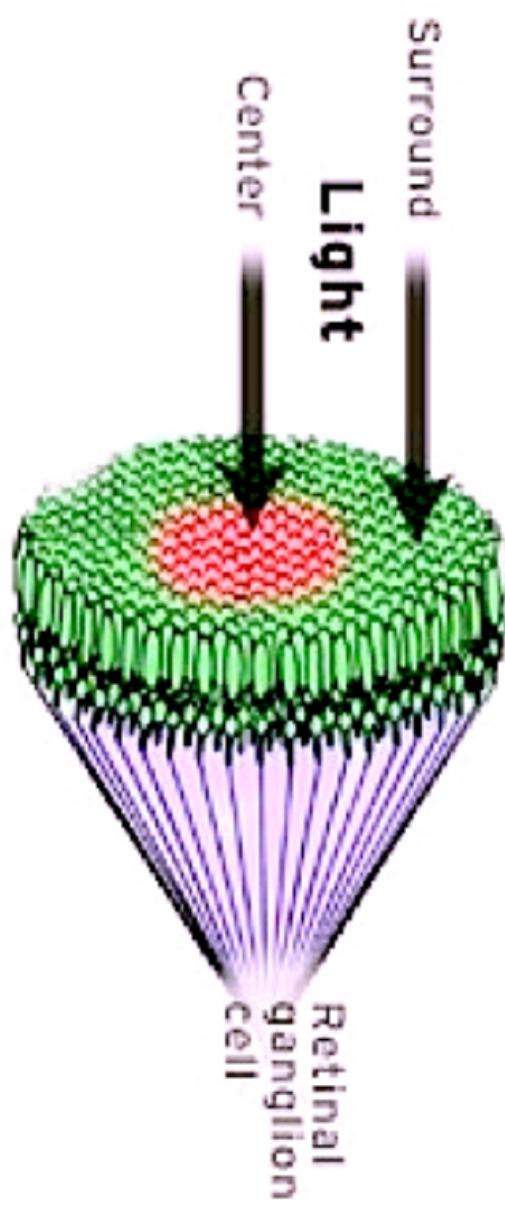
foveal  
representation

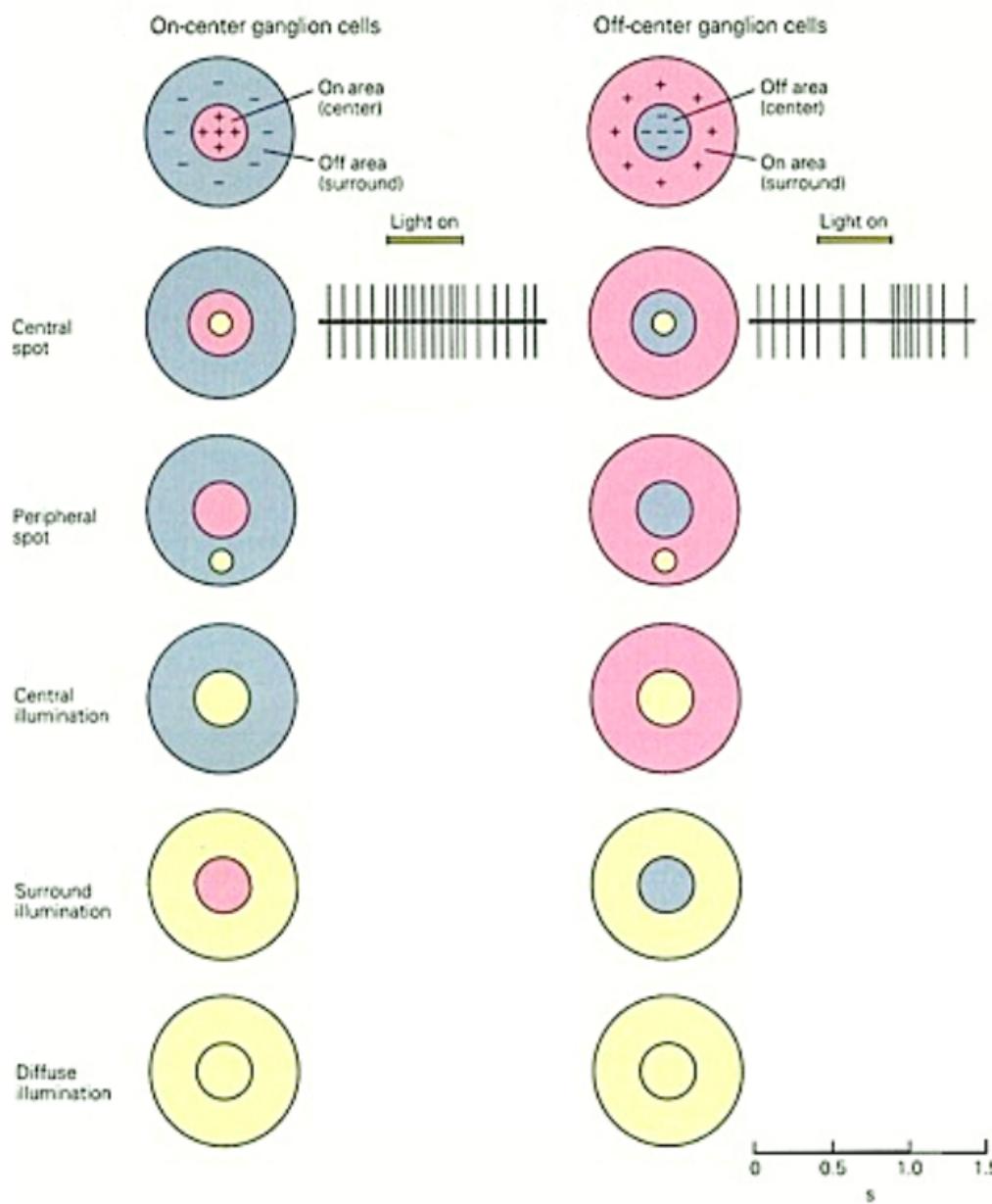
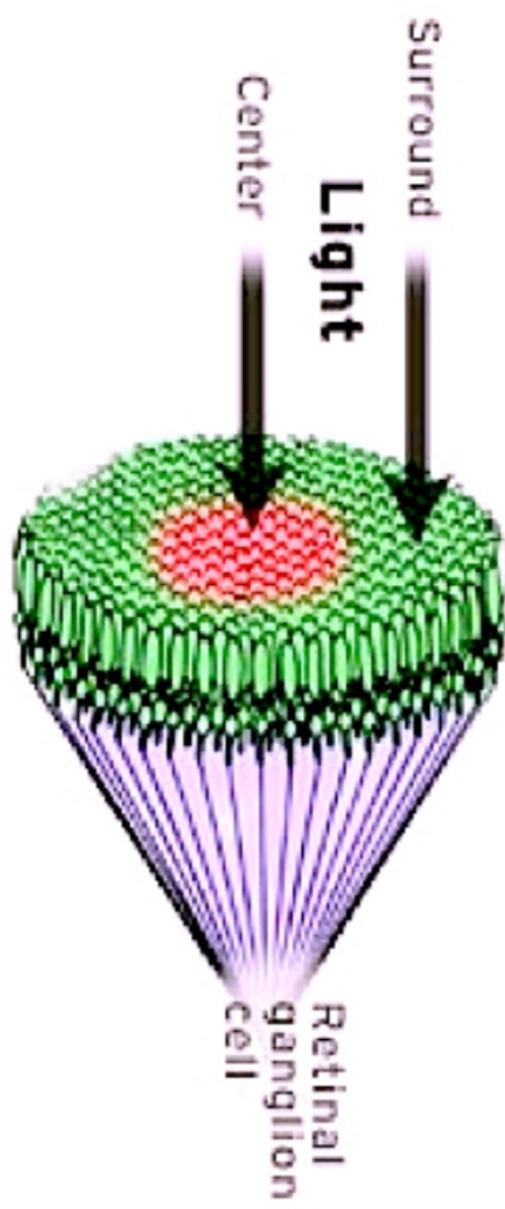


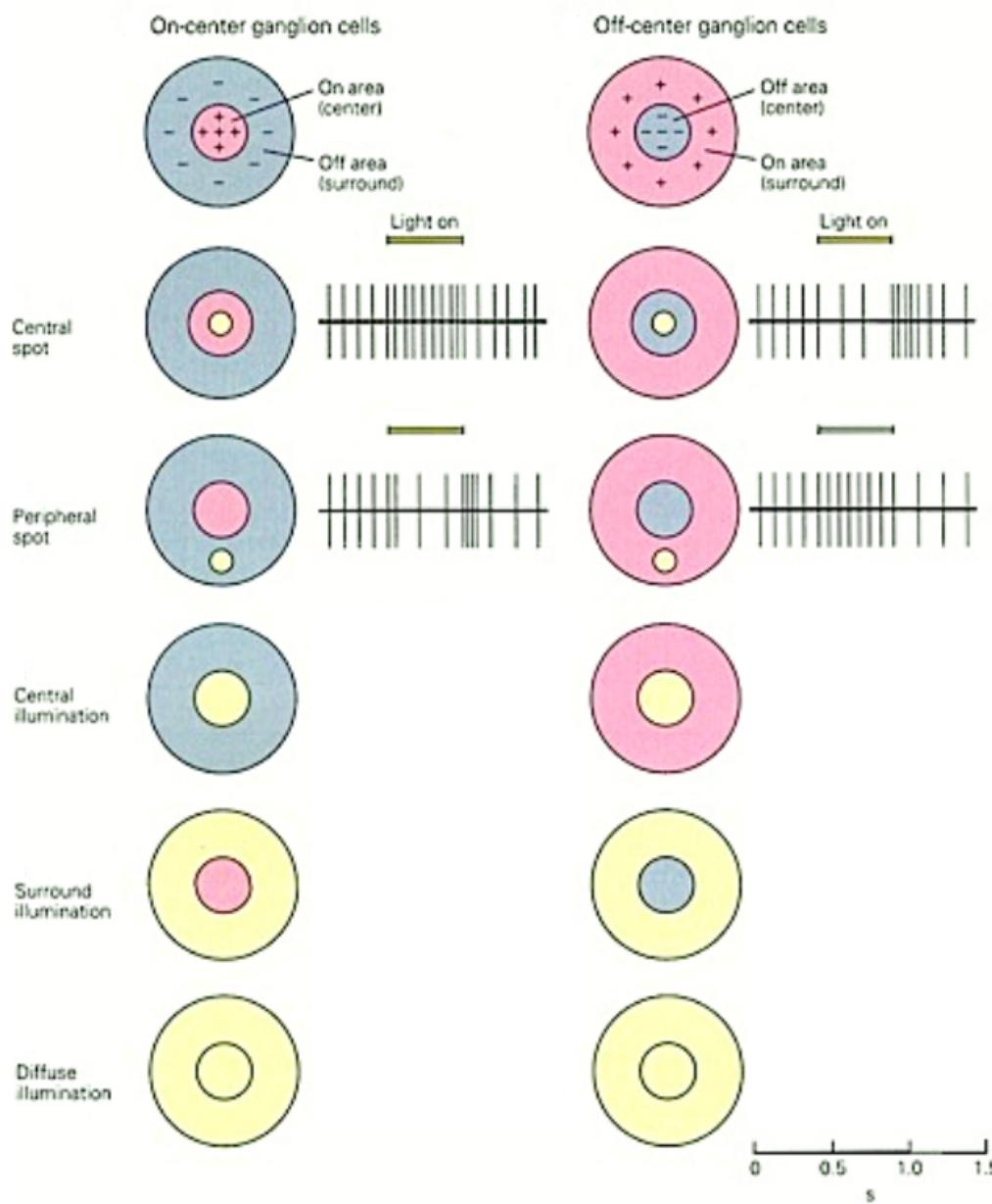
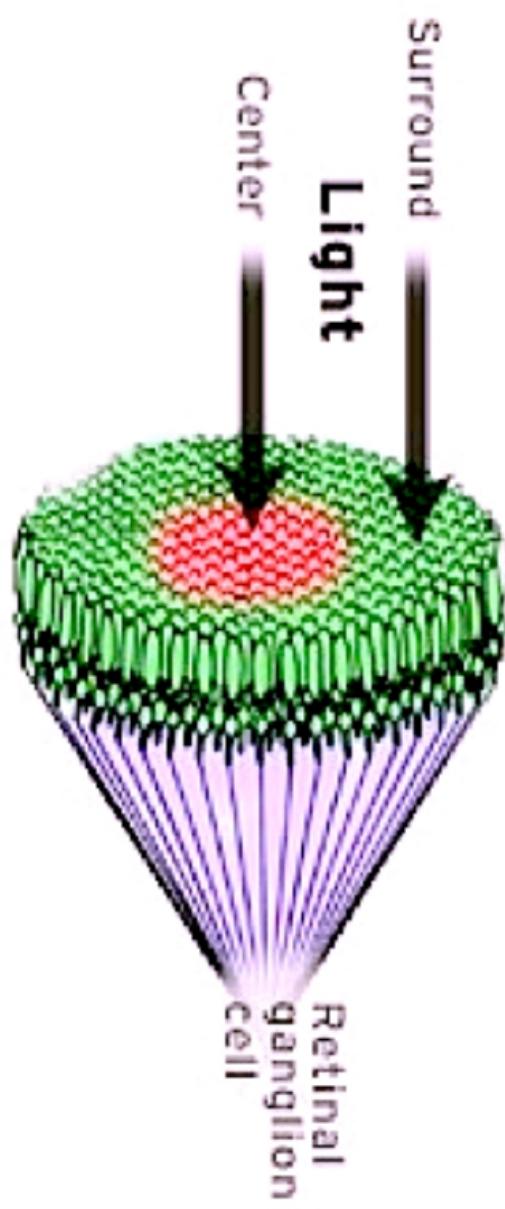
extra-foveal  
representation

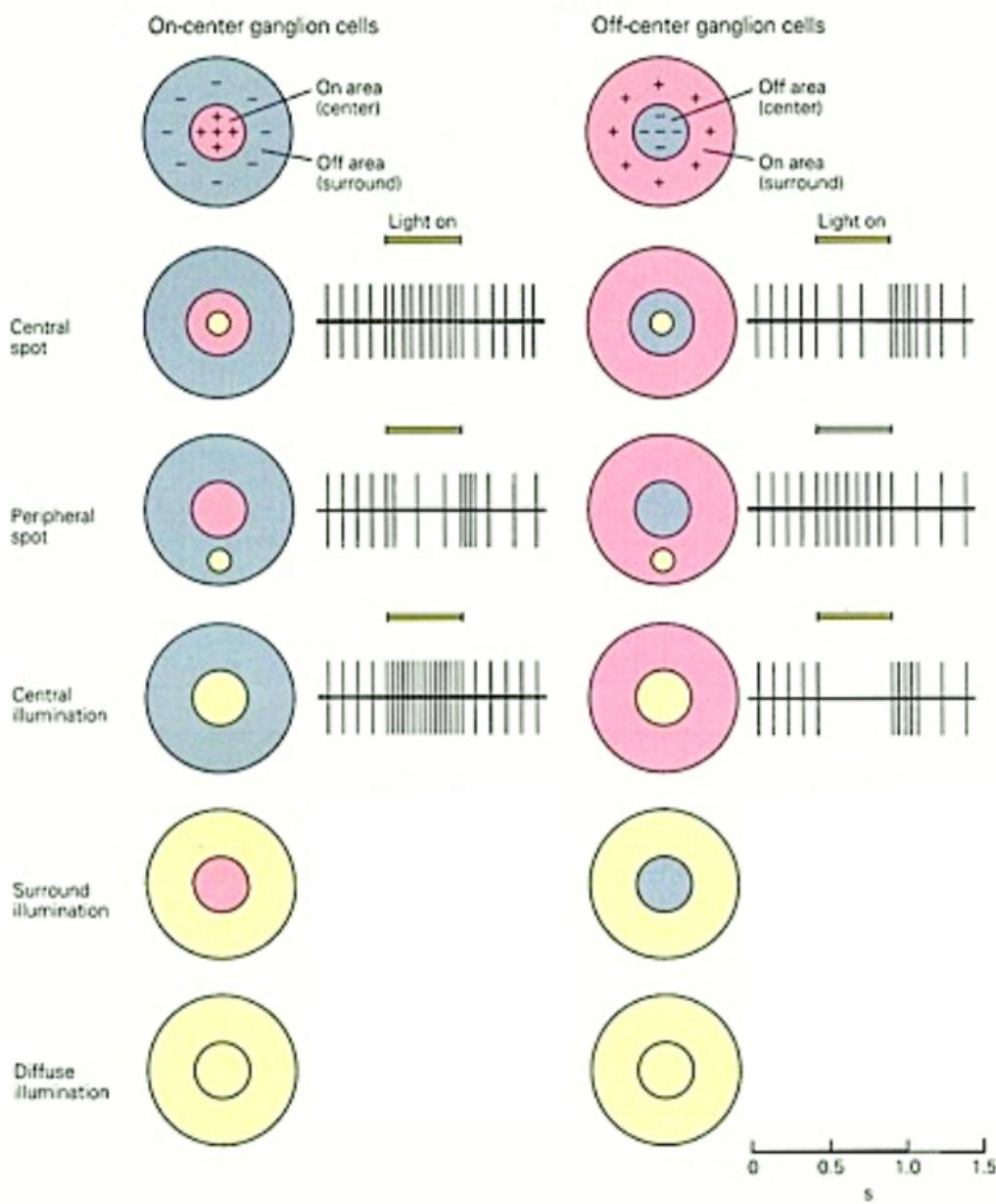
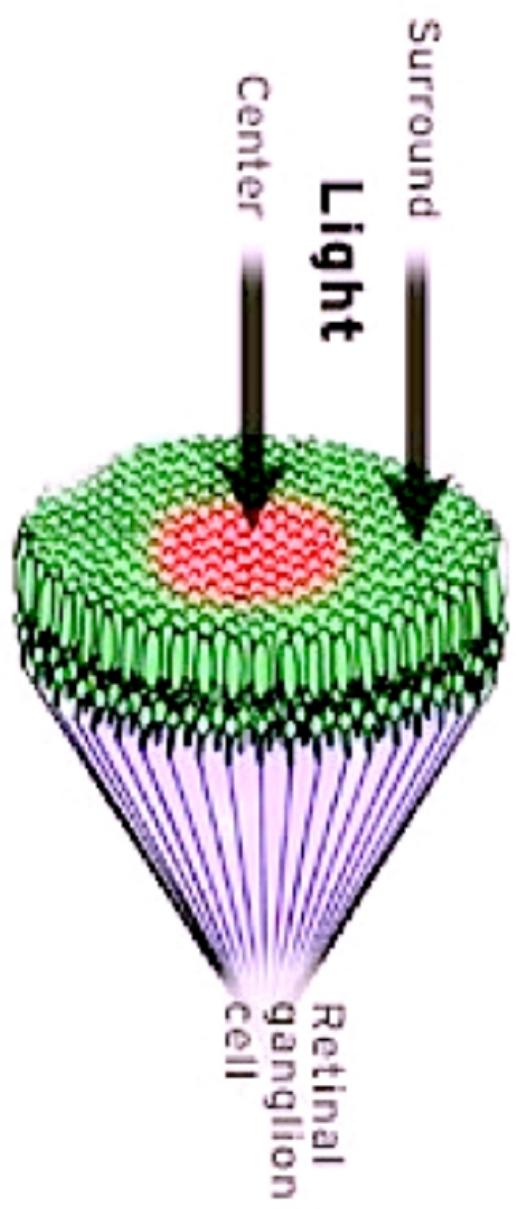


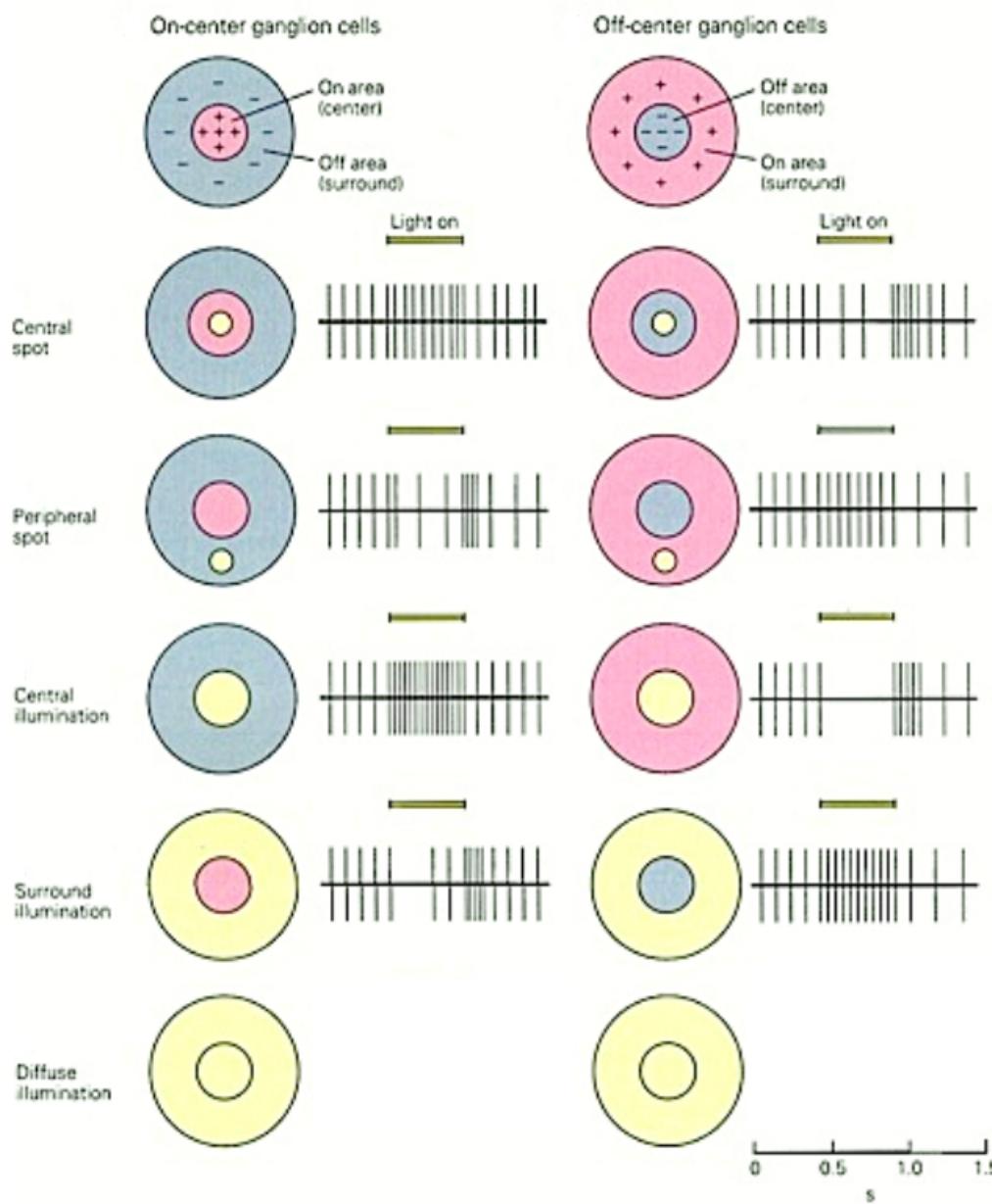
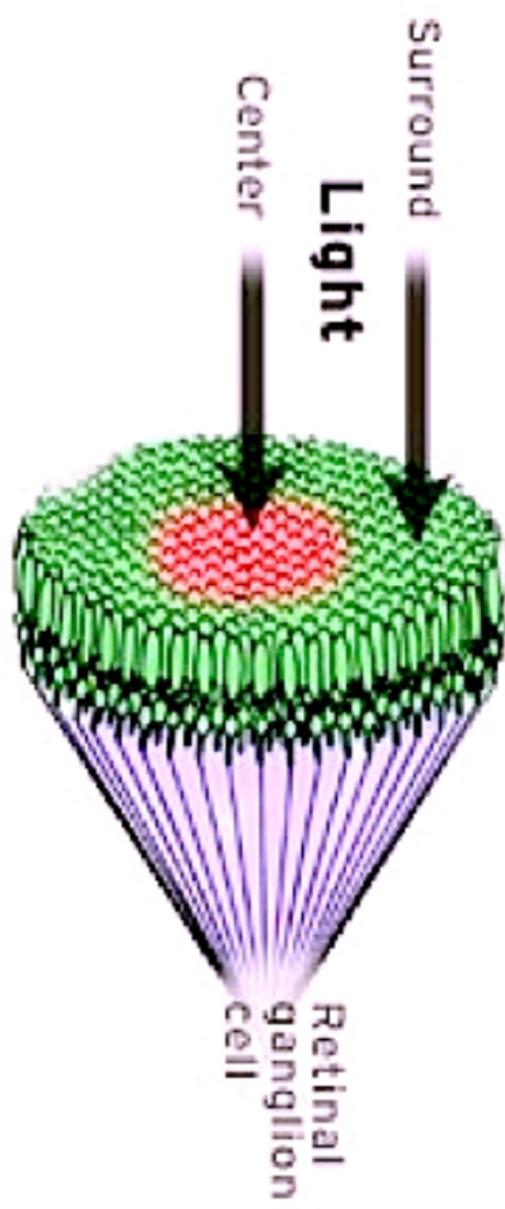
# Spatial properties of RF











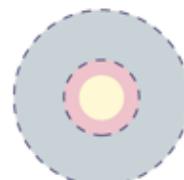
# Temporal properties of RF

■ On area  
□ Off area

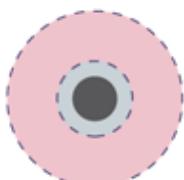
■ } Stimuli

Stimulus pattern

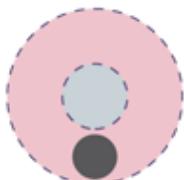
1 Center only



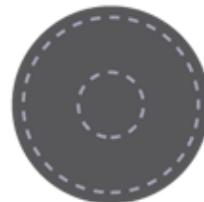
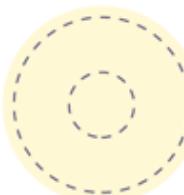
ON cells



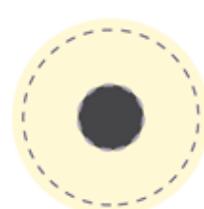
2 Surround only



3 Center and surround uniform



4 Center and surround opposite



Stimulus

0

Time (s)

1

2

0

Time (s)

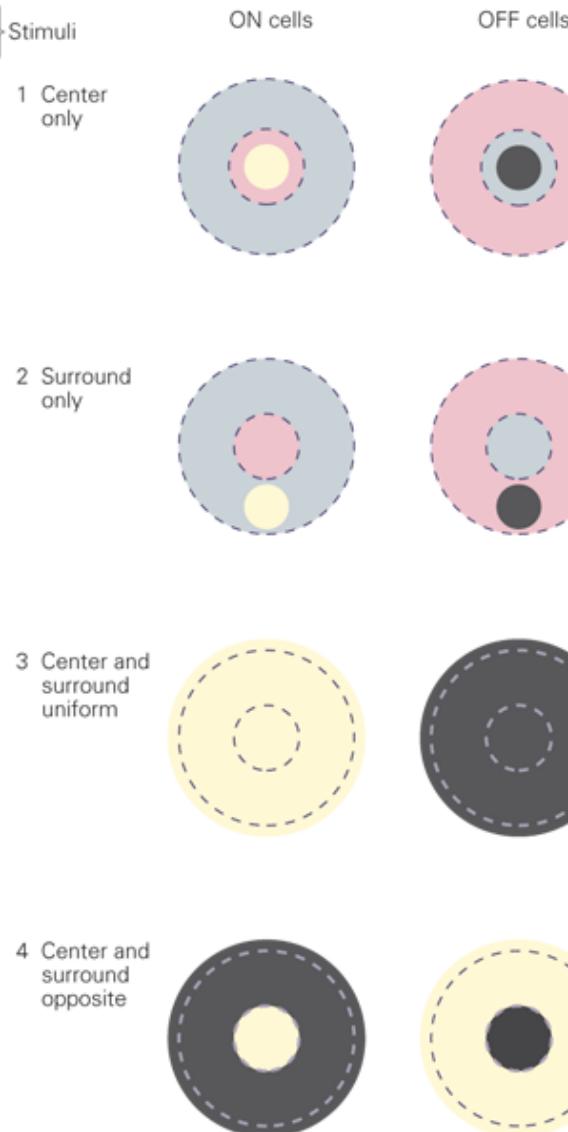
1

2

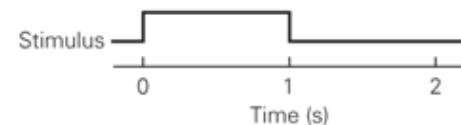
■ On area  
■ Off area

■ Stimuli

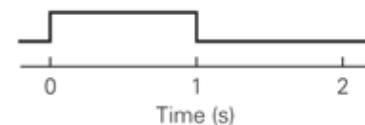
Stimulus pattern



M-type



P-type



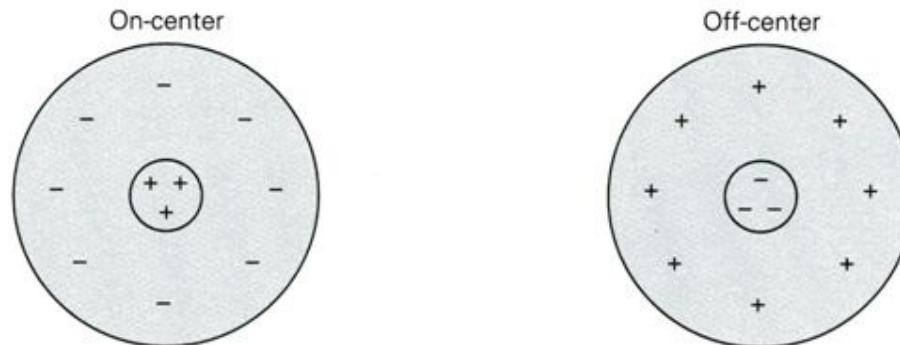
# M,P,K cell types

- P-type are 90% of the population
- M-type are 5% of the population
- M-type
  - Larger RF
  - Faster (conduct APs faster)
  - Transient
  - Achromatic

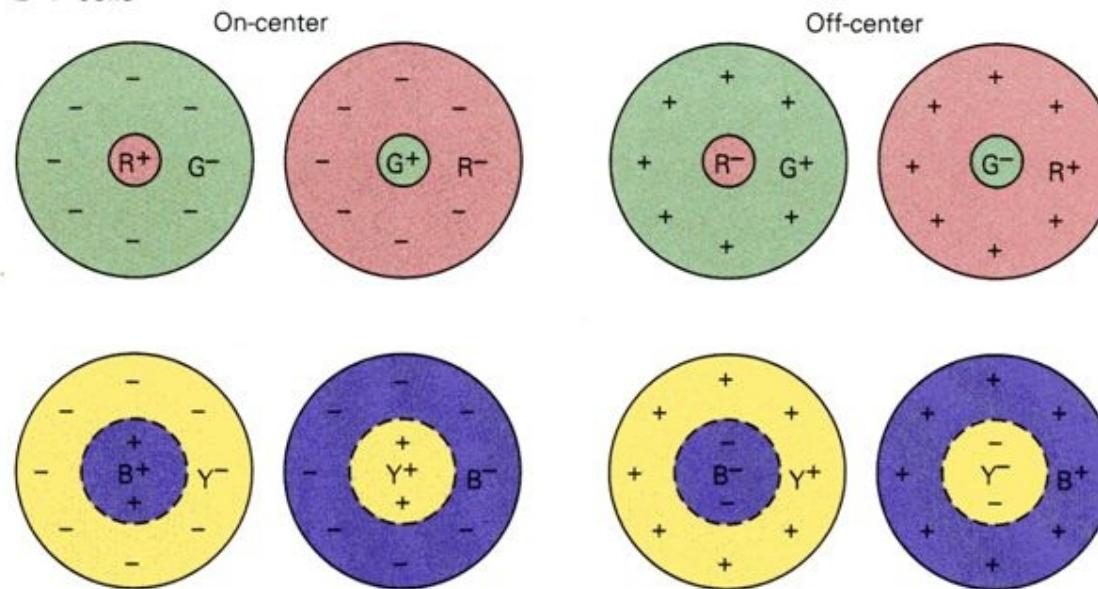
# Color properties of RF

# Colour opponent ganglion cells

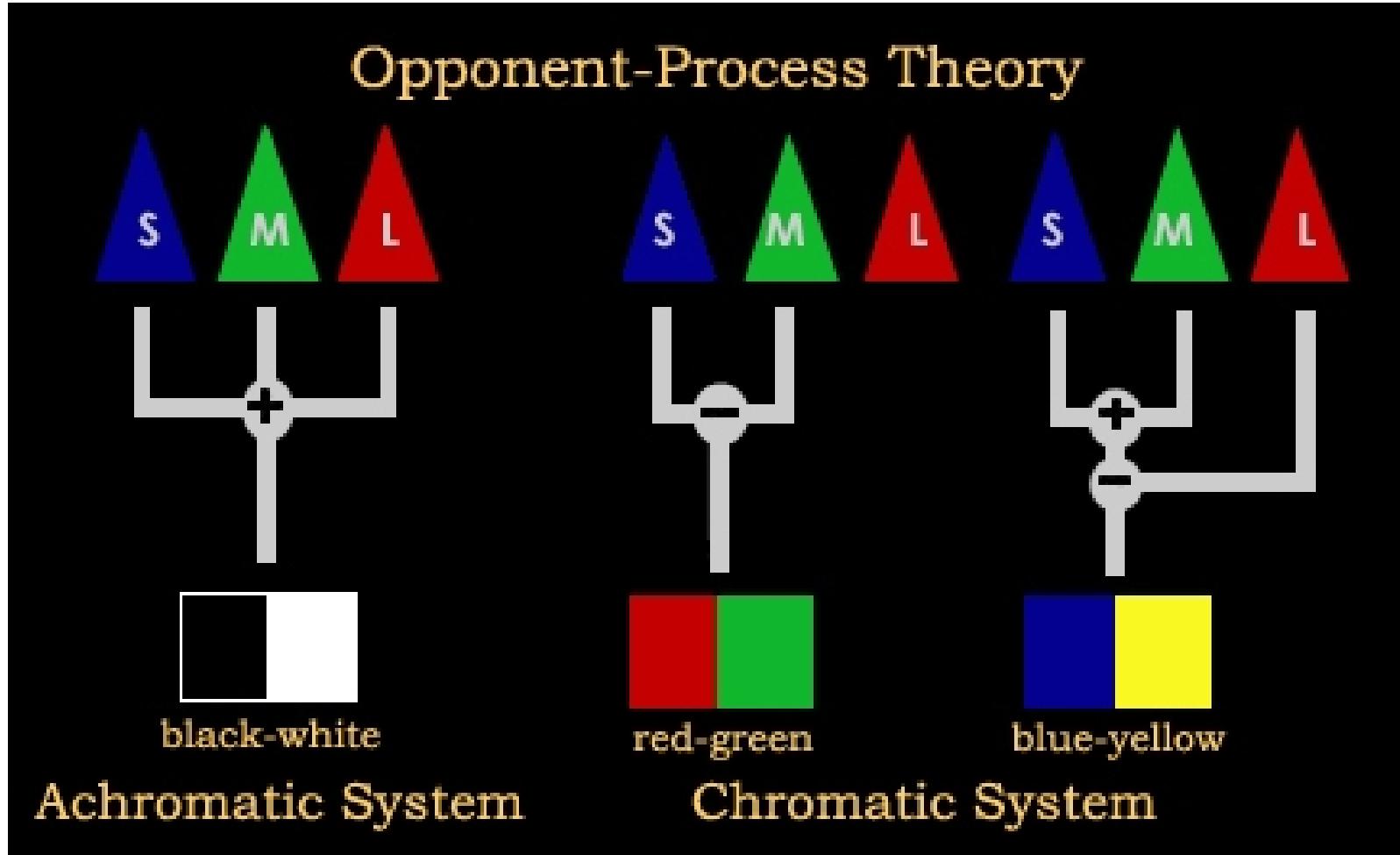
A M cells



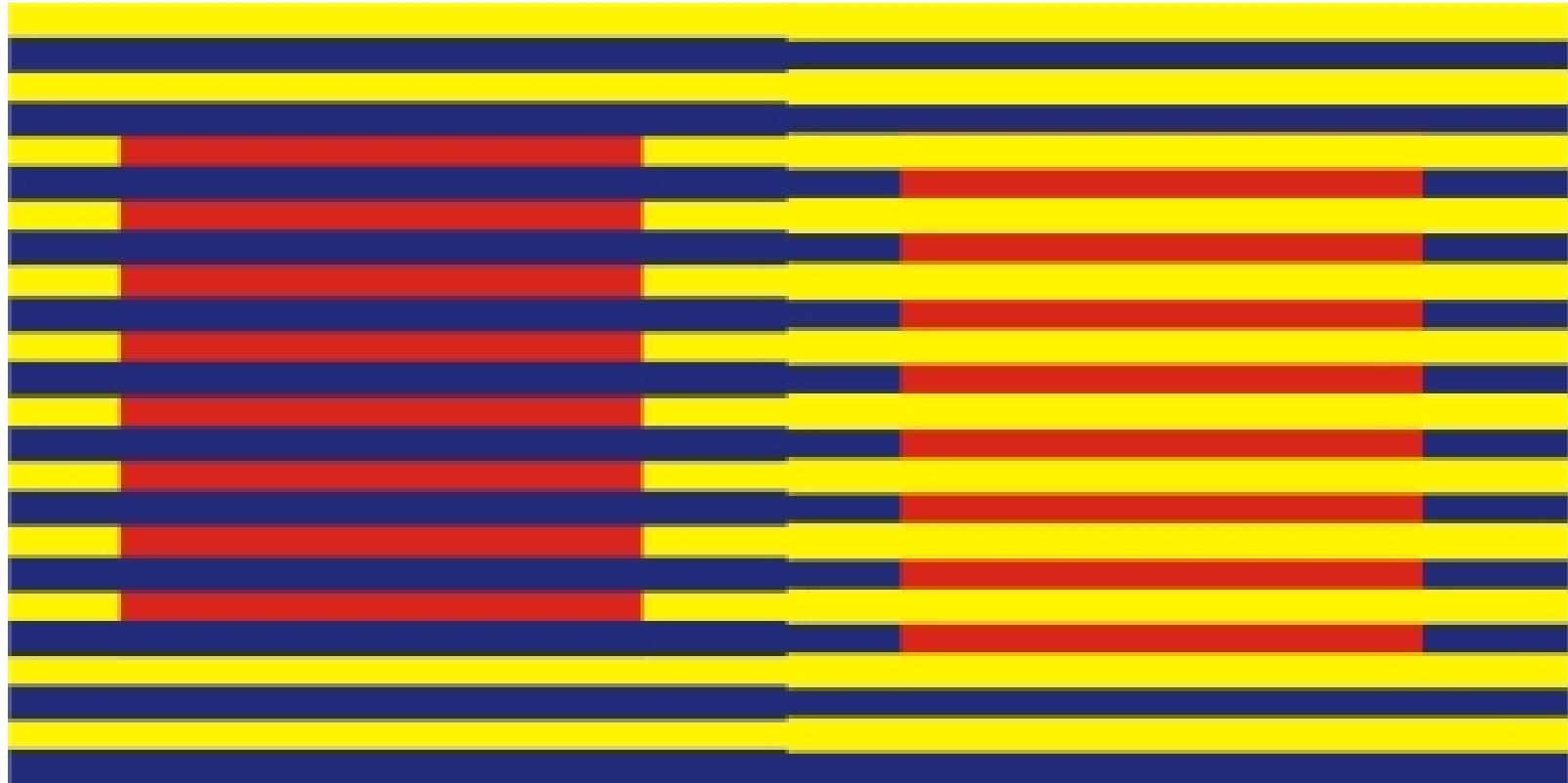
B P cells



# How are they constructed?







# Retinal mosaics

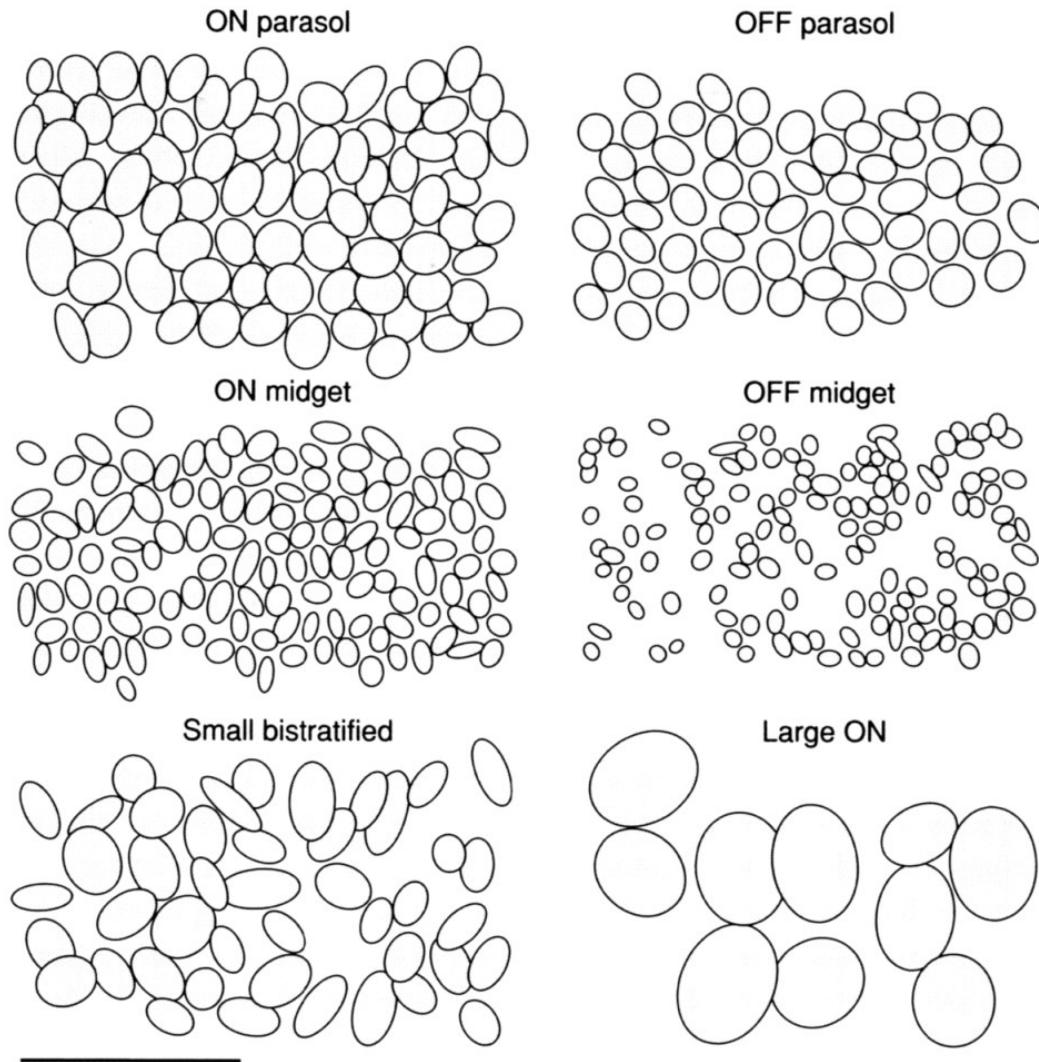
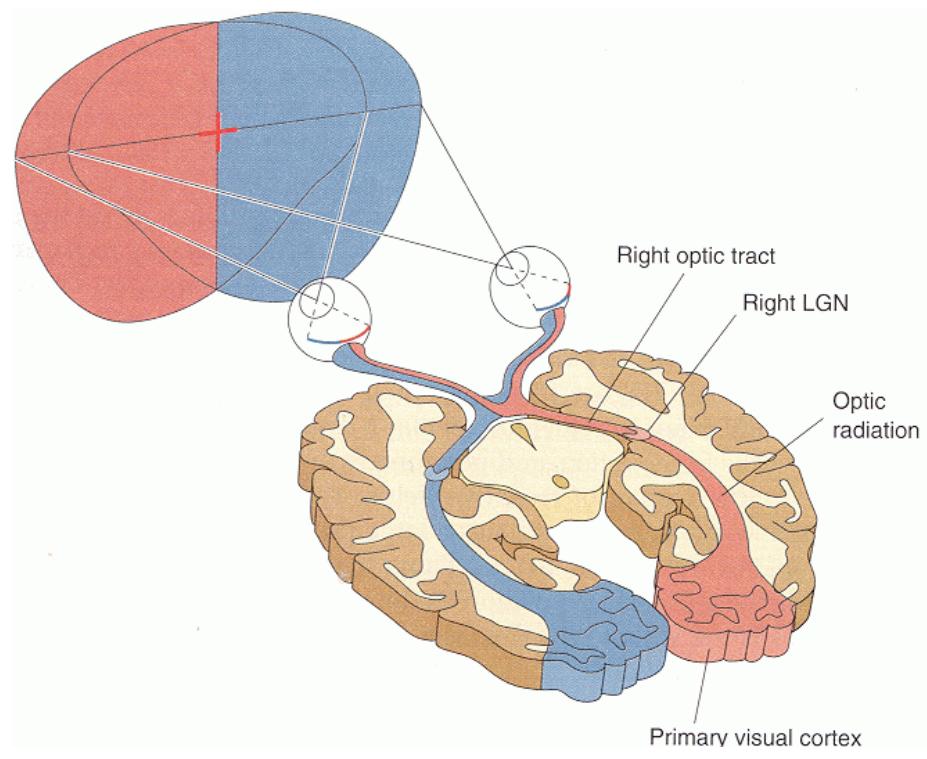
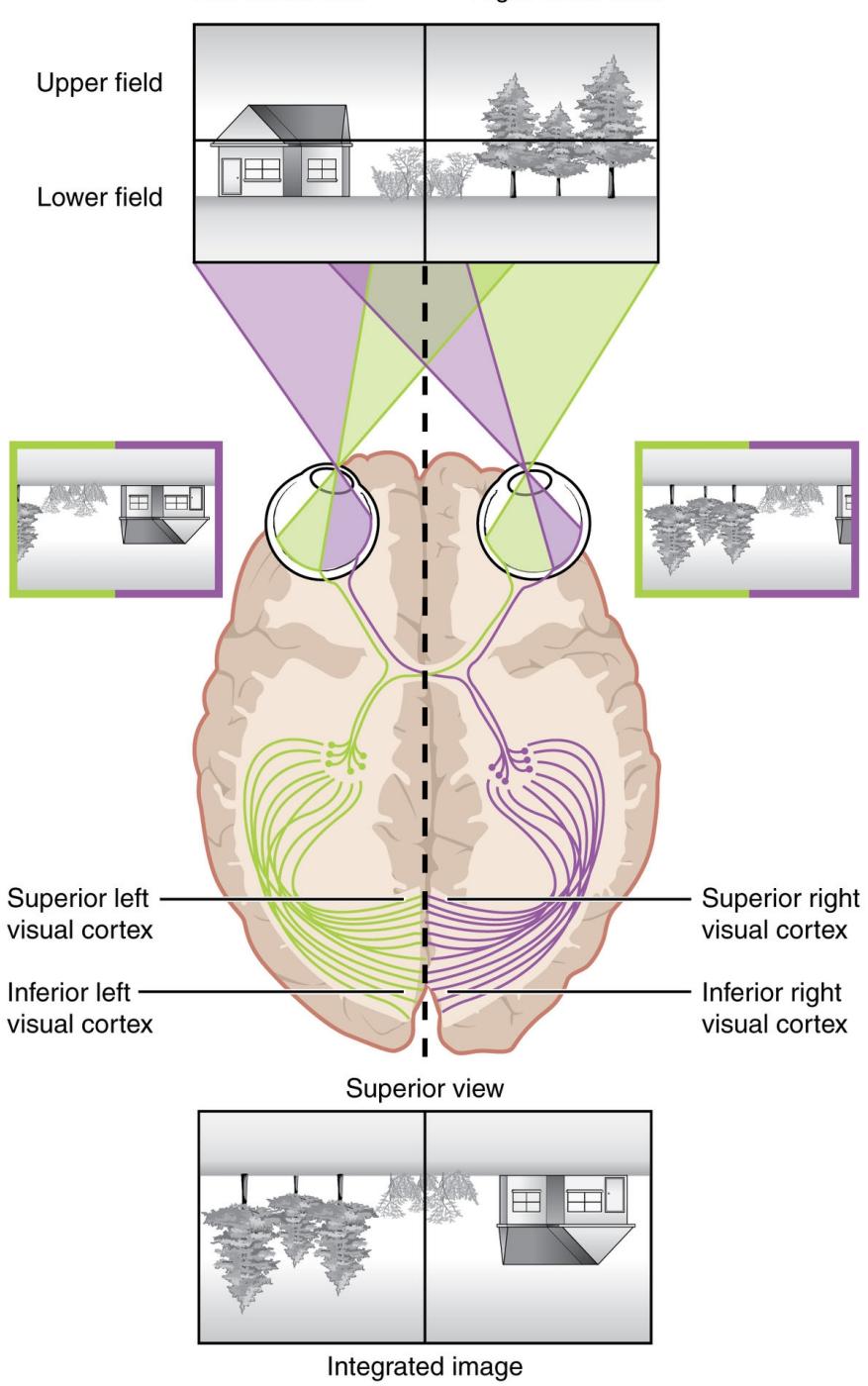
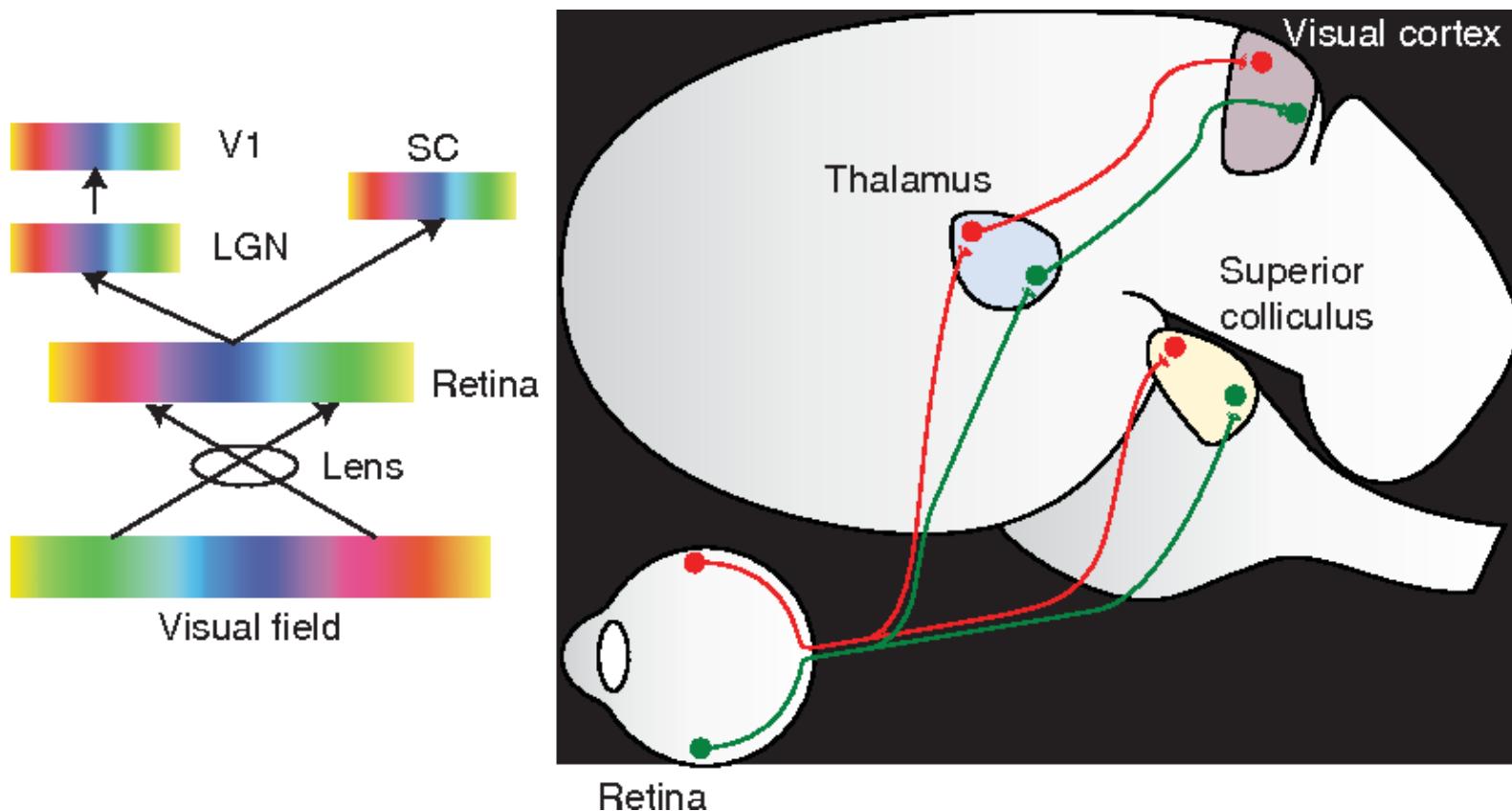


Figure 3

# Organization of visual field

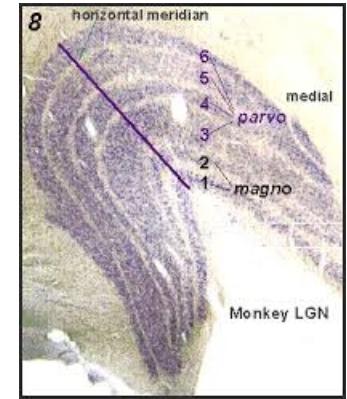


# Retinotopy



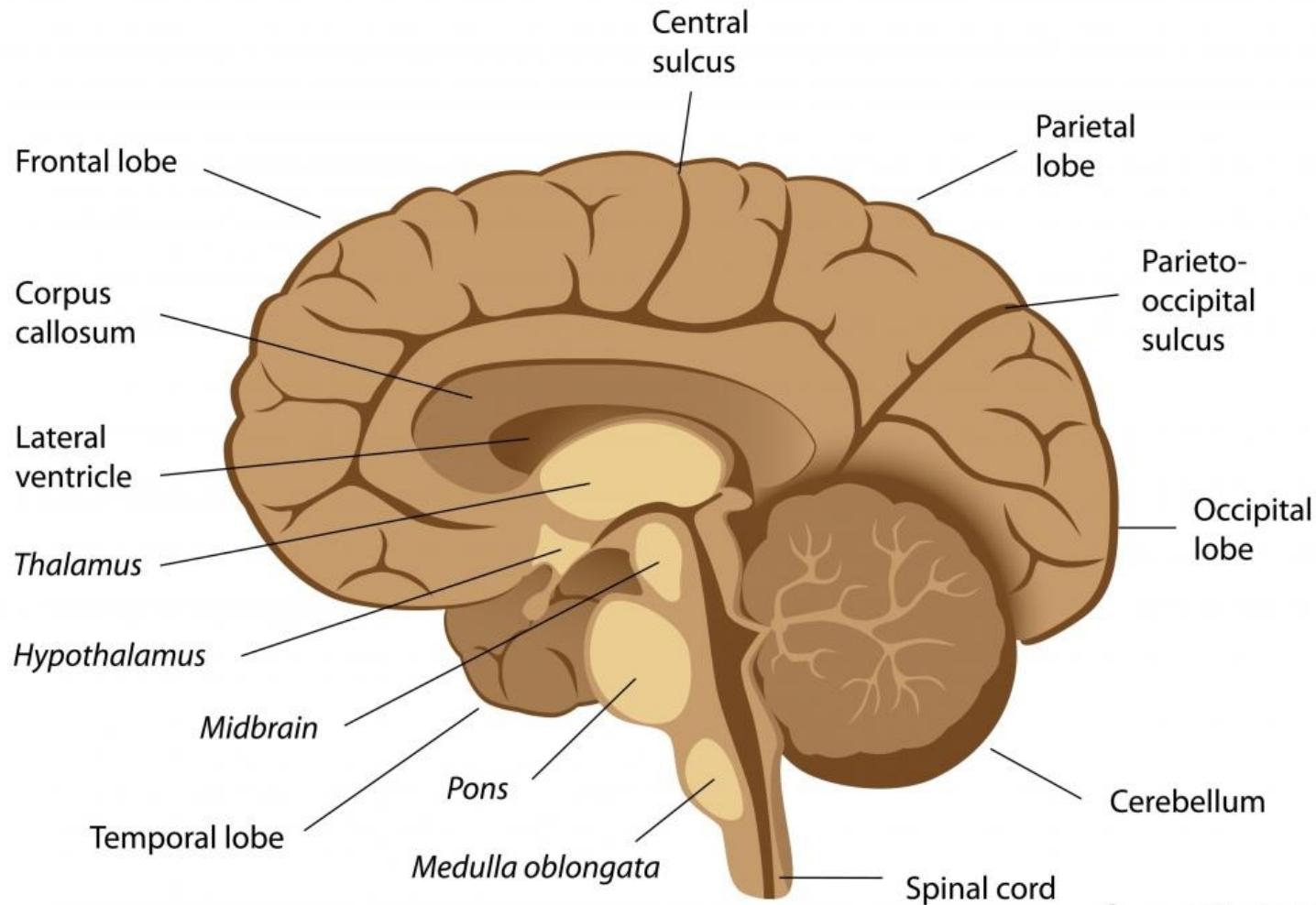
90% retinal output goes to thalamus  
10% to superior colliculus

# THALAMUS



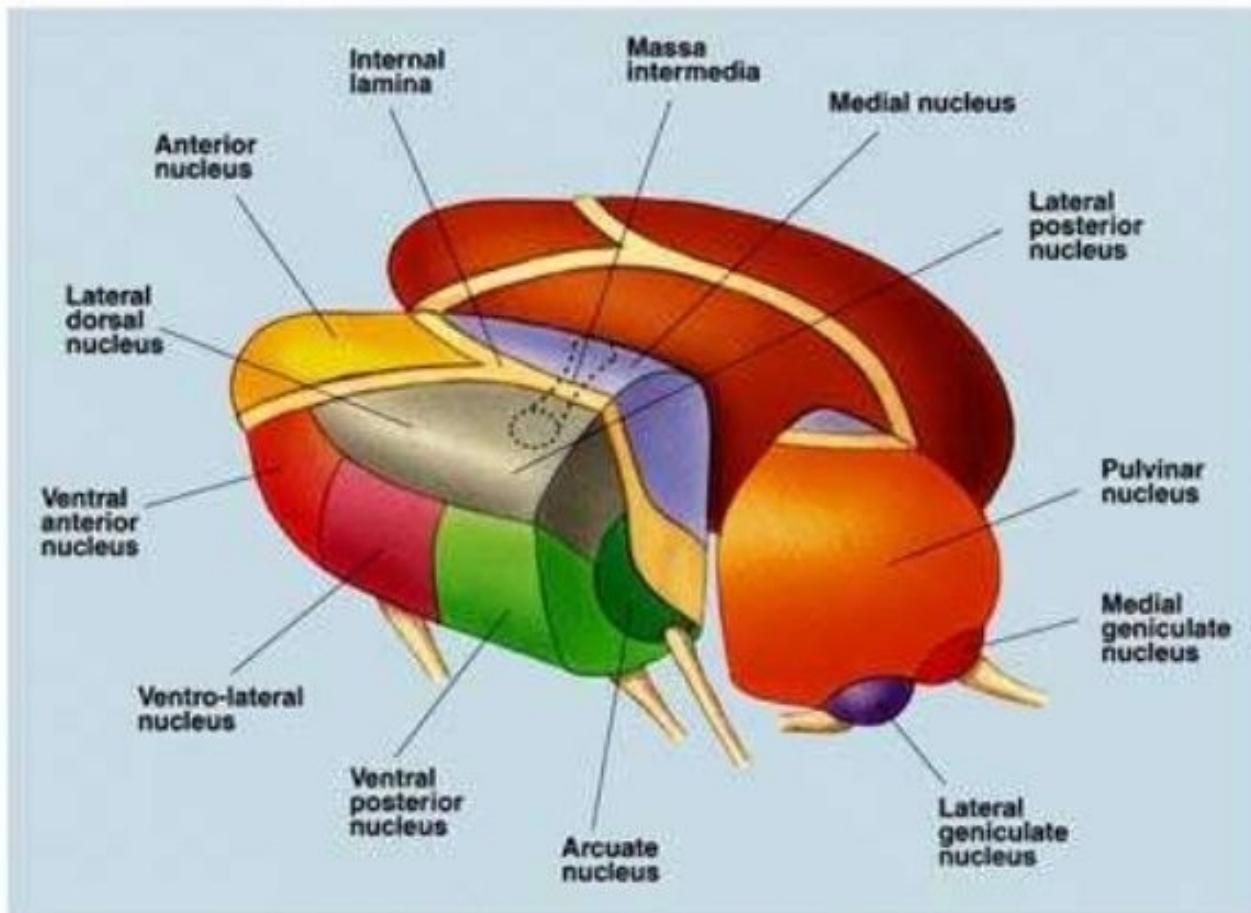
## LATERAL GENICULATE NUCLEUS (LGN)

# Where is thalamus?

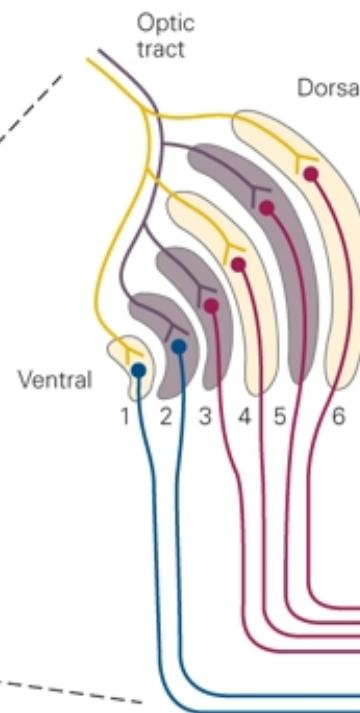
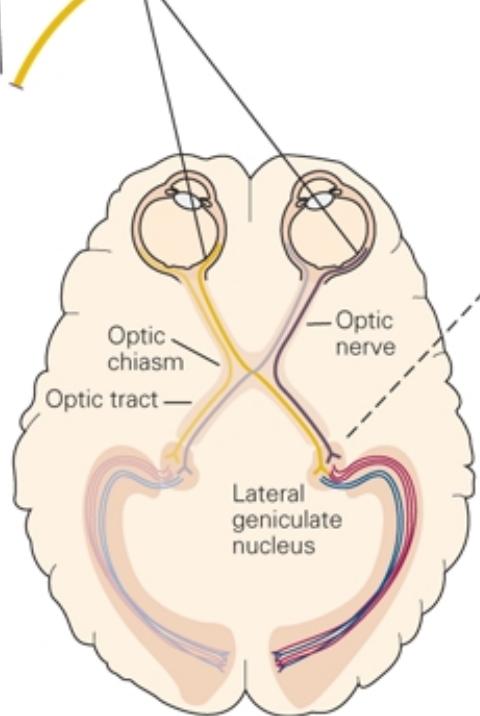
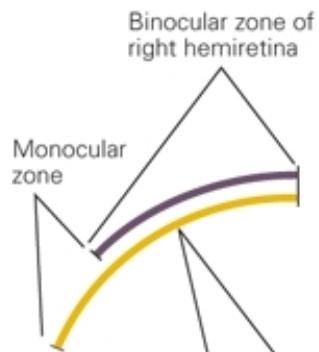


# Where is LGN

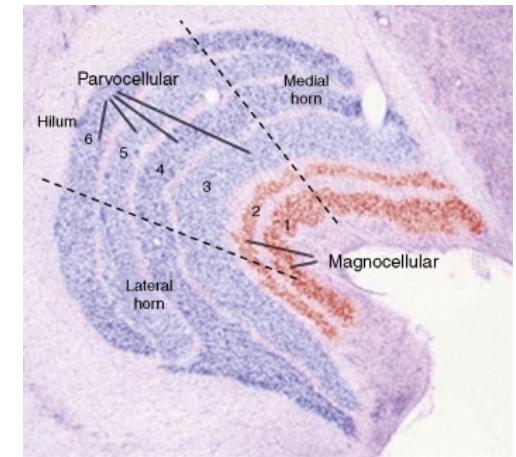
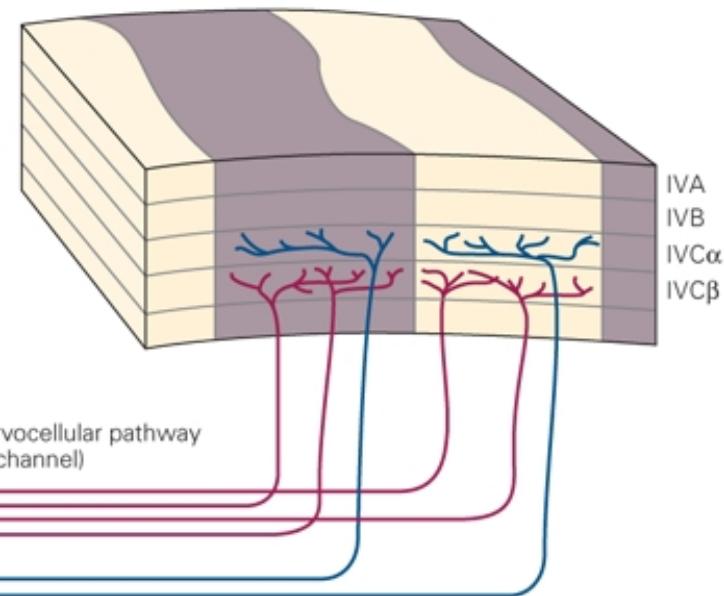
## ► Nuclei of the Thalamus



# The Magno & Parvo pathway



Magnocellular pathway  
(M channel)

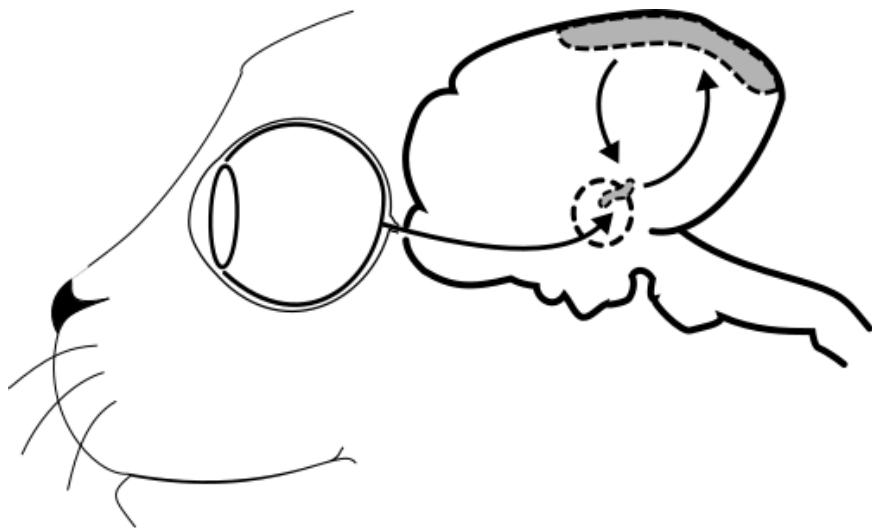


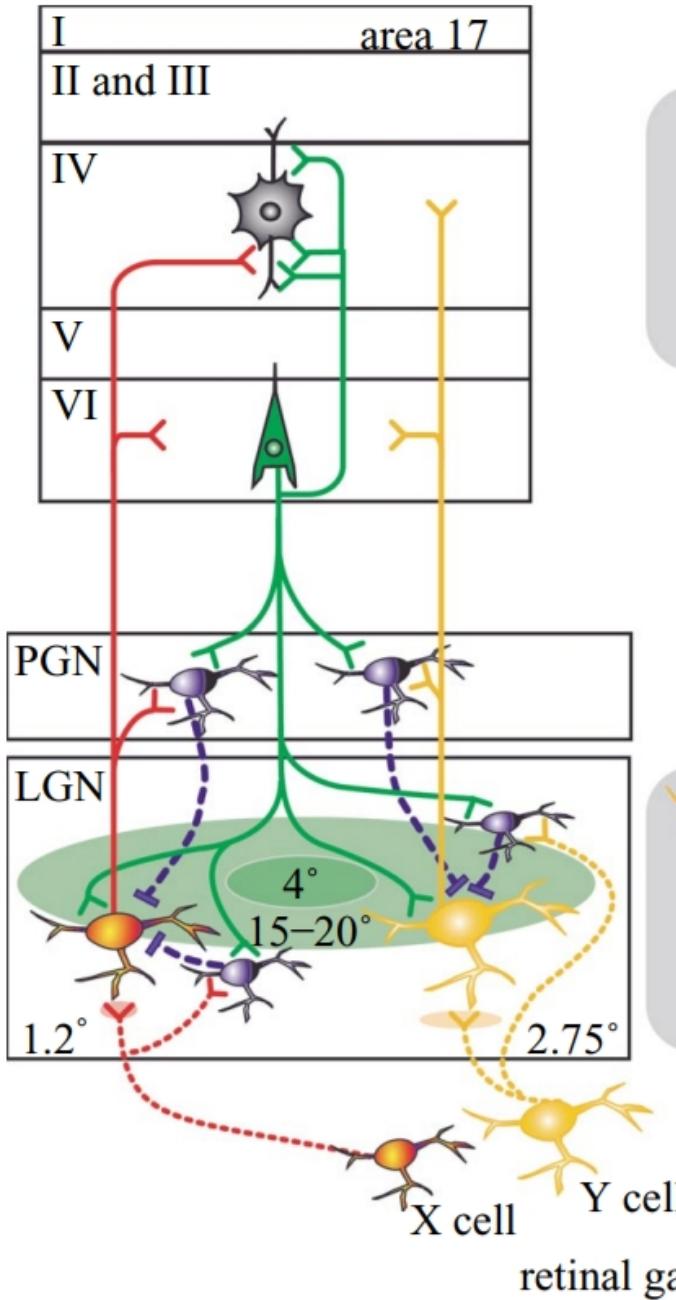
# Receptive fields in LGN

- ON/OFF
- Magnocellular
  - Contrast detection already at 2%
  - Low acuity (spatial resolution)
  - Fast (high temporal resolution)
- Parvocellular
  - Contrast detection at 10%
  - Color
  - High acuity

Most text-books stop here, but  
there is a lot more to LGN!

# Massive feedback from cortex to LGN





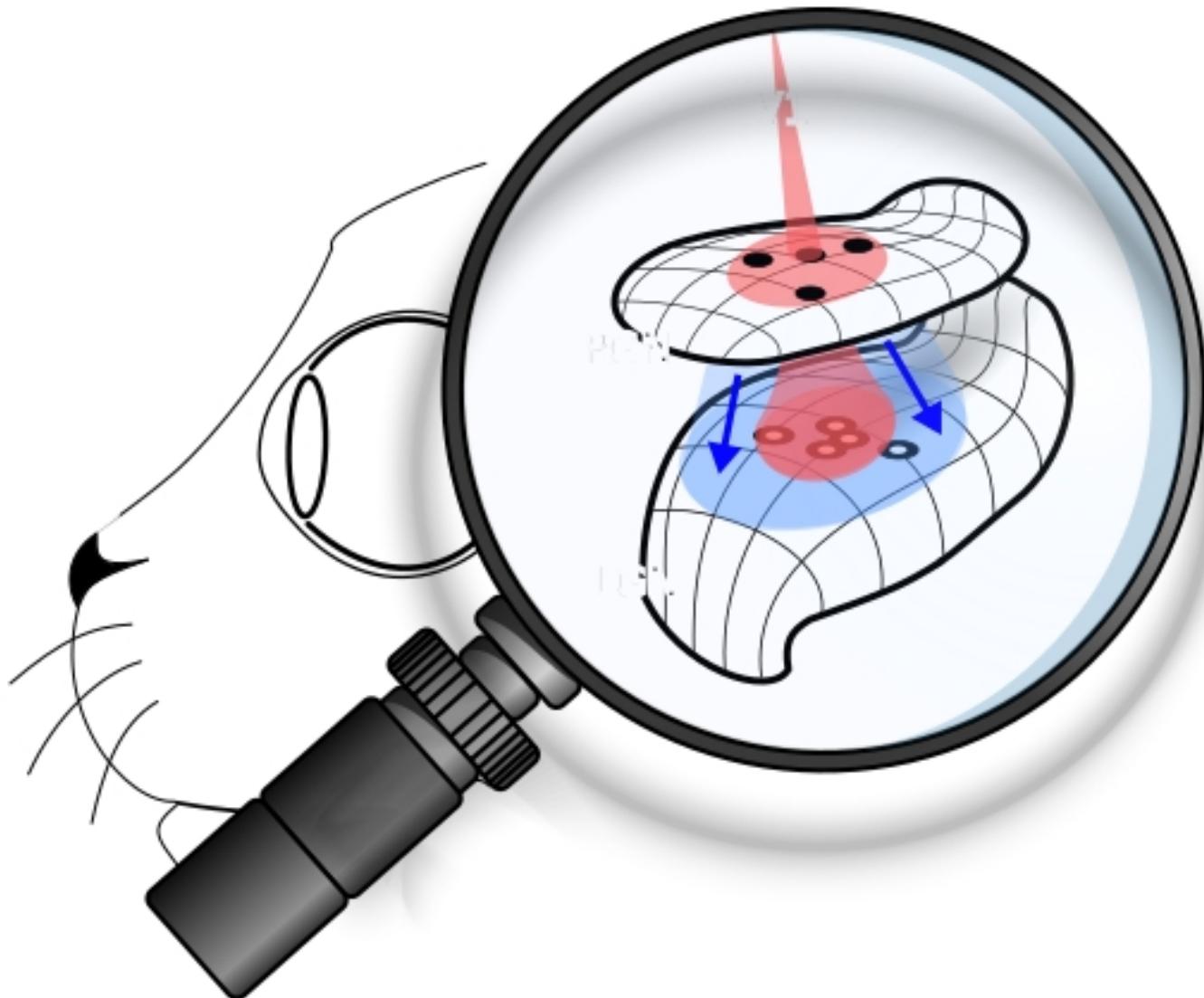
# Connectivity LGN

+ modulation from brain stem





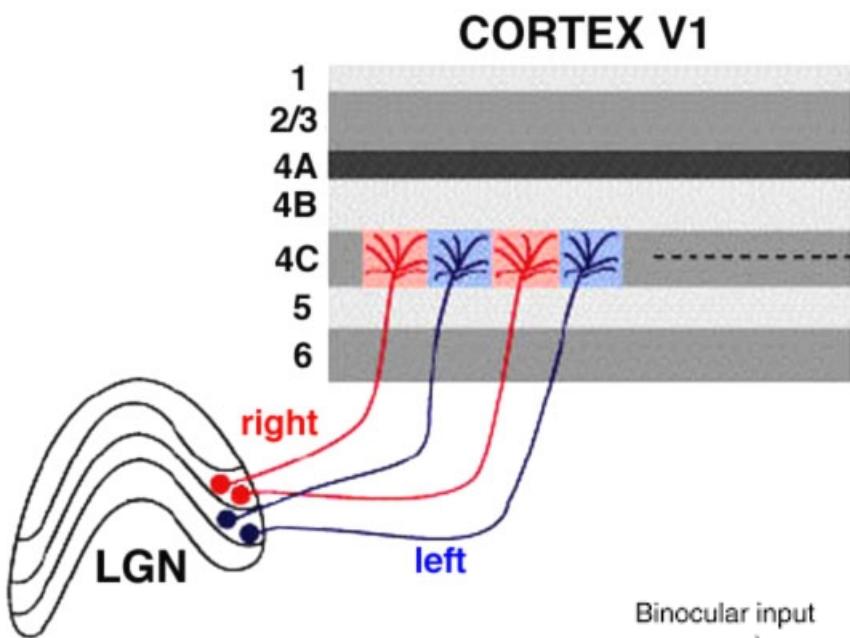




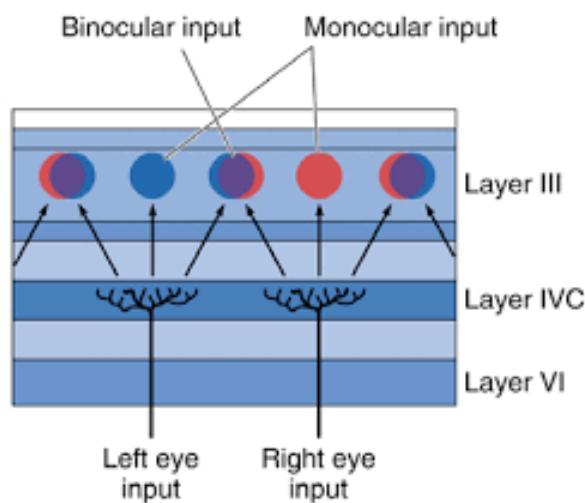
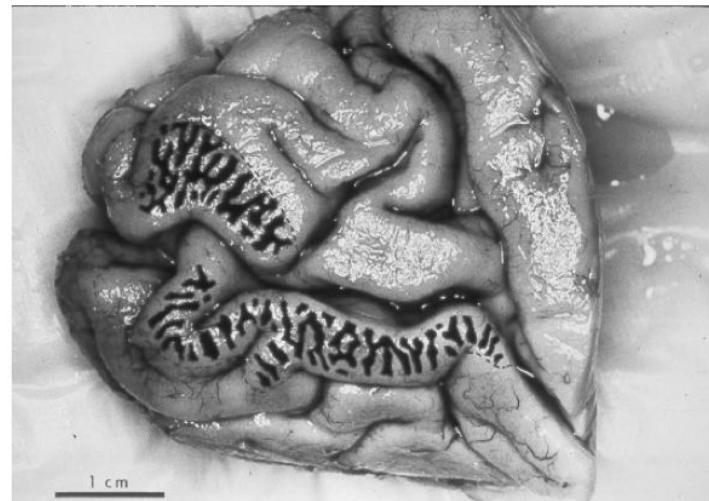
Classice short-range excitation and  
long-range inhibition circuit motif?

What is all of this good for?

# Visual pathway continued

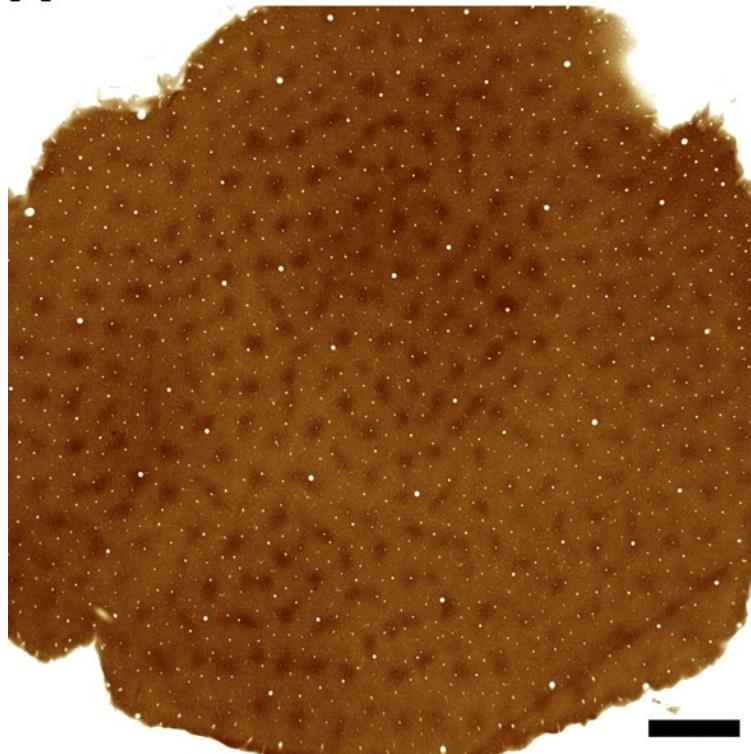


Human ocular dominance columns

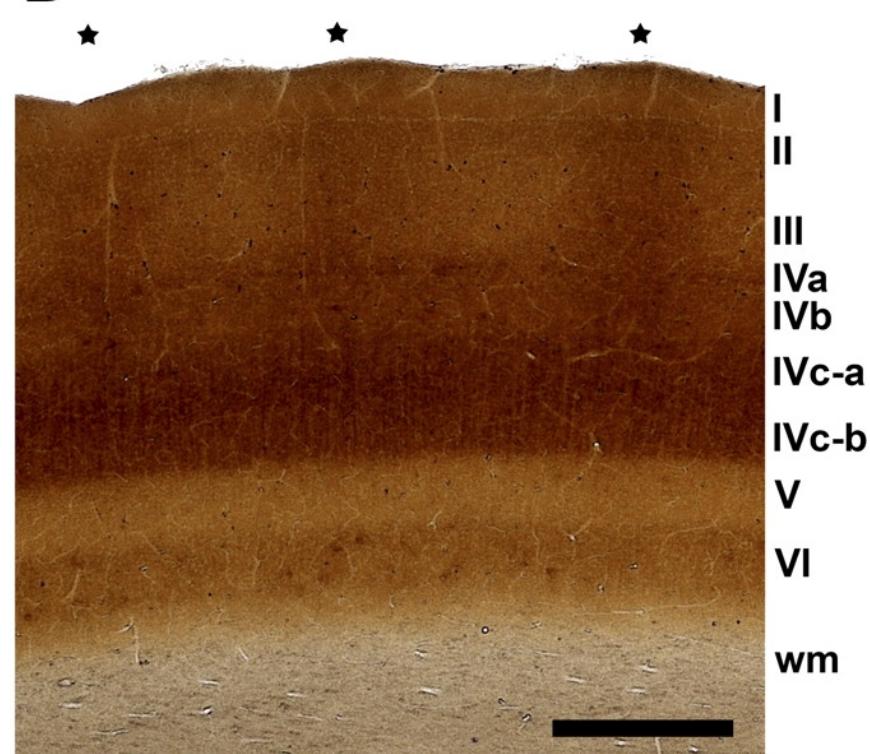


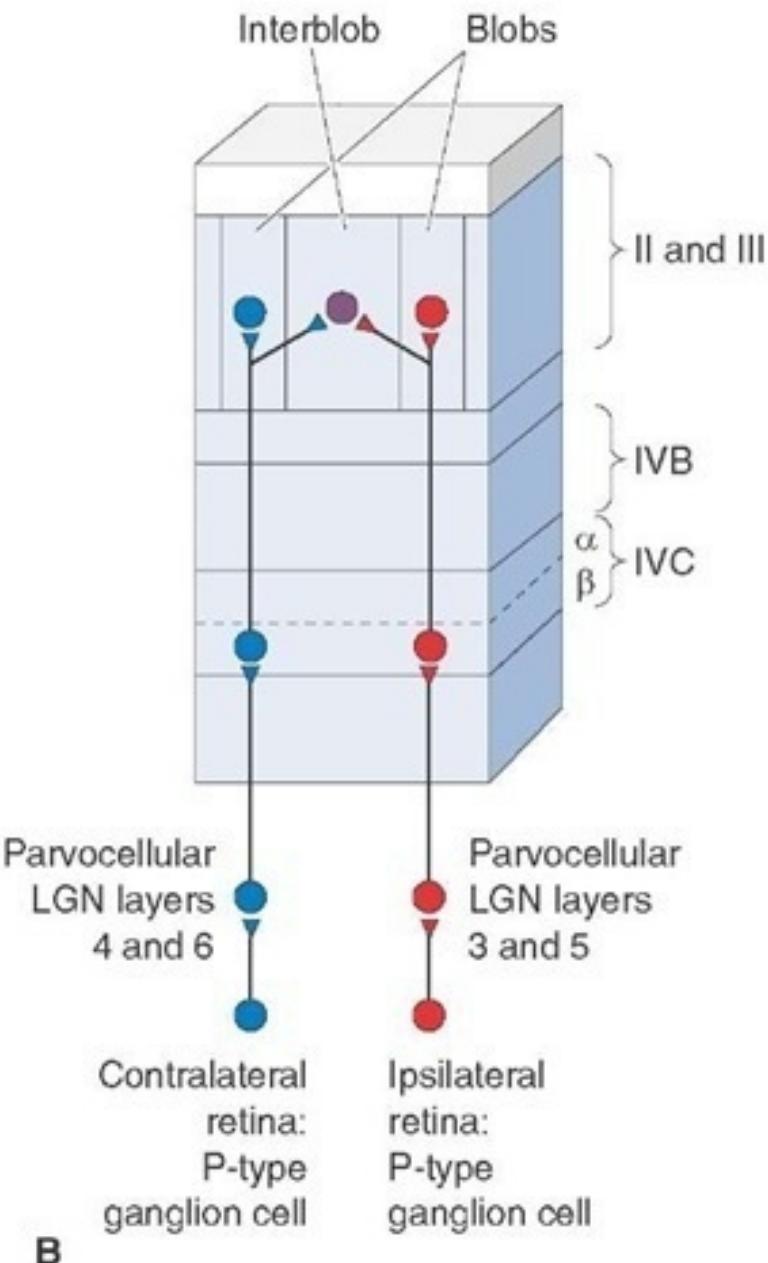
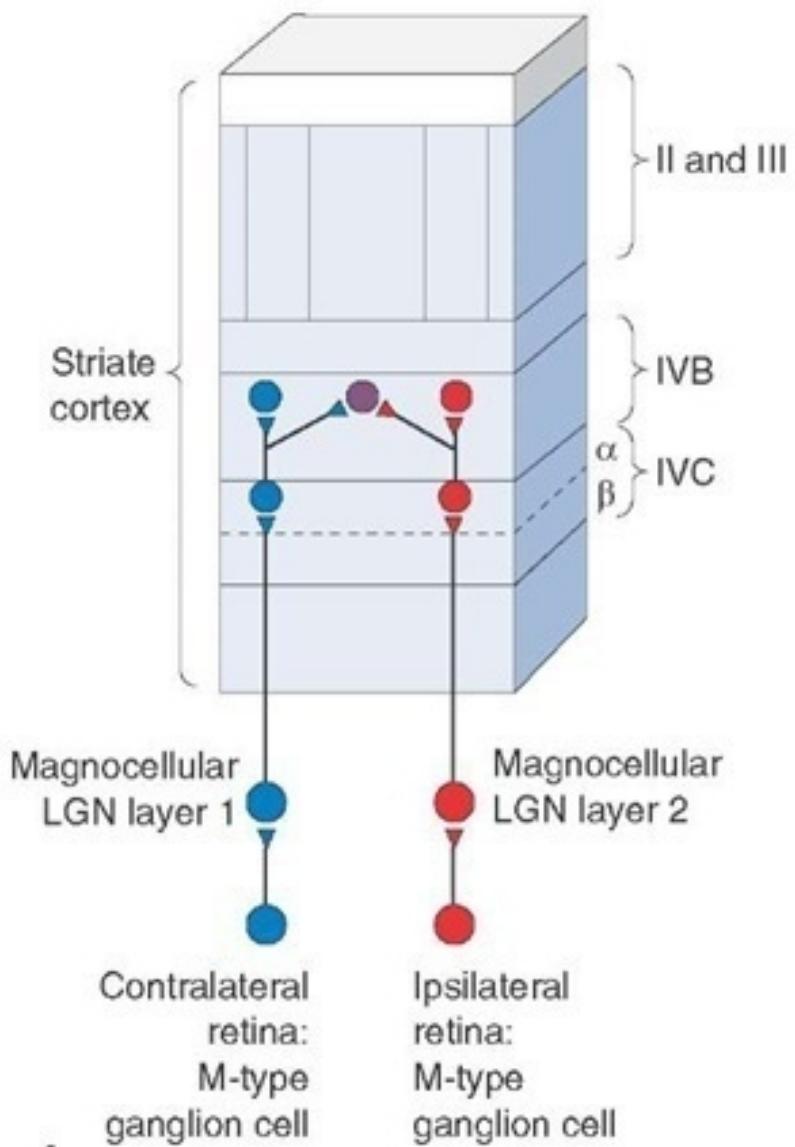
# Blobs and interblobs

A

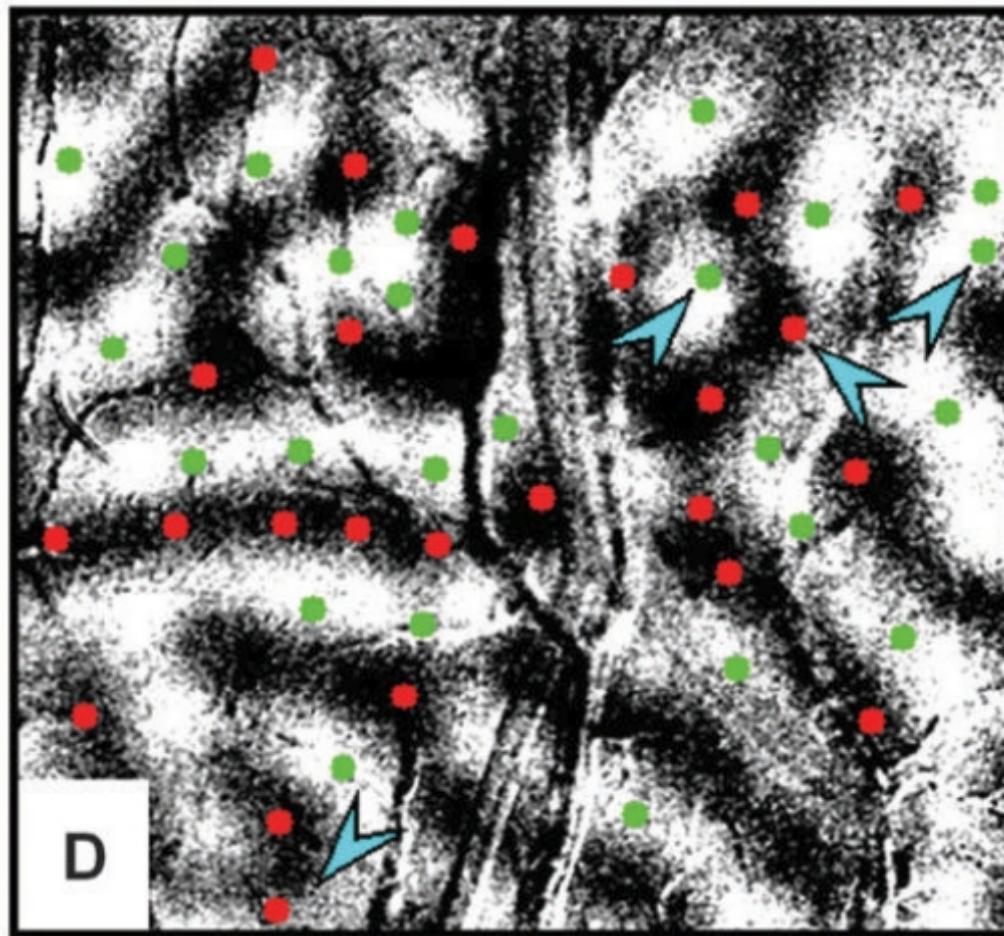


B





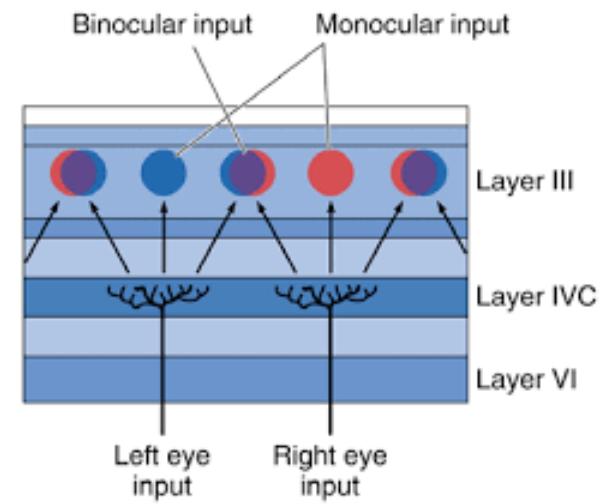
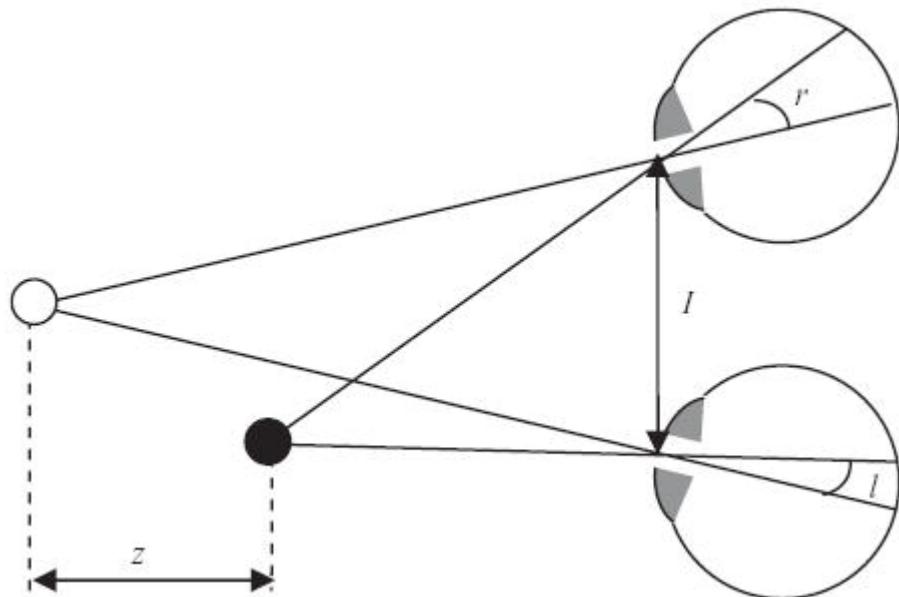
# Alignment of color-blobs and OD maps



# Blob vs. inter-blobs

- Inter-blobs
  - Orientation & direction selective
  - Binocular
  - Simple & complex
  - Mostly achromatic
- Blobs
  - Color sensitive
  - Monocular
  - Not orientation & direction selective
  - Coincide with ocular dominance maps.

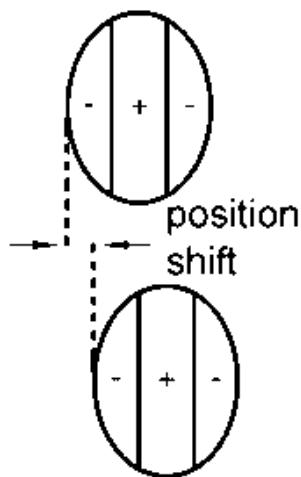
# Binocular vision & stereopsis



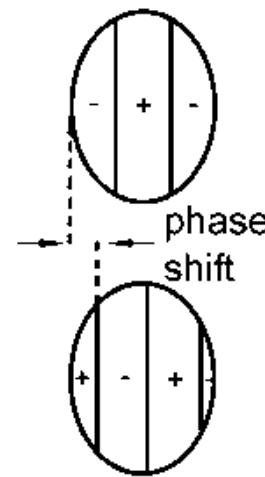
# Disparity sensitive V1 neurons

A

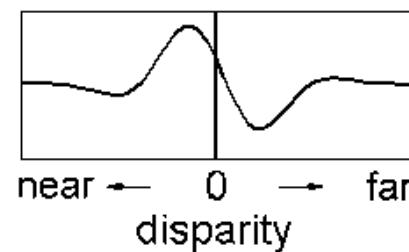
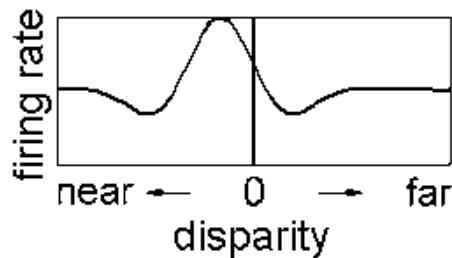
Position Shift  
Model



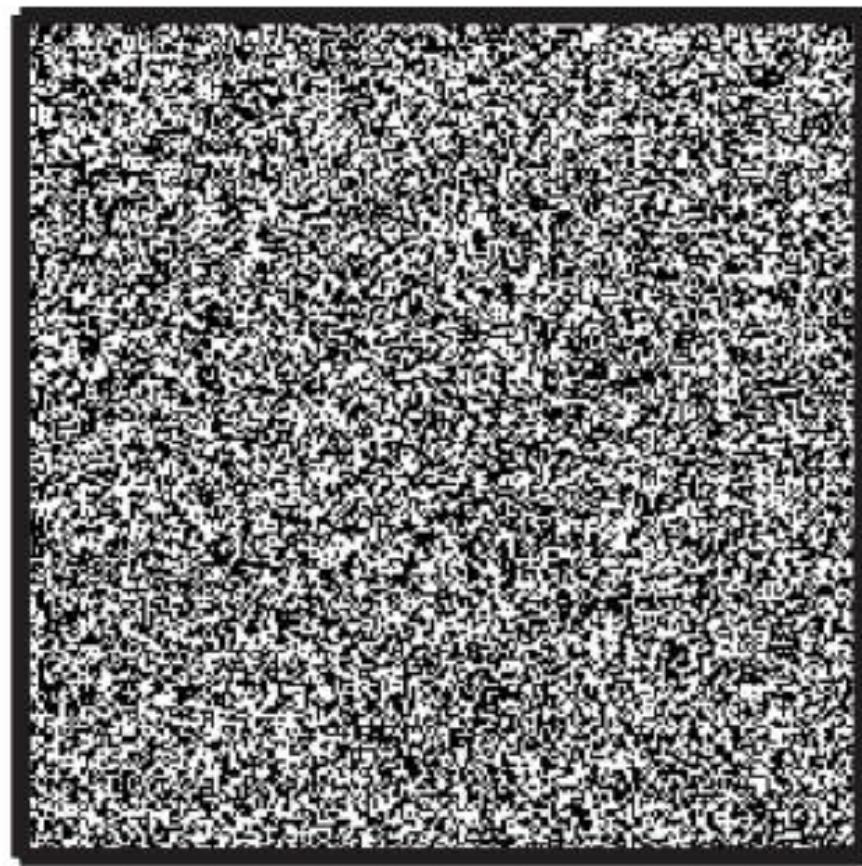
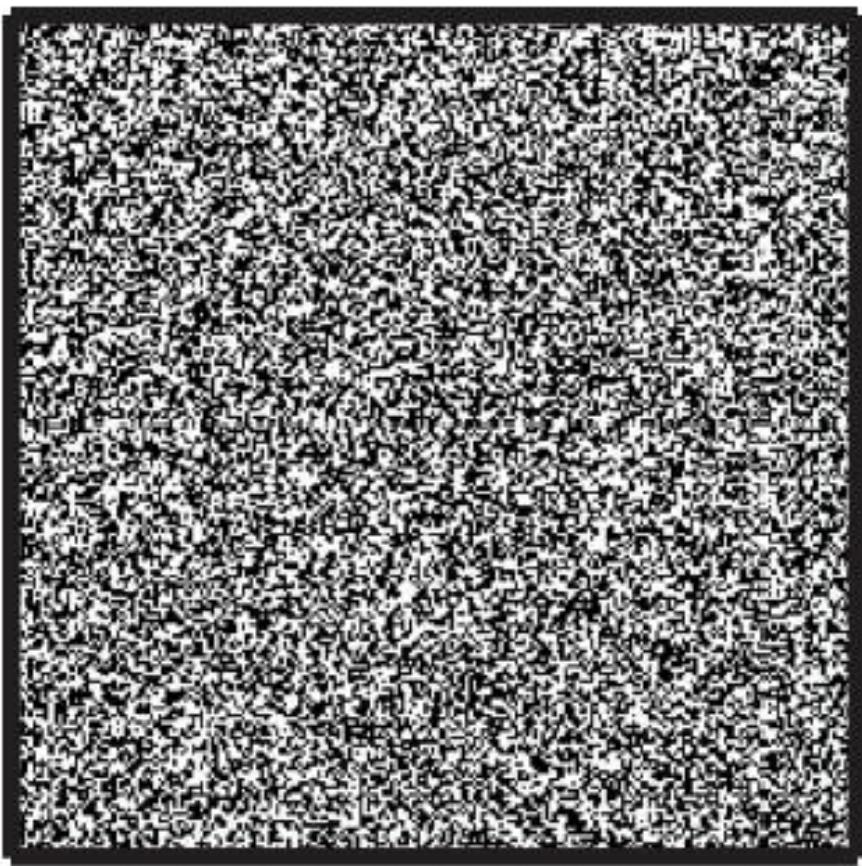
Phase Shift  
Model

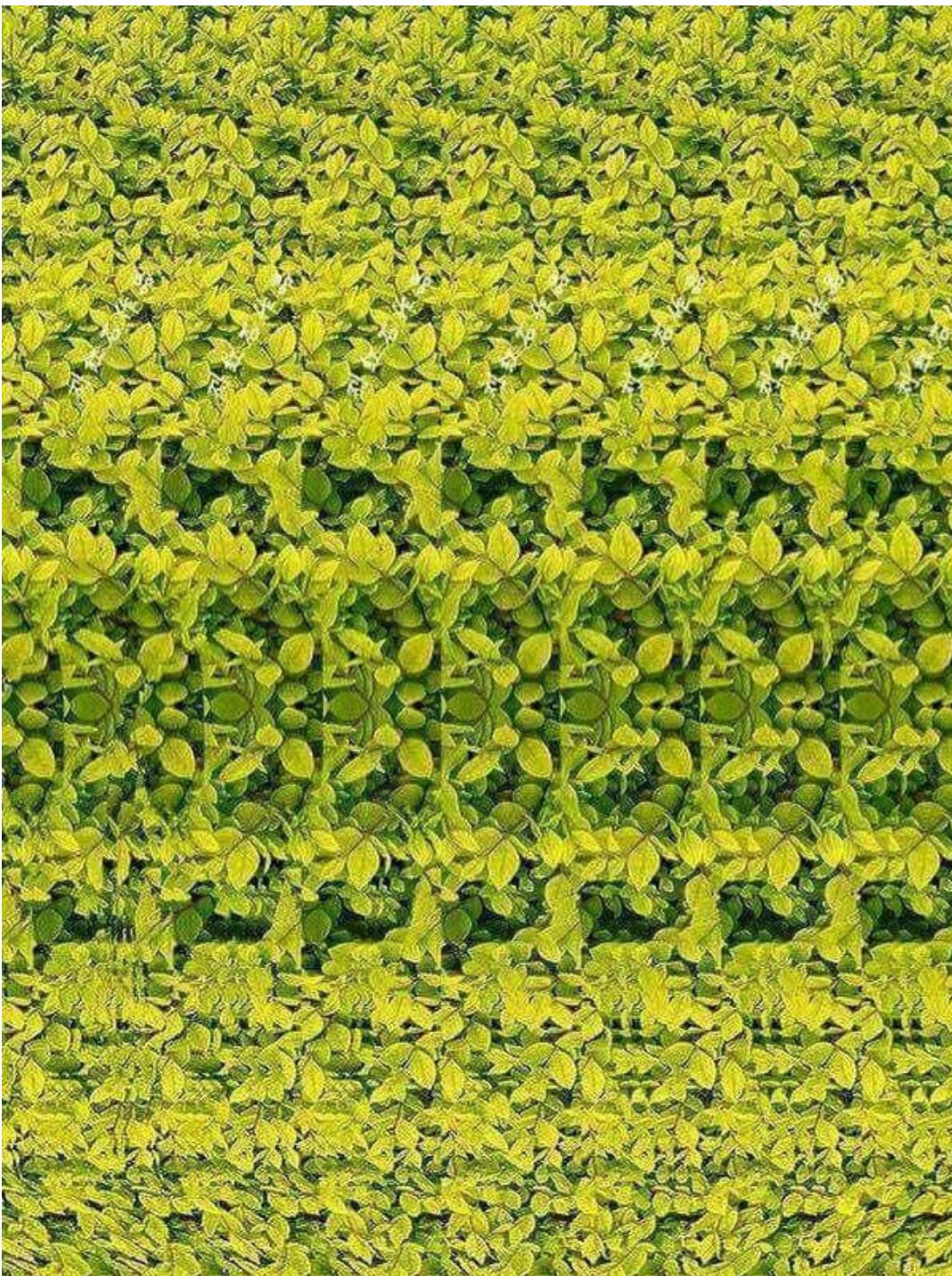


B

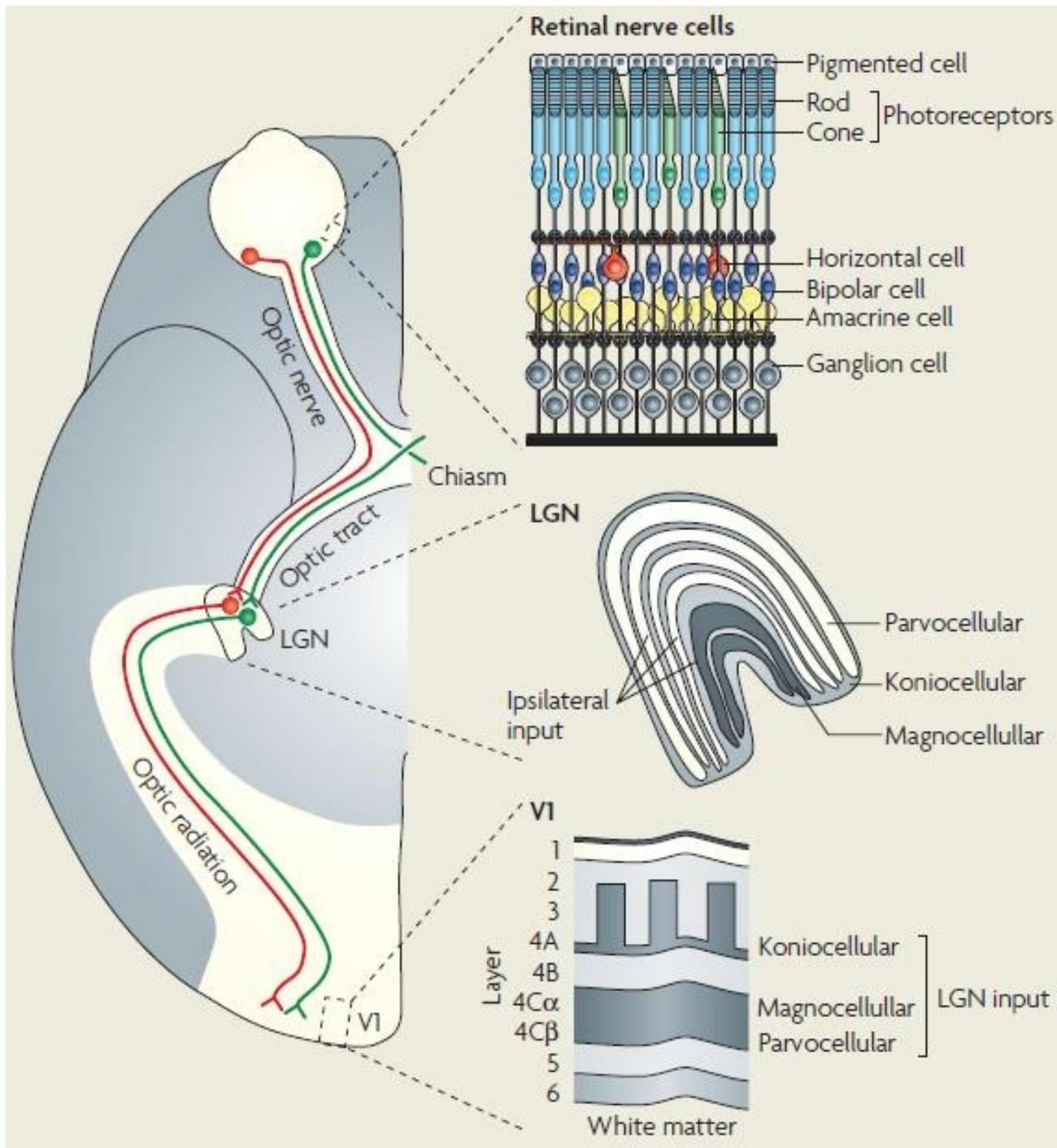






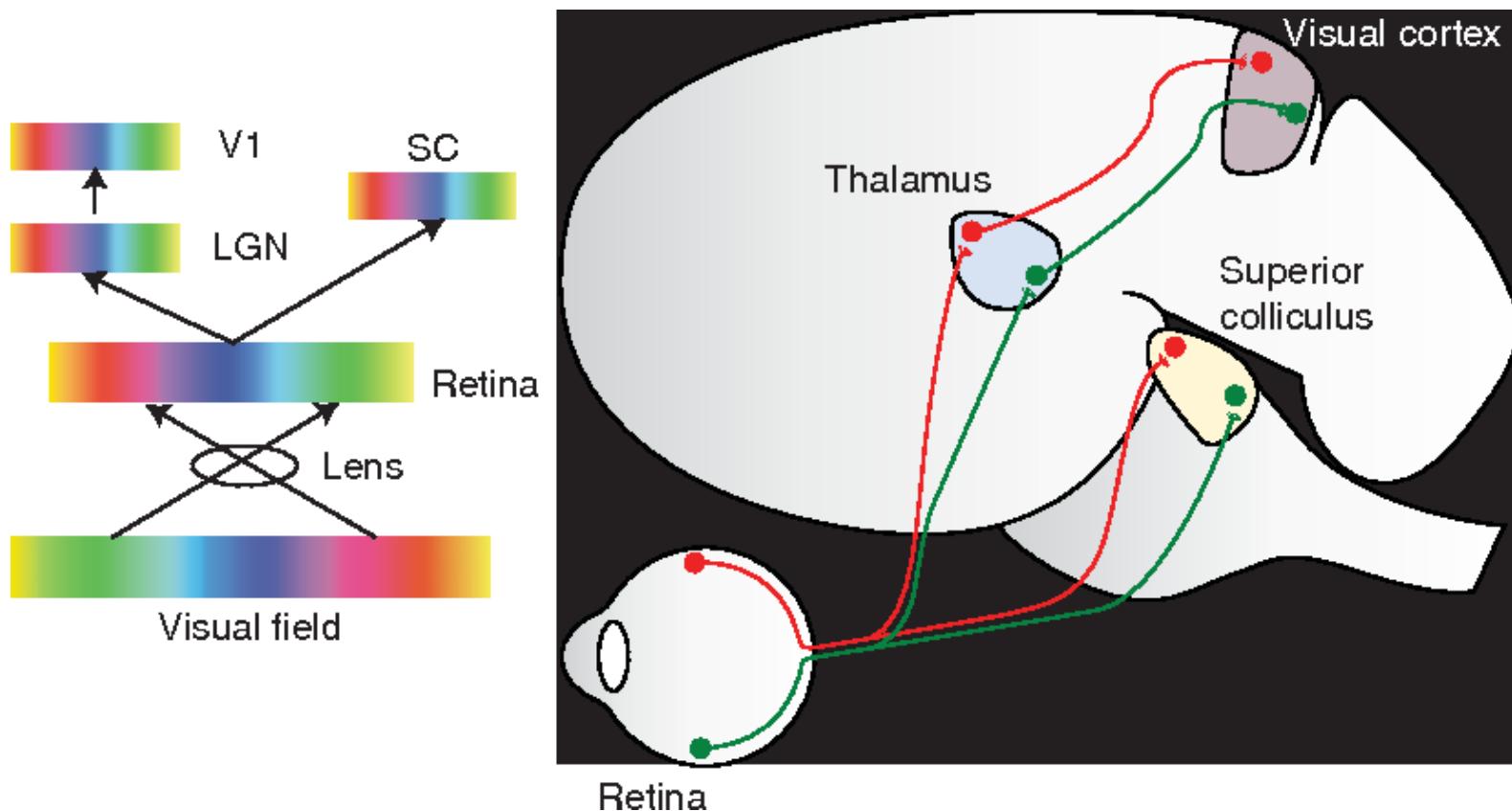


# Summary of broad organization

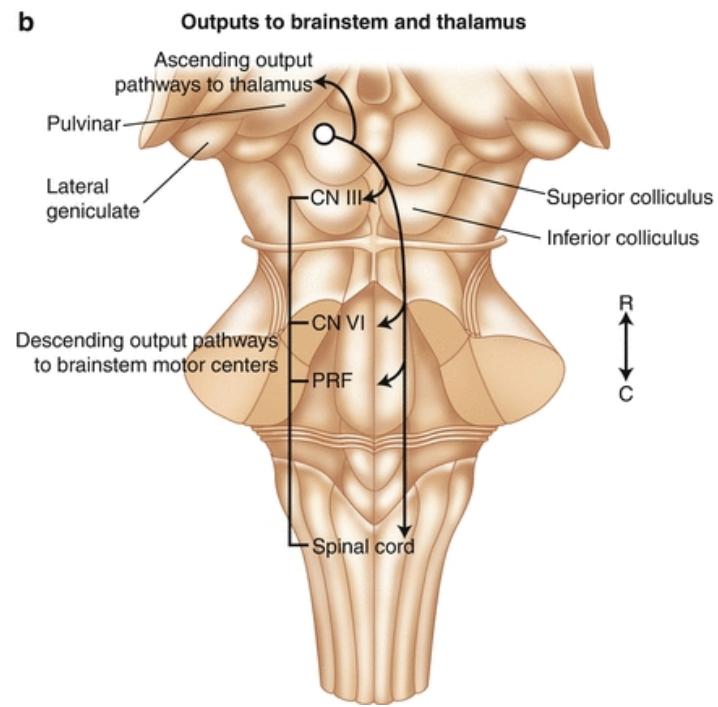
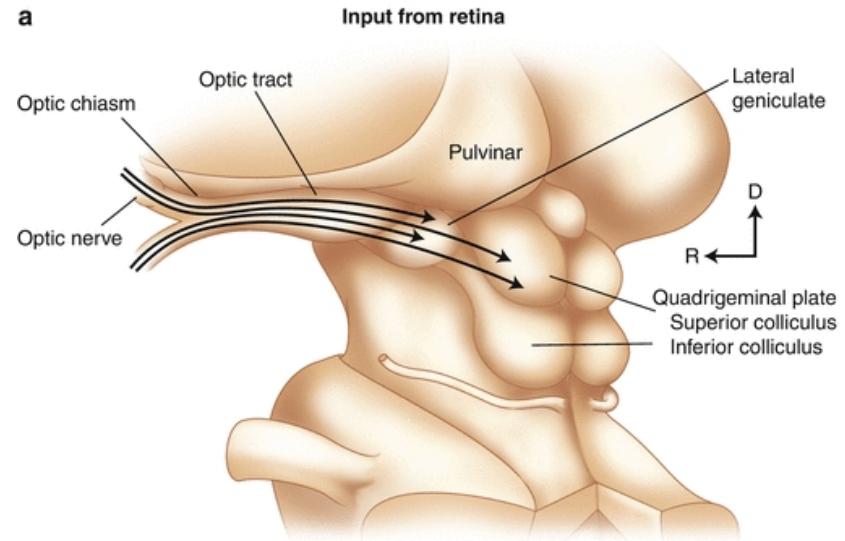
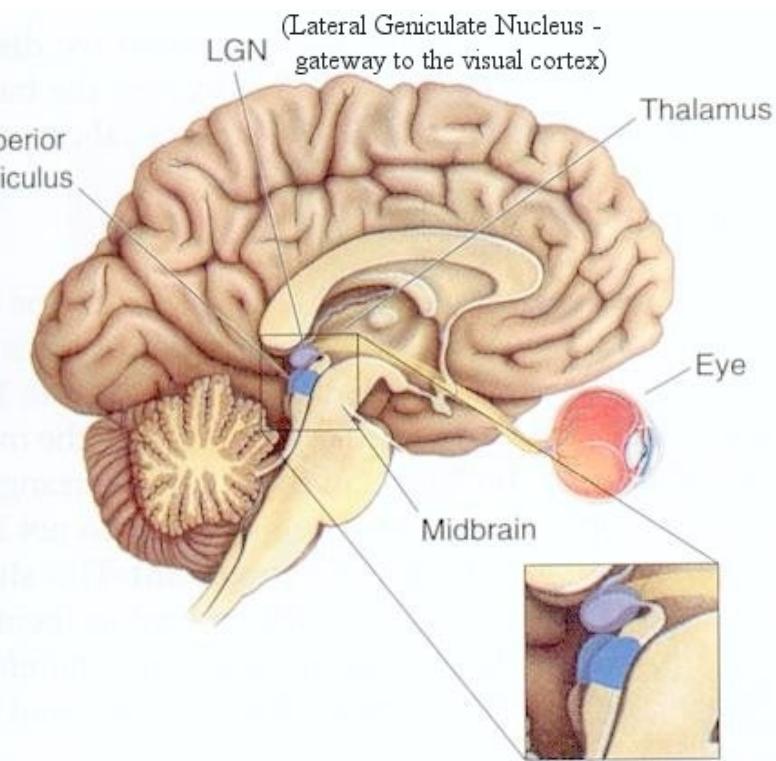


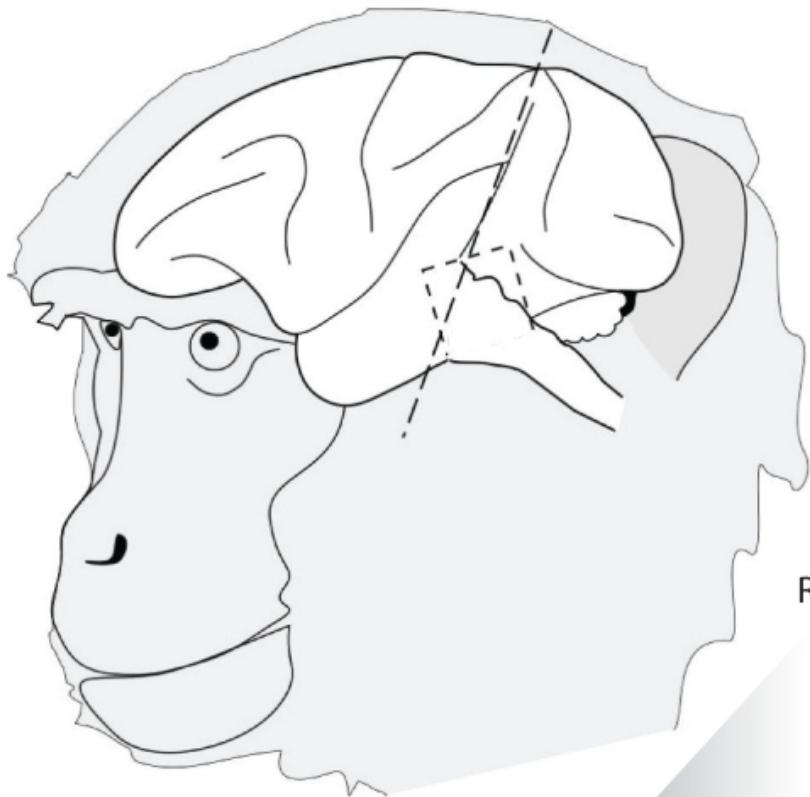
# Superior Colliculus

# Retinotopy

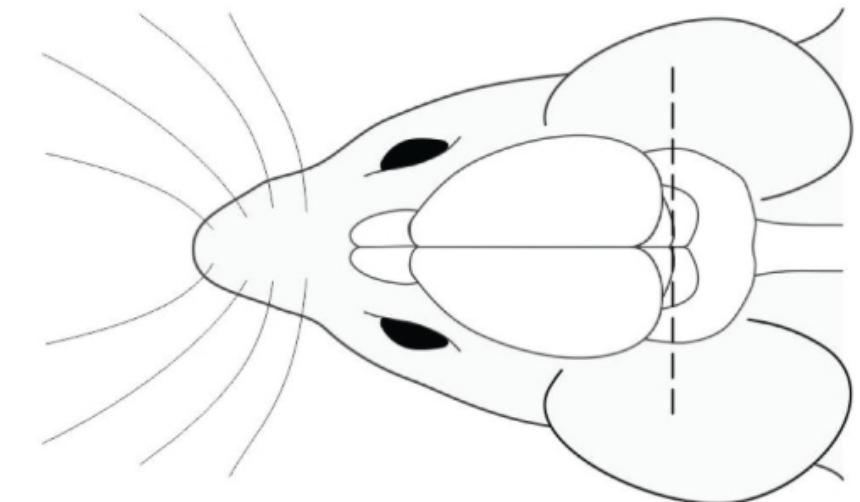


90% retinal output goes to thalamus  
10% to superior colliculus

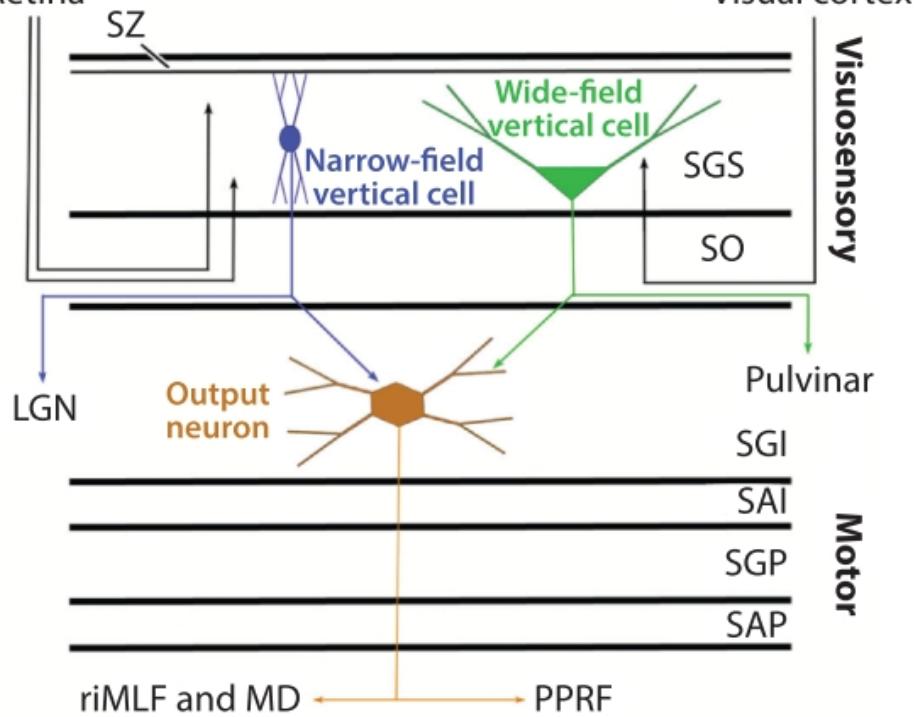




**Visuosensory**



**Retina**



**Visuosensory**

**Pulvinar**

**SGI**

**SAI**

**SGP**

**SAP**

**Motor**

# Inputs to *visuosensory* layers of SC

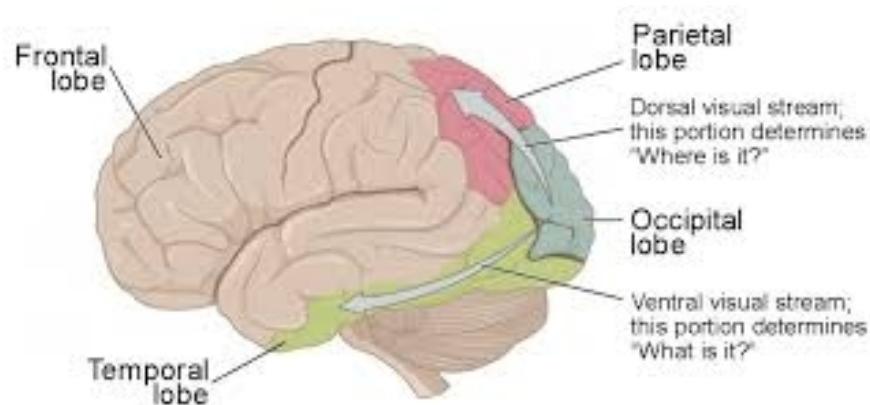
- Primary inputs
  - Retina (M and K type)
  - V1
  - Higher cortical visual areas
  - Inputs spatially segregated
- Secondary inputs
  - Ventral LGN
  - parabigeminal nucleus
  - Prepectum
  - locus coeruleus

# Outputs to *visuosensory* layers of SC

- Dorsal neurons to LGN
- Ventral neurons to Pulvinar (*attention, visuo-motor behavior*)
- Retinal afferents more densely target colliculo-geniculate neurons, and cortical afferents more densely target tecto-pulvinar neurons

# The role of visuosensory layers of SC

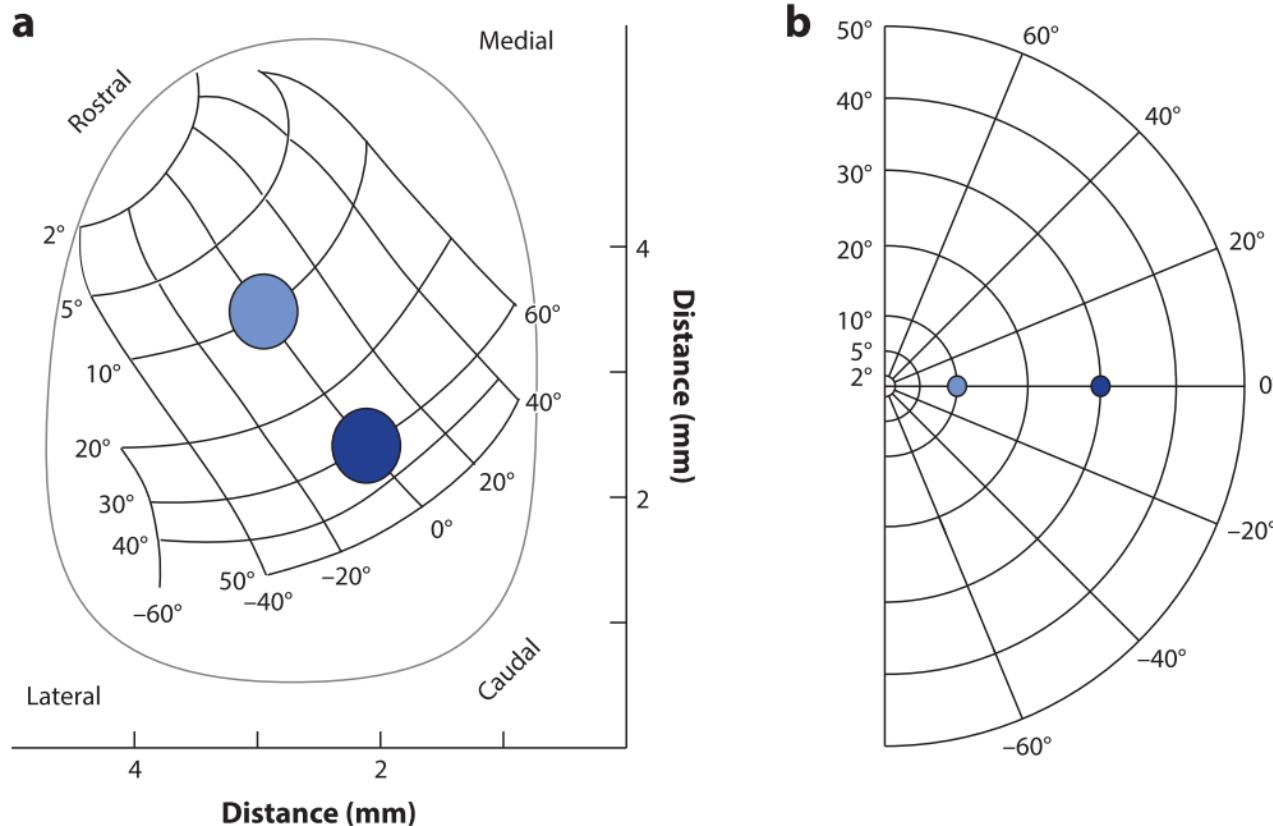
- V3 and MT of the dorsal stream, but not areas V2 and V4 of the ventral stream, are targets of collicular outputs
- Process and relay visual information related to motion and orienting
- Not high-res ‘what’ vision



# *Motor layers of SC*

- Inputs from virtually the entire brain and parts of the spinal cord
- Outputs target nuclei throughout the neuraxis (pons, spinal cord, thalamus)
- Roles
  - orienting
  - attention
  - decision making
- Patchy molecular markers in motor layers

# SC and eye-movements



- Two maps: one of visual space (a), superficially, and one of saccadic eye movement space(b), ventrally
- Neurons in the motor layers discharge in close temporal relationship to the generation of eye movements (**movement field**)

# SC eye-movements II

- The location of the maximal discharge of movement neurons on the collicular map determines the vector of saccades, whereas the frequency of their discharge determines their speed
- Other orienting movements also involved
- Auditory and somatosensory maps also present
- Sparks (1988) proposed that all the maps were organized according to motor error—the position of the eyes relative to the target position.



