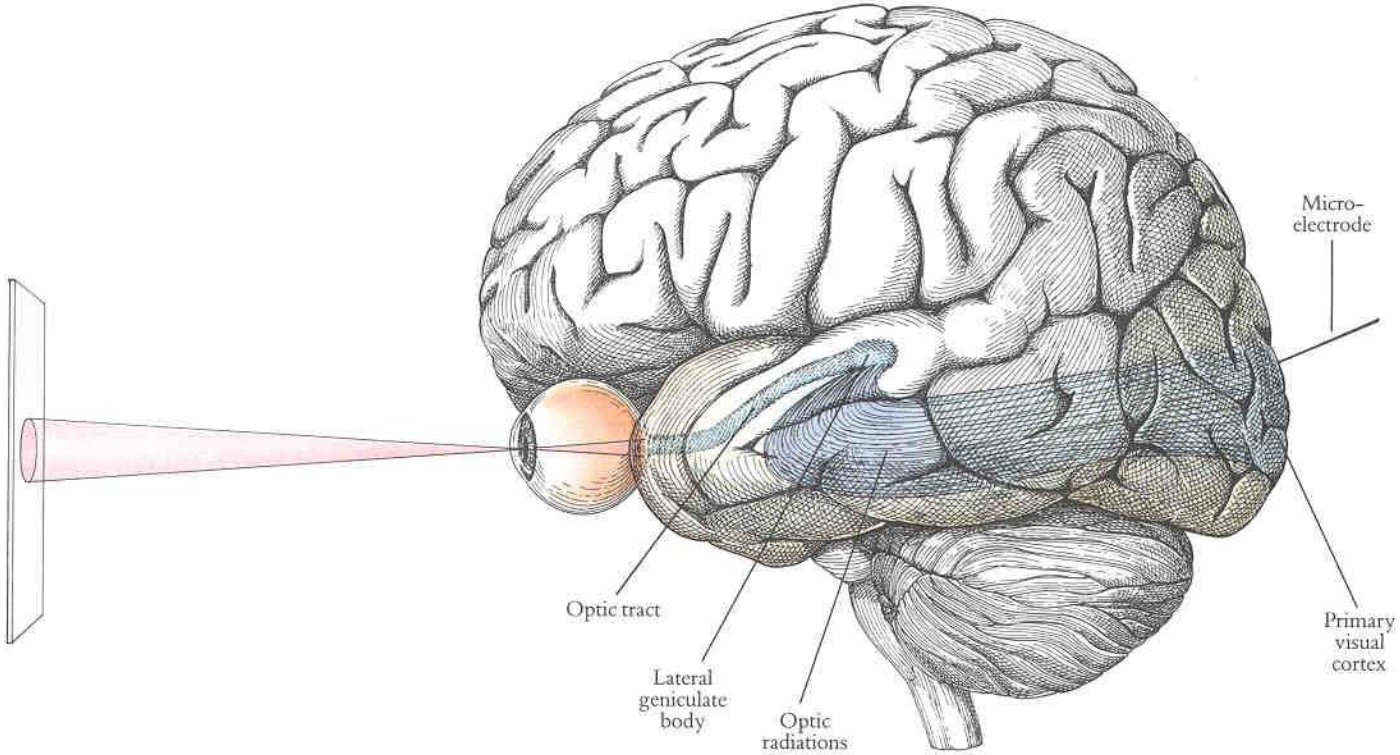
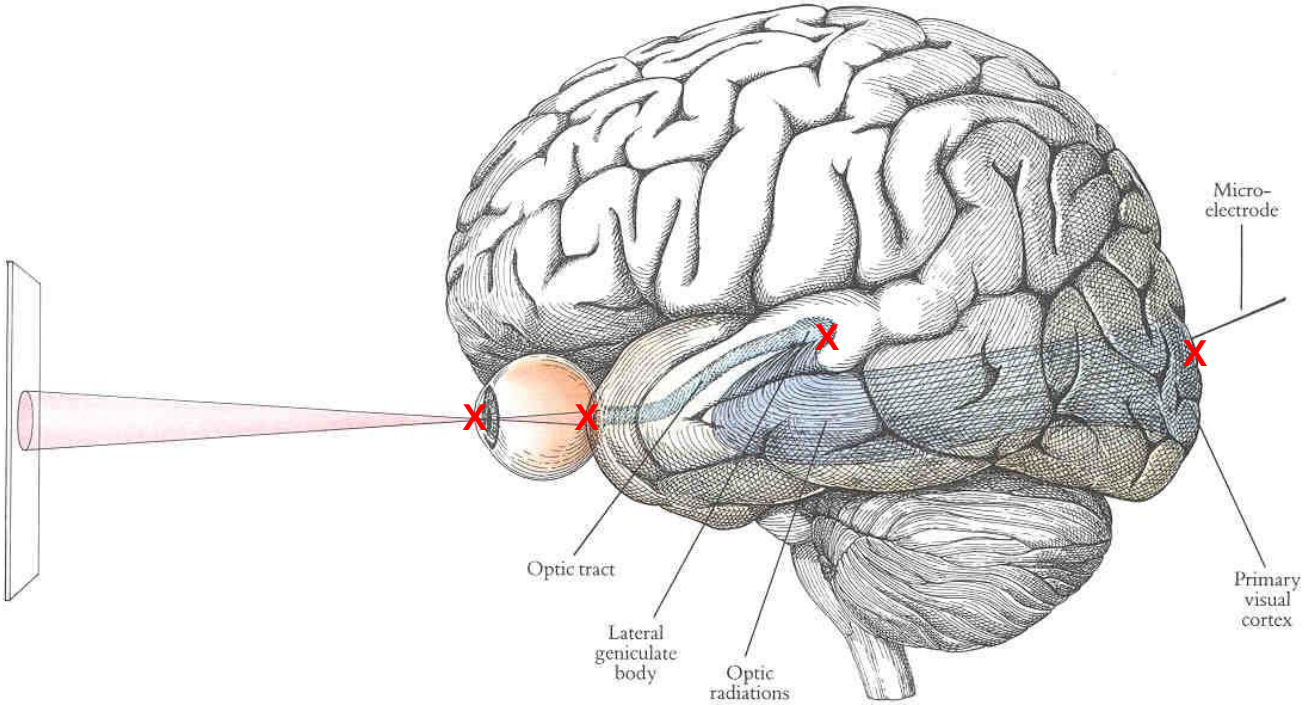
Vision I: Retina and Thalamus

3/1/2019

What is visual impairment?



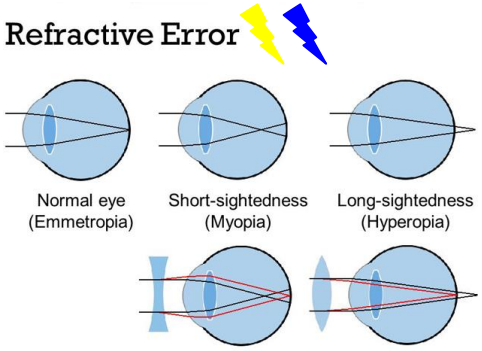
A lot of things can go wrong



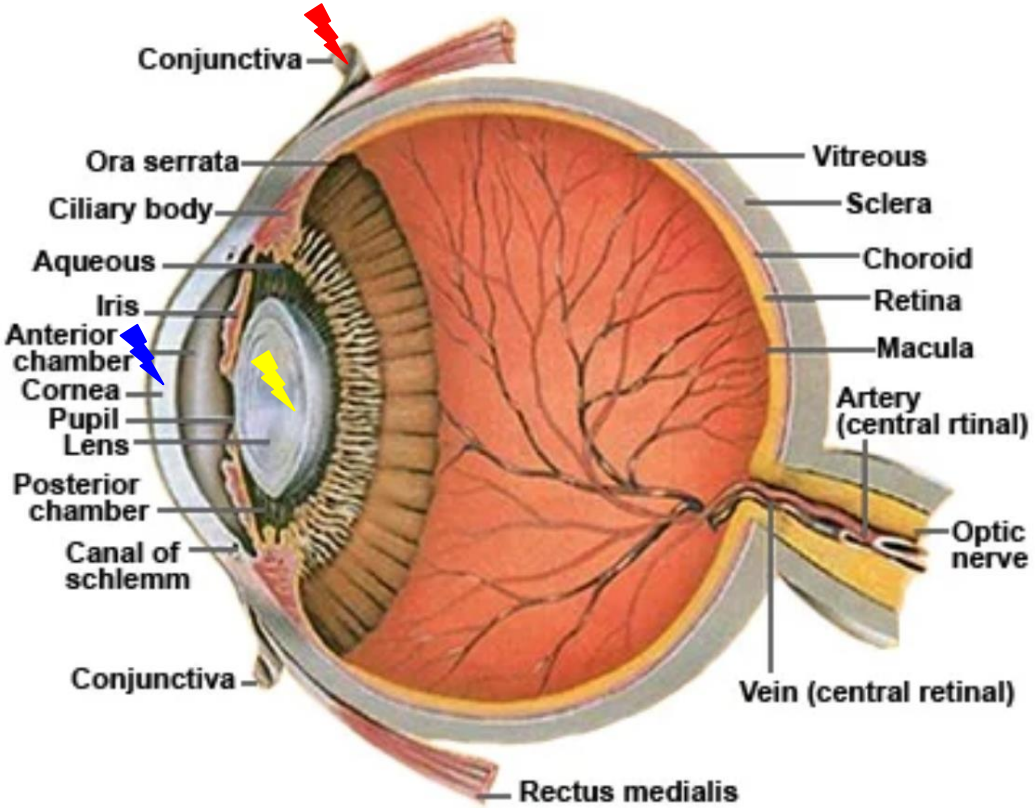
Disease outside of the nervous system

Cataracts

Keratoconus



Conjunctivitis

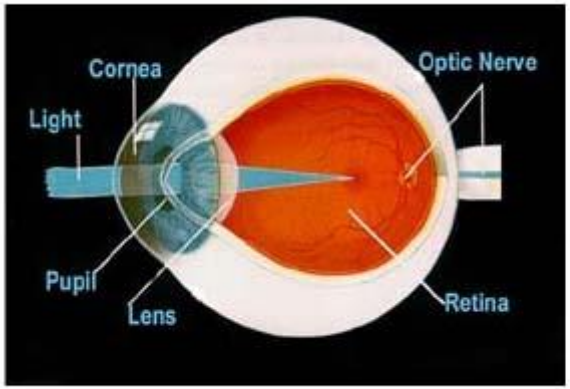


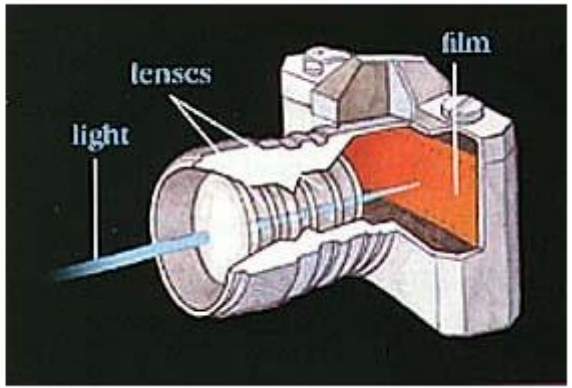

Myopia


Cataract

Does the eye function like a camera?

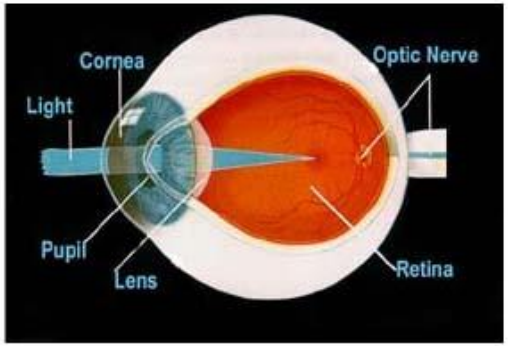
- In some ways the eye can be compared to a camera.
- Pupil = diaphragm
- Cornea and lens = refractive optics that carry the light to the back of the camera (retina).

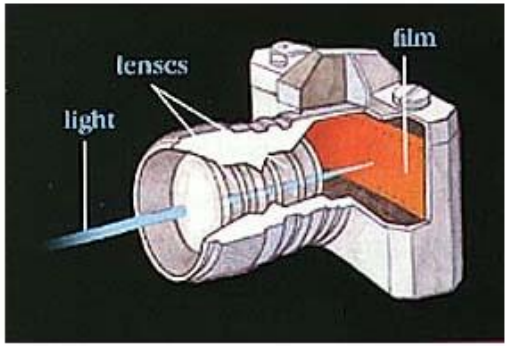




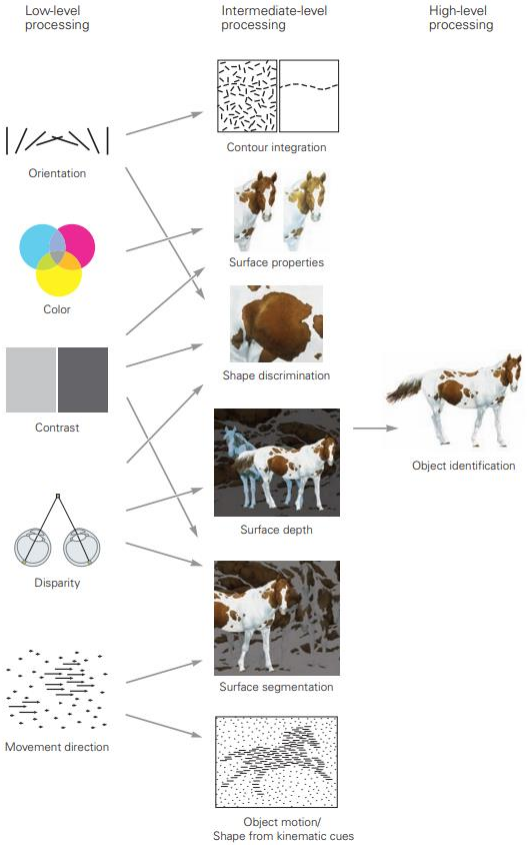
Does the visual system of the nervous system function like a camera?

- A camera produces a picture through point by point light intensities
- Unlike a camera, the eye conveys a representation of our visual field through signaling different components of said field, such as color, contrast, shape, brightness, and motion.
- (It does not function like a camera)



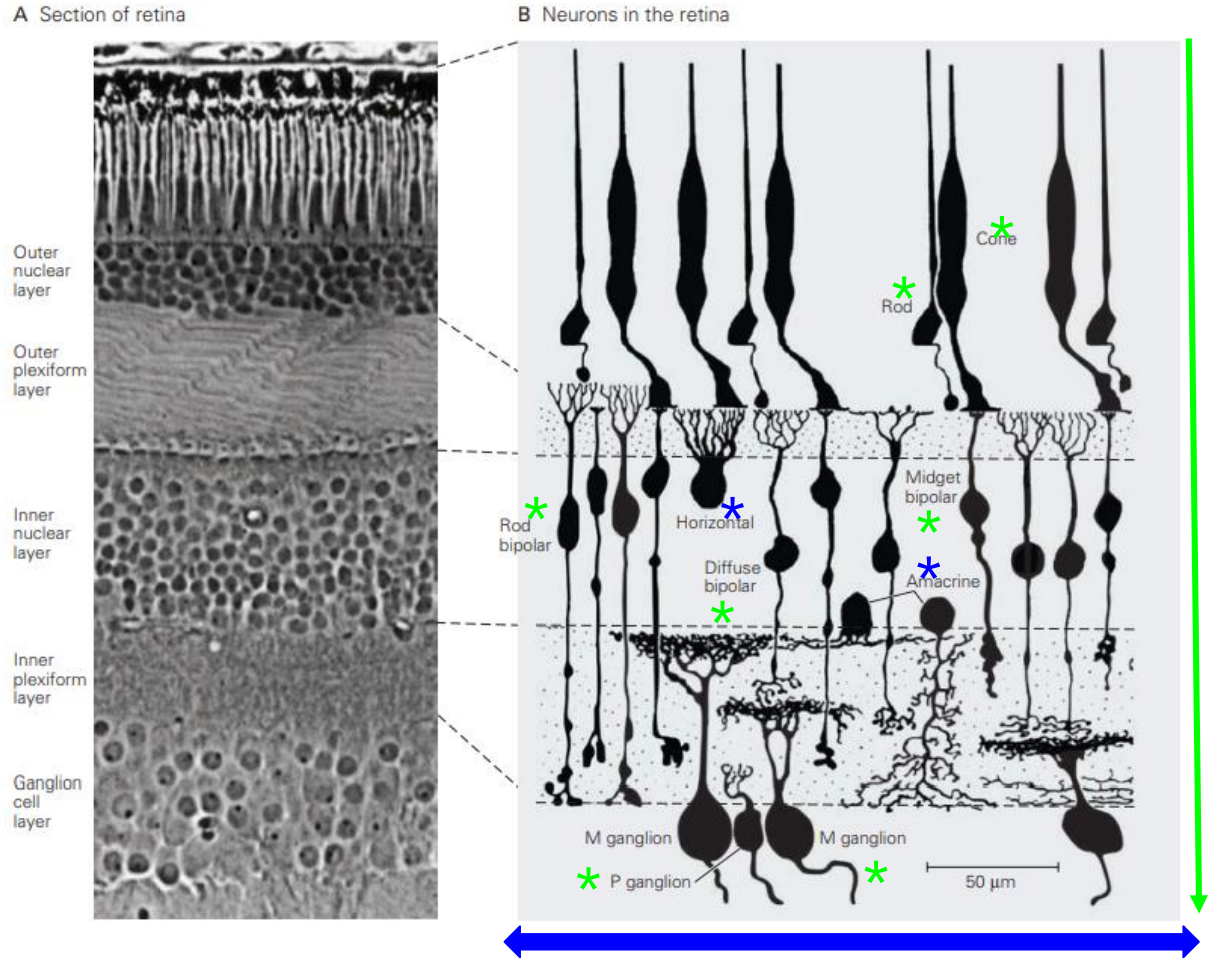


Visual processing in the nervous system



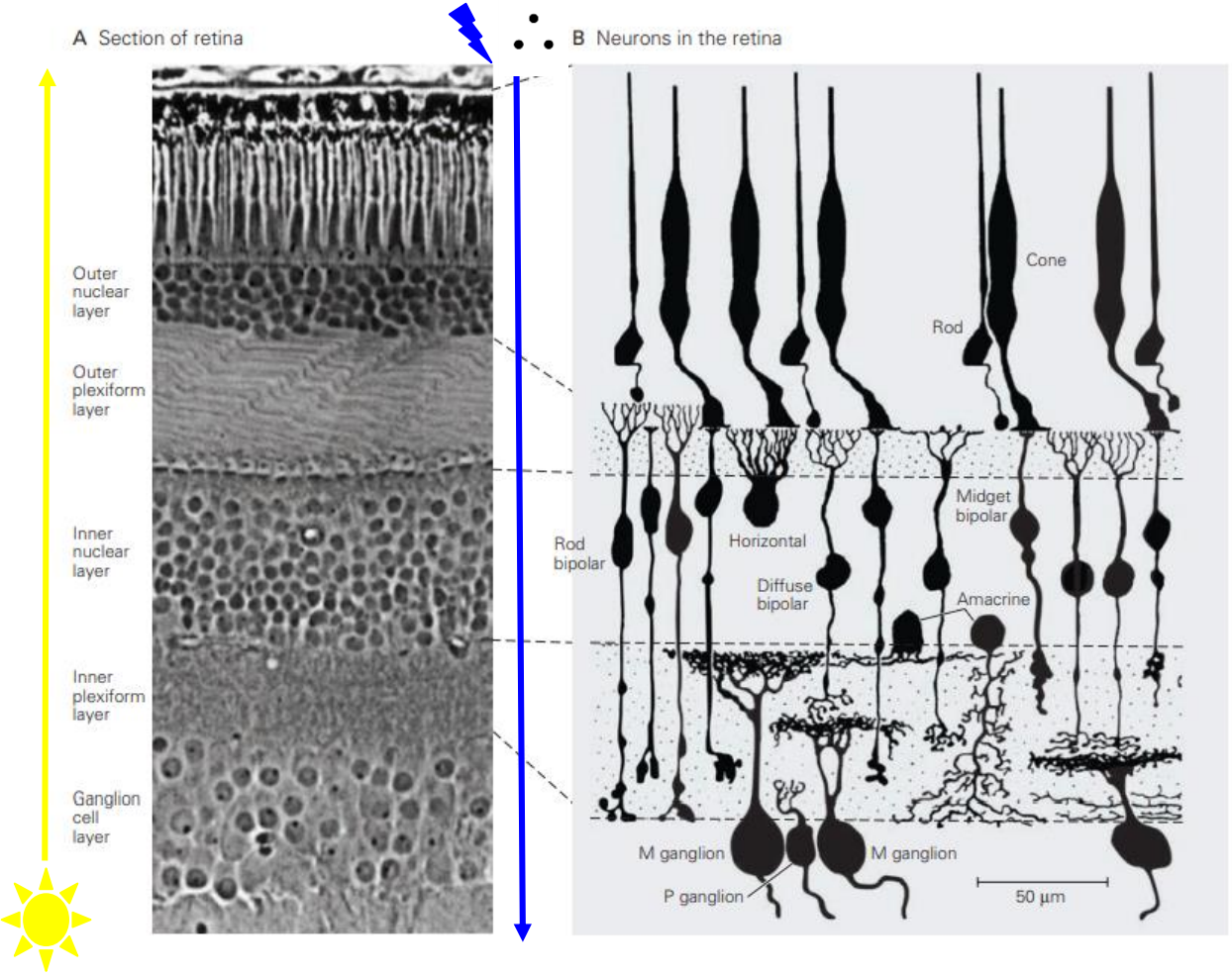
- Low-level occurs at the retina and thalamus.
- Intermediate-level occurs at the visual cortex.
- High-level occurs at the frontal, parietal, and temporal lobes.

Retina



- The retina is organized into layers based on cell type and nuclei or axon/dendrite location.
  - I.e. outer nuclear layer contains nuclei, outer plexiform layer contains the axons of those nuclei.
- Some cell types take part in the vertical pathway across layers towards the rest of the brain (in green).
- Other cells facilitate horizontal communication across the retina, within layers (in blue).

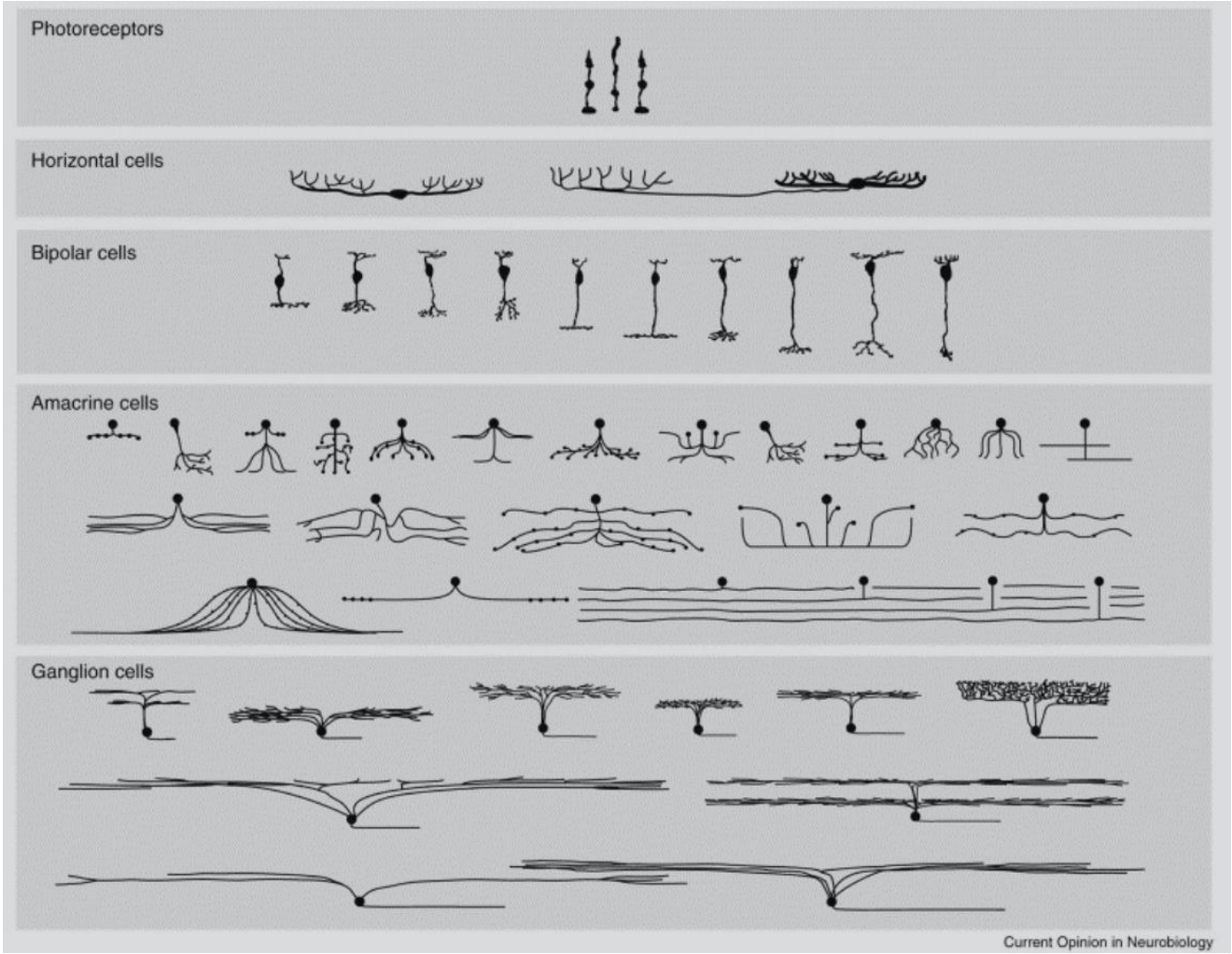
Retina- The vertical pathway



- The direction of light in the retina is opposite to the signal transmission.
- Photons enter the anterior portion of the retina starting with the ganglion cell layer, travels to the posterior retina.
- Photons activate cells at the posterior retina, activated cells release glutamate to postsynaptic cells toward the anterior retina.

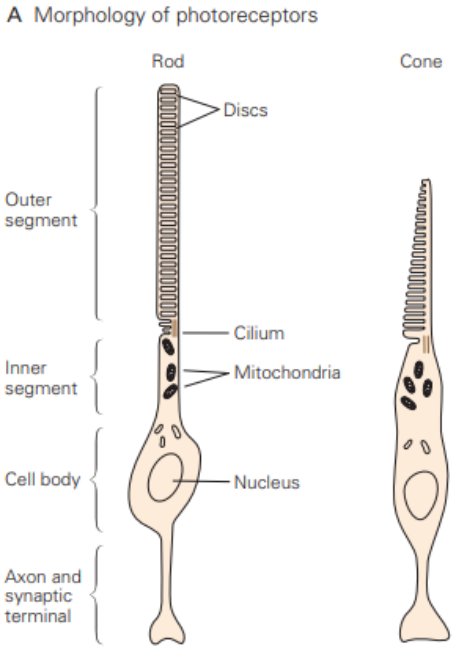
Cell types

- Why would some cells have more subtypes than others?



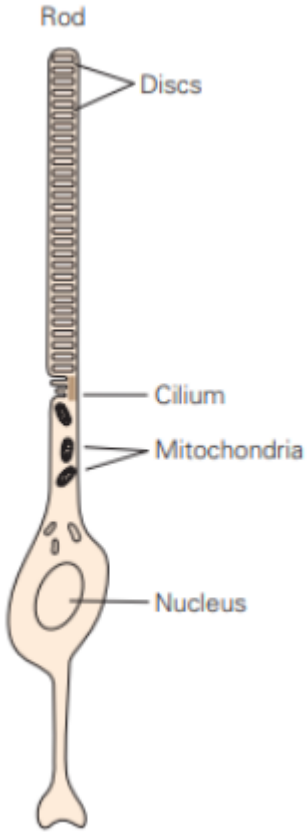
Photoreceptors

- When activated, photoreceptors **hyperpolarize** in response to light.
- When depolarized, photoreceptors release the neurotransmitter glutamate.
- Do not fire action potentials.
- Synapse onto bipolar and horizontal cells.
- Photoreceptors are divided into two cell types: rods and cones.



Rods

- Rods are activated in response to light patterns during dim and dark conditions.
- These cells can signal in response to a *single* photon- which is why they are useful for dark/dim conditions.
- Because of their sensitivity to single photons, rod function is overwhelmed/caps out as light levels increase toward dawn.



Cones

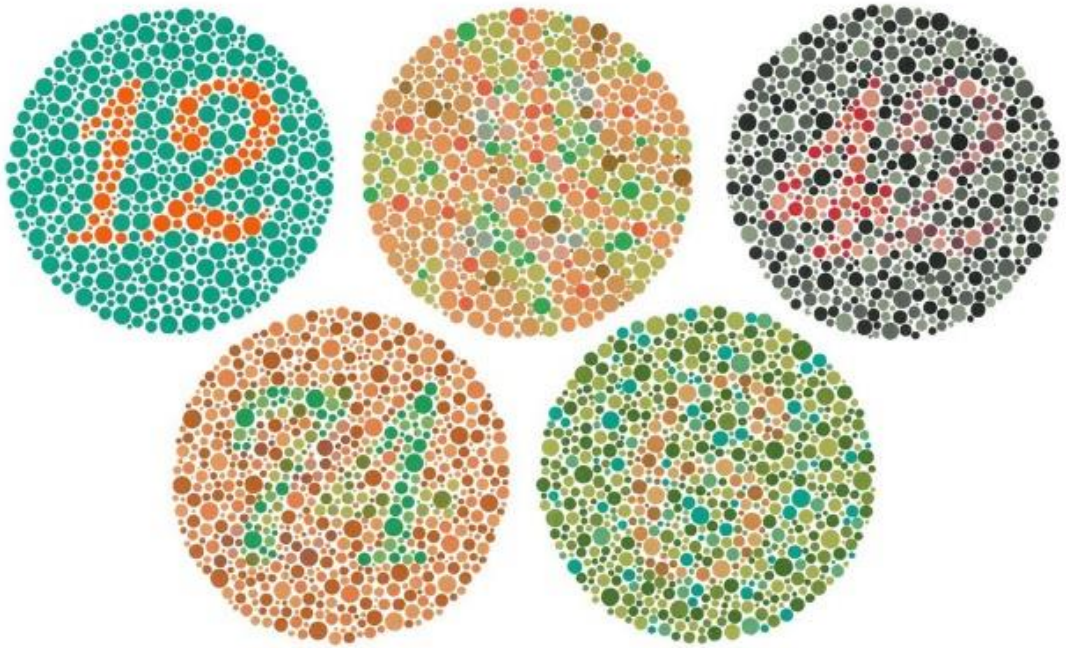
- Cones are not as sensitive to light as rods, are not activated in dim conditions.
- Day time vision
- Activated by different wavelengths of light. There are three types of cones, classified by the wavelength and corresponding color of light that activates them:
  - S cones are activated by short wavelengths (blue light)
  - M cones are activated by medium wavelengths (green light)
  - L cones are activated by long wavelengths (red light)
- The ability of a cone to detect a specific wavelength depends on the opsin protein the cell expresses.

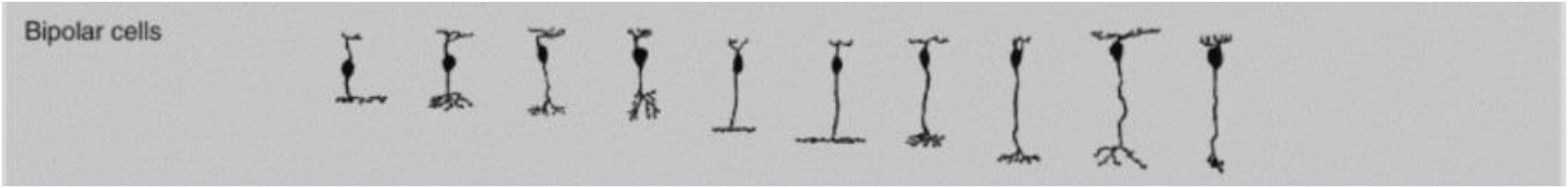
Fovea

- High acuity vision
- Cones only
- Other cell layers are pushed to the side so as to reduce the scattering of light onto the cones.
- 50% of the visual cortex is used to process foveal vision!

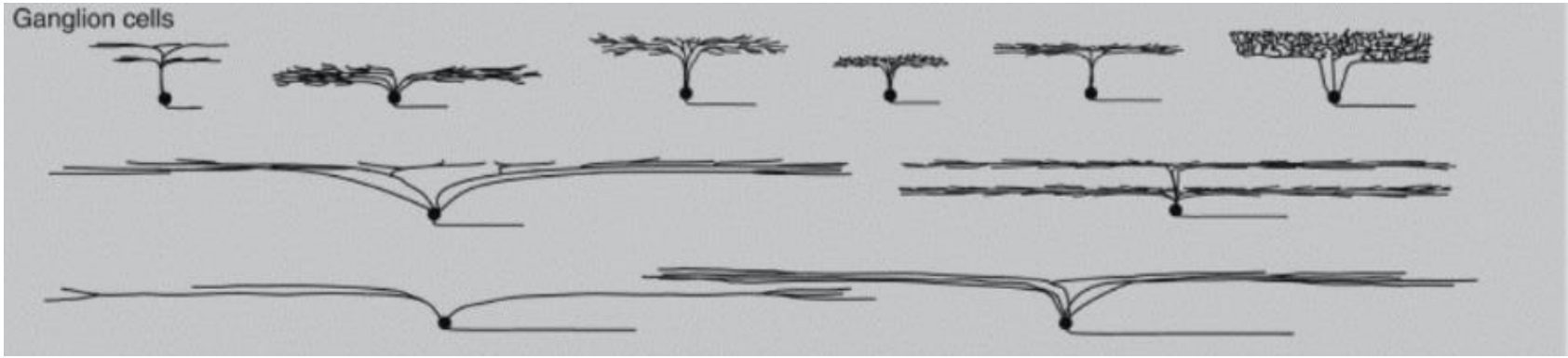
Color Blindness

- Defect in one or more cone opsins.
- Sex-linked gene: color blindness more prevalent in males.

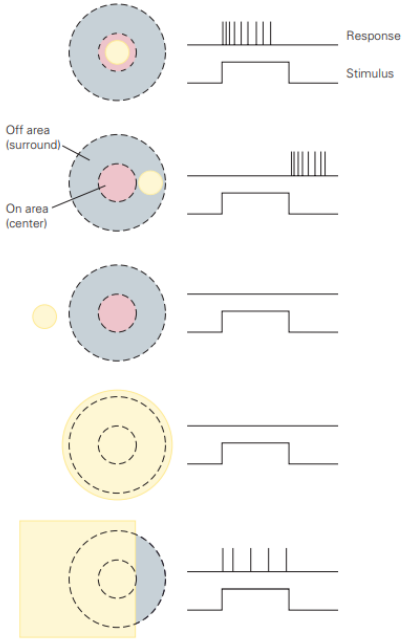


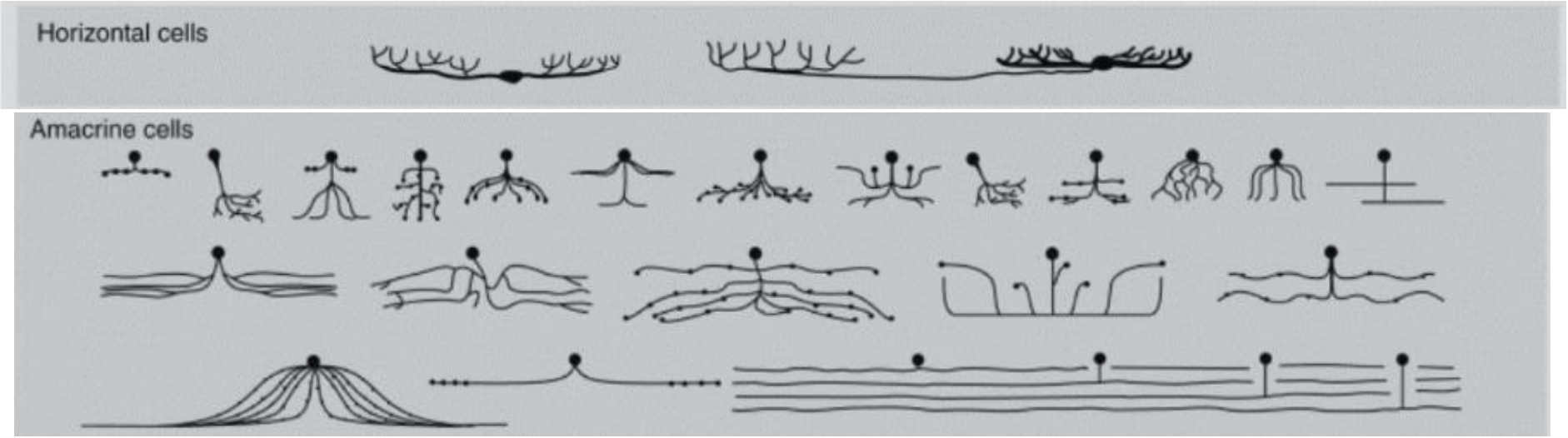


- Receives input from photoreceptors
- ON and OFF cells- ON cells activated in light, OFF cells activated in darkness.
- Cell types based on ON/OFF properties, presynaptic targets, postsynaptic targets, morphology.
- Release the neurotransmitter glutamate in response to activation.
- Do not fire action potentials.
- Synapse onto ganglion and amacrine cells.
- Also known as interneurons- bipolar cells connect the beginning of the vertical pathway (photoreceptors) and the end of the vertical pathway (ganglion cells).



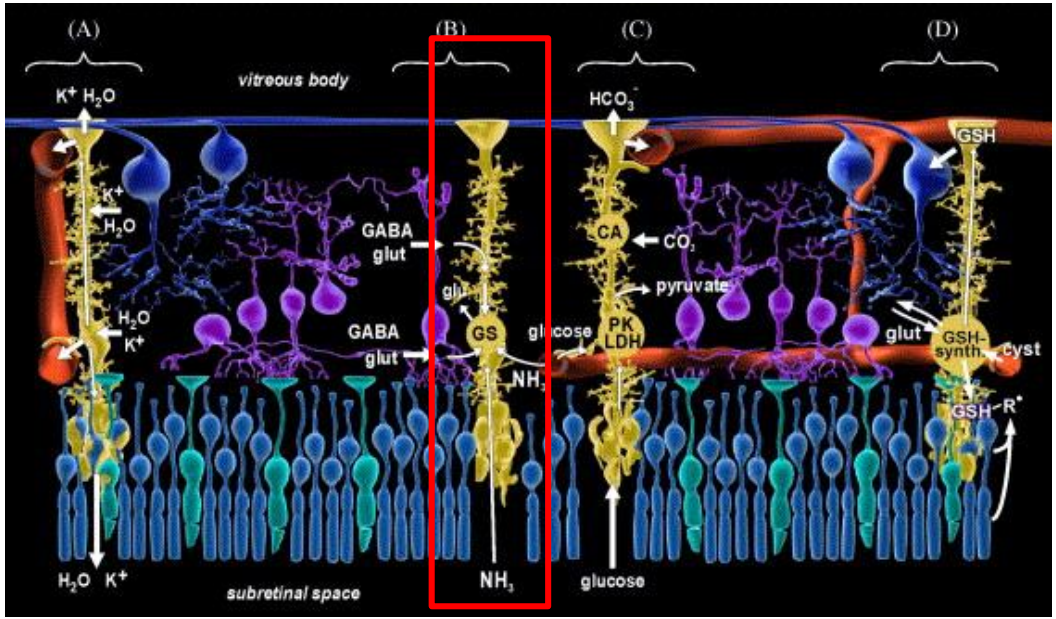
- ON cells and OFF cells
- Axons converge to form optic nerve, which exits the retina and projects to other areas of the brain.
- Center-surround receptive fields: in an ON cell, a spot of light in the center of the receptive field activates the cell, while a spot of light in the surrounding area of the receptive field activation is suppressed.
- Cells tiled in a way that every part of the retina is within the receptive field of at least one ganglion cell.





- Modify the vertical pathway through lateral interactions, often through inhibitory signals.
  - Notice the horizontal spread of the dendritic fields.
- Horizontal cells both project to and receive inputs from photoreceptors.
- Amacrine cells receive bipolar cell projections and synapse onto bipolar and ganglion cells.
- Horizontal cells will synapse onto other horizontal cells of the same type to create large, lateral networks.
  - Similar structure with amacrine cells.

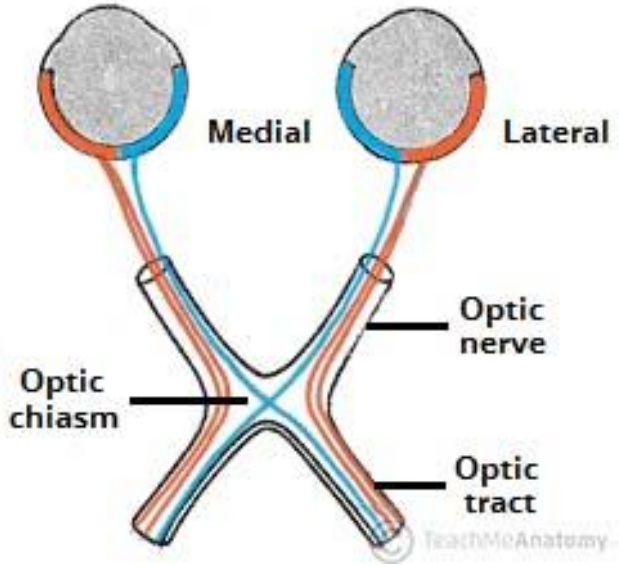
Müller Cells



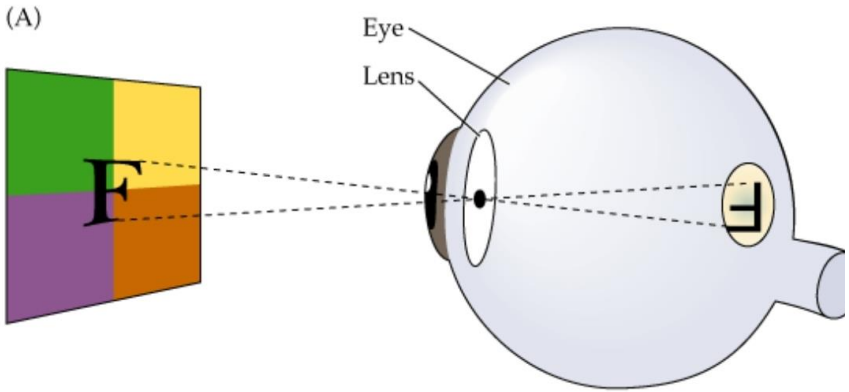
- Glial cells that span across all layers of retina in a vertical orientation.
- Similar function to astrocytes- transport glutamate from the extracellular space.

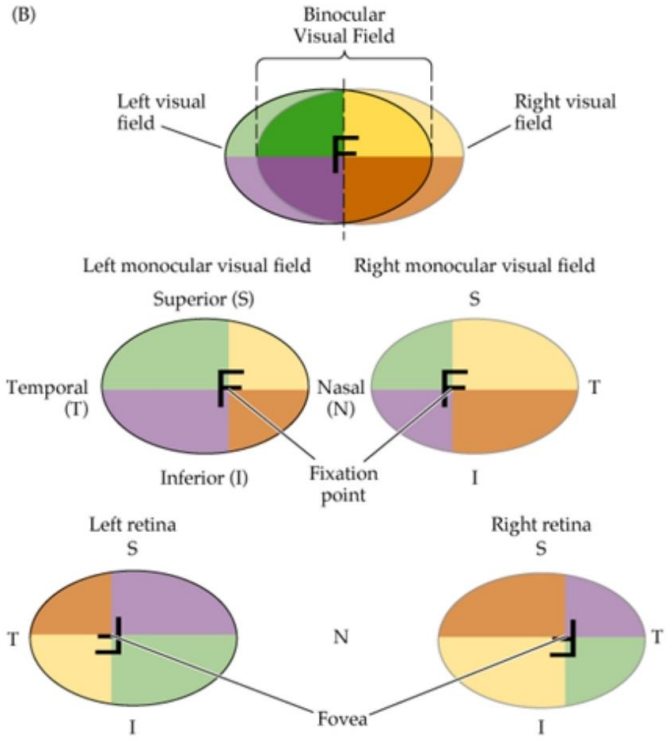
Where do the ganglion cells project to?

- Ganglion cell axons converge to form the optic nerve (which isn't actually a nerve).
- Nasal axons (i.e. axons from cells originating from the side of the retina closest to the nose) project to the contralateral side of the brain through the optic chiasm.
- Temporal axons (i.e. axons from cells originating from the side of the retina closest to the temples) project to the ipsilateral brain through the optic chiasm.



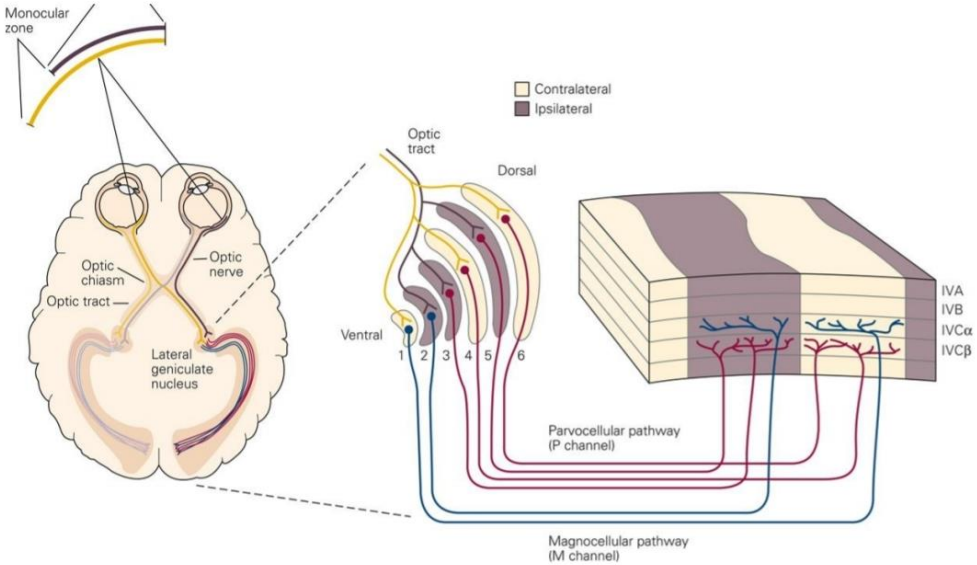
Vision Fields





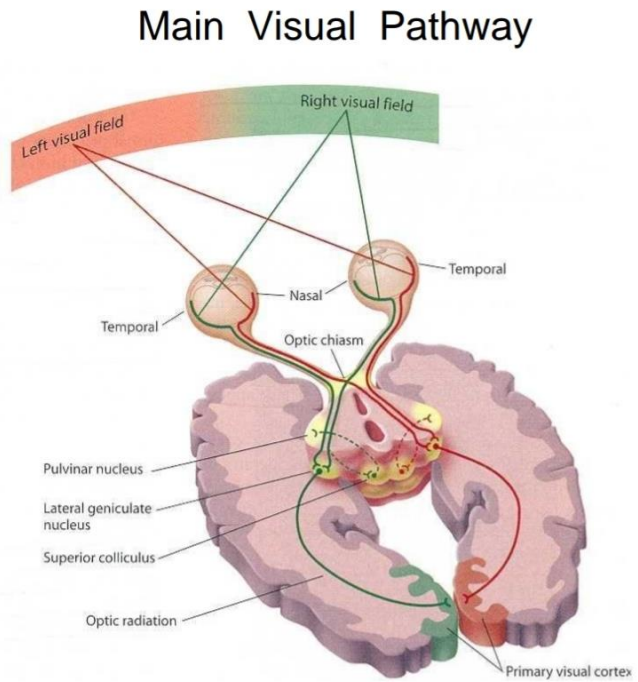
The optic tract projects to the lateral geniculate nucleus

- The lateral geniculate nucleus (LGN) acts a relay center from the retina to the rest of the brain.
- Each layer of the LGN receives a projection from **either** the ipsilateral or contralateral retina.

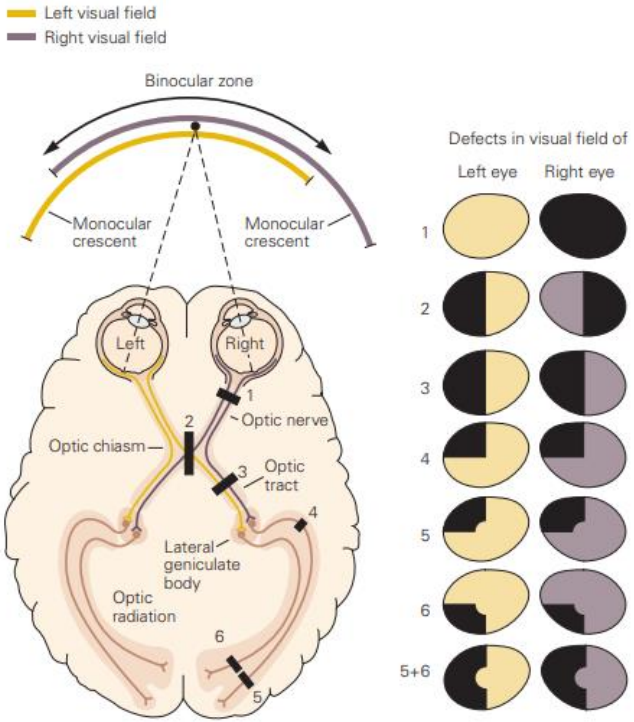


Projections from the LGN: 2 pathways

- One set of projections goes to the primary visual cortex of the occipital lobe, the other goes to the superior colliculus.
  - Optic radiations
- Superior colliculus plays a role in eye movements
  - Cranial nerves

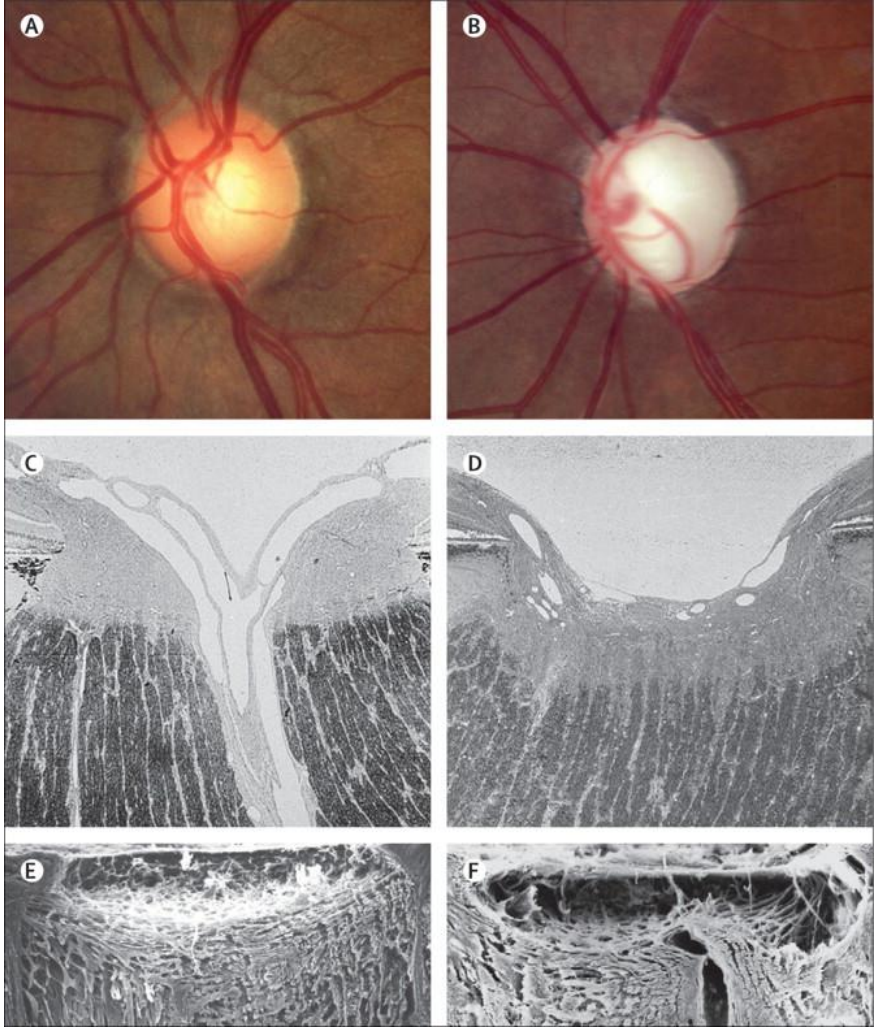


Lesions in the retina, LGN, LGN projections result in loss of sight in specific areas of visual field.



Glaucoma

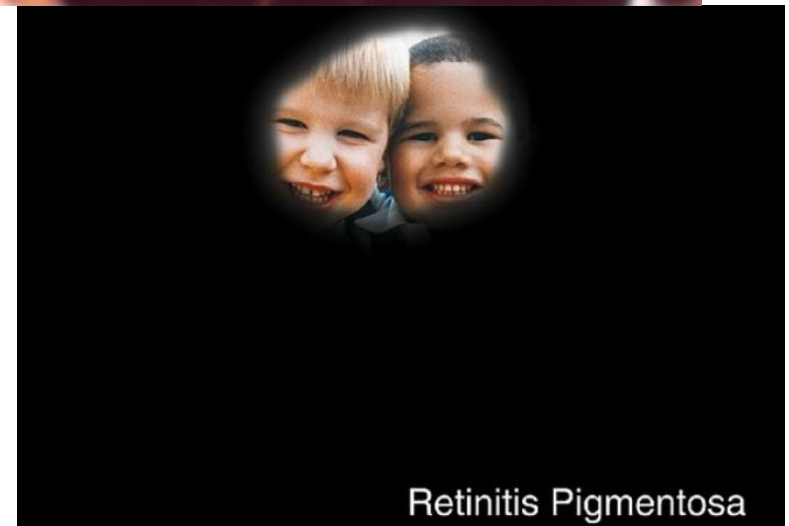
- Loss of vision due to optic nerve damage due to increased intraocular pressure.
- Angle-closure glaucoma- drainage between cornea and iris is blocked, preventing fluid circulation. Gradual or acute onset.
- Open-angle glaucoma occurs due to clogging of aqueous humour in eye. Gradual onset. More common.
- Old age seems to be the most prevalent risk factor.
- Glaucoma management includes medications, surgery, lasers, all aimed at lowering intraocular pressure.



Quigley 2011

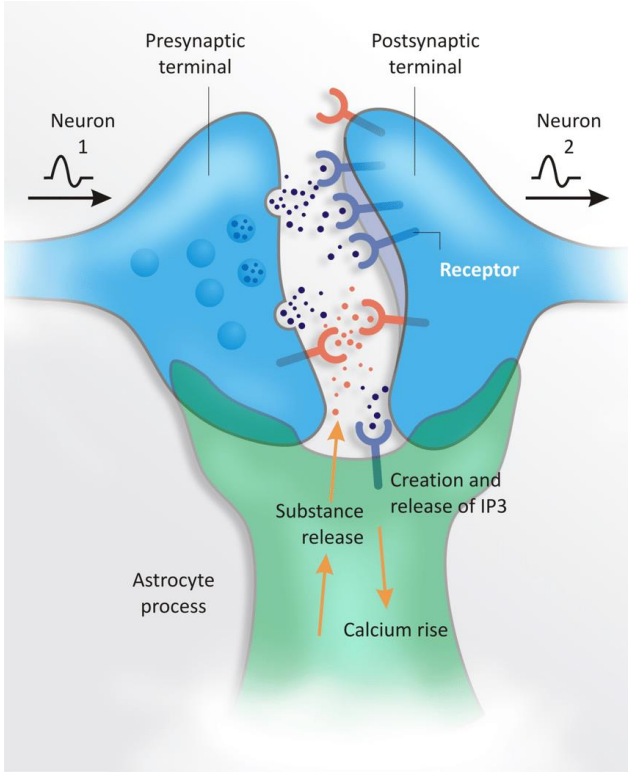

Diabetic Retinopathy

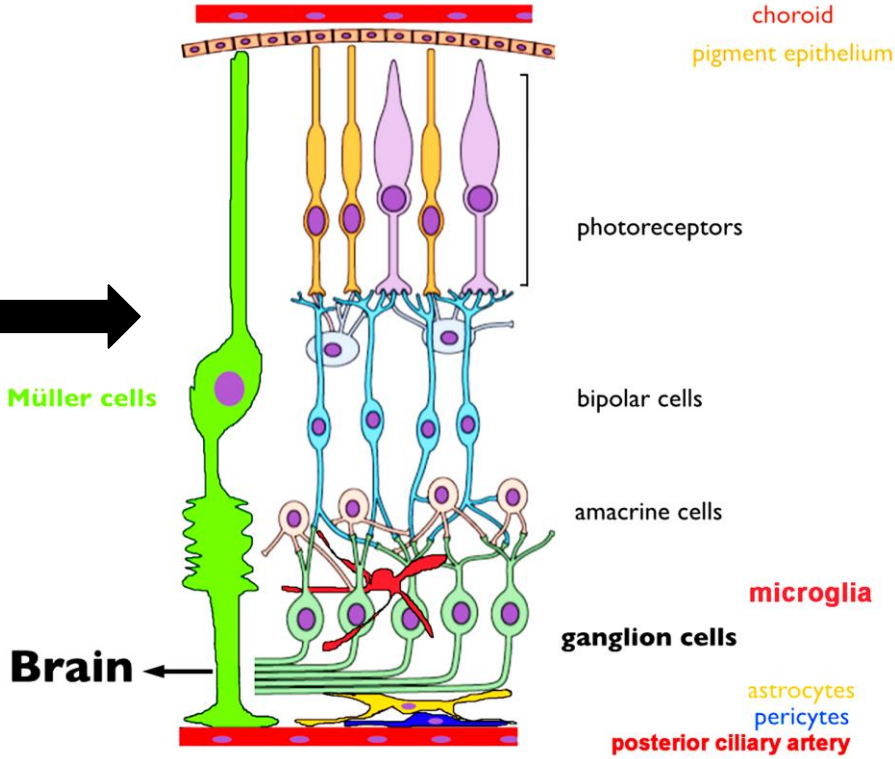

Age-related Macular Degeneration


Retinitis Pigmentosa

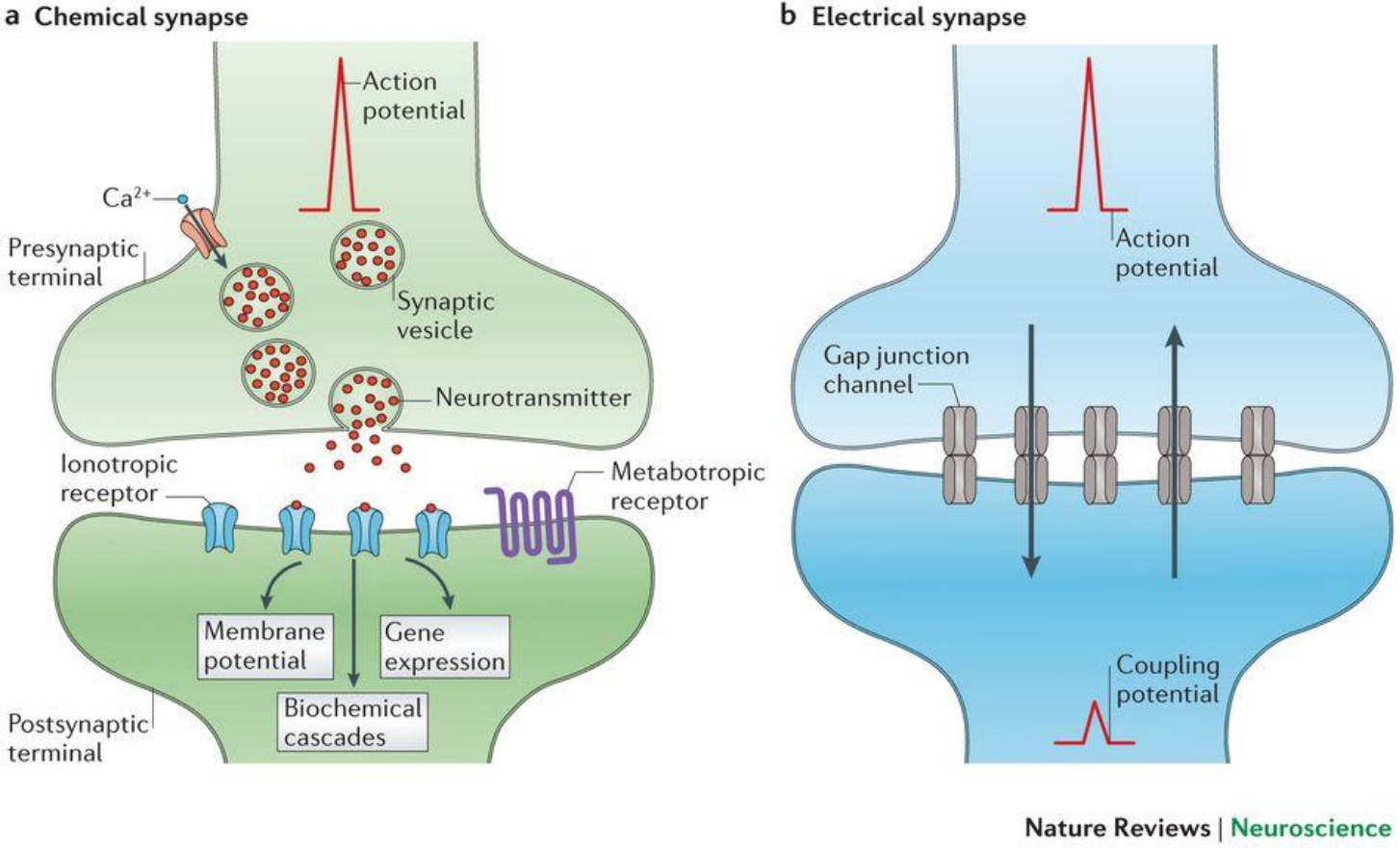

Glaucoma

Research in the retina- glial modulation of synapses

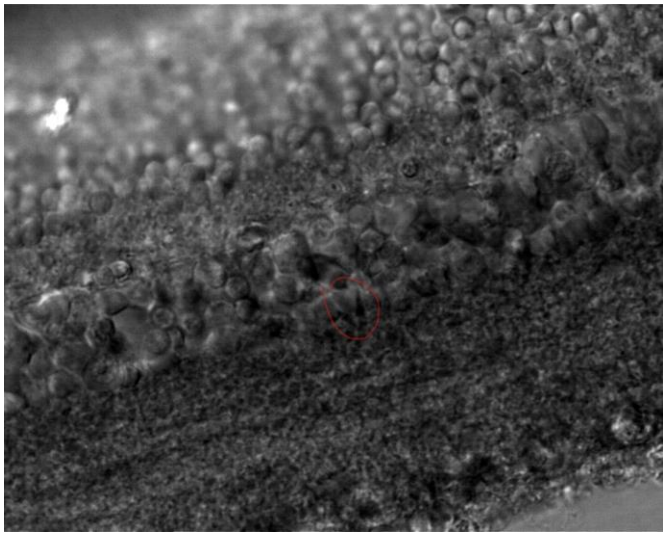


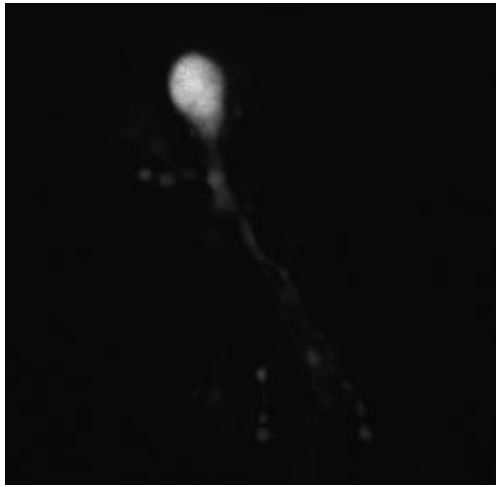


Chemical vs. Electrical synapses



Glial modulation of electrical synapses between AII Amacrine cells





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