Section 5
Vision

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COGS 17 A05

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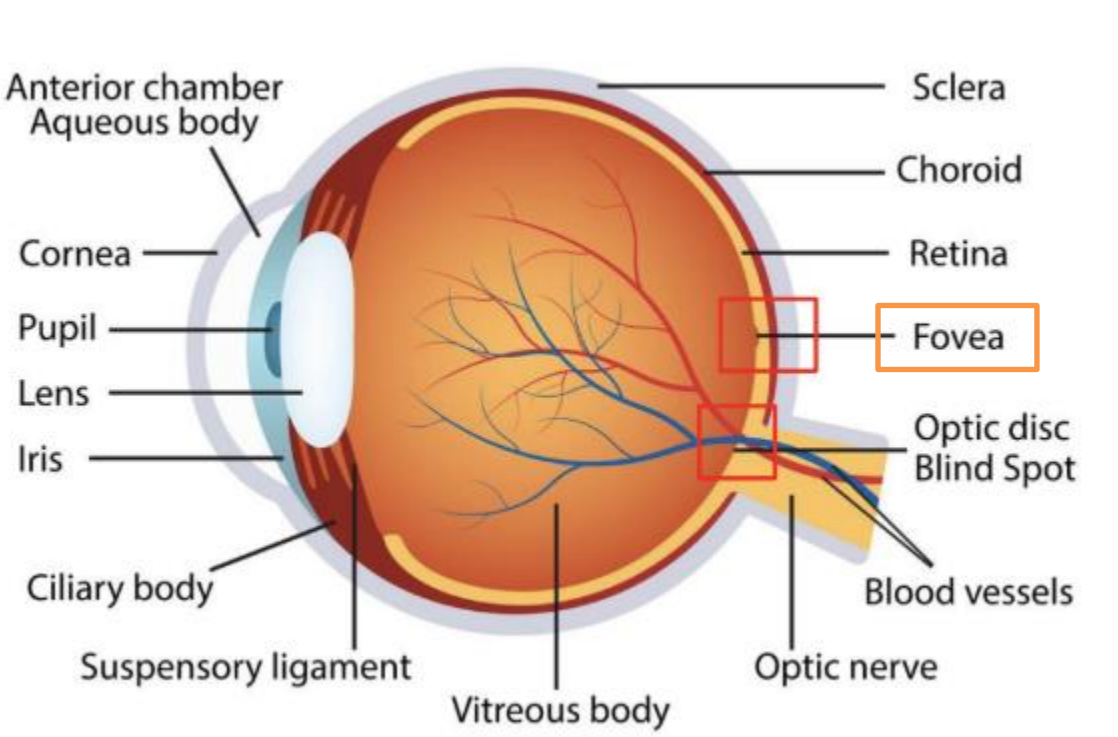
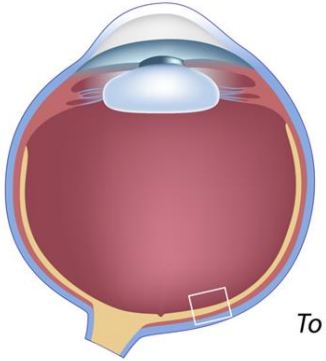
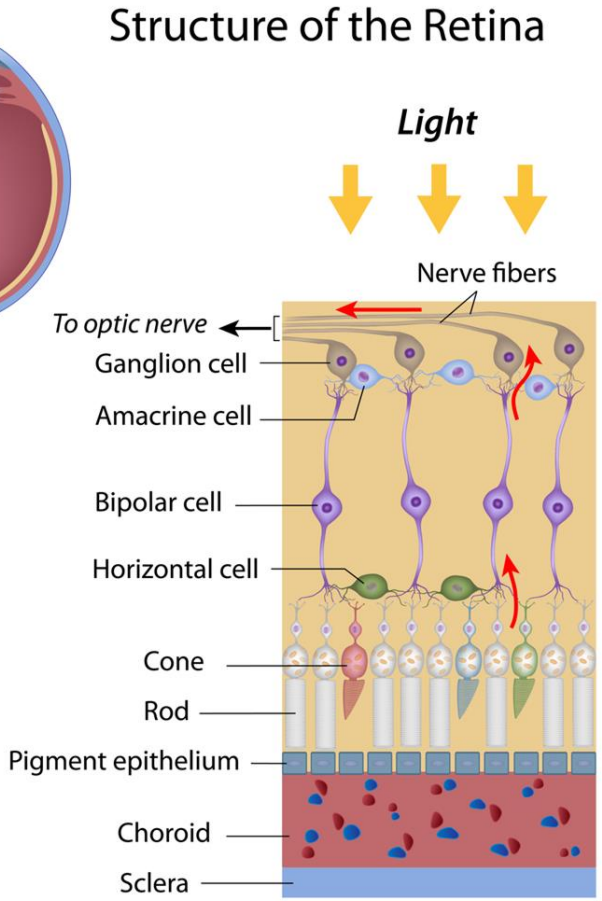
The Eye



- **Fovea**: point of central focus, high concentration of photoreceptor - **Cones,** for high **detail** resolution
- Retina: senses light and sends information to the brain through optic nerve
- Blind spot: No receptors here
- Light needs to pass through outer layers of the eye before reaching receptors (Cornea > Pupil > Iris > Lens > Receptors)

The Retina



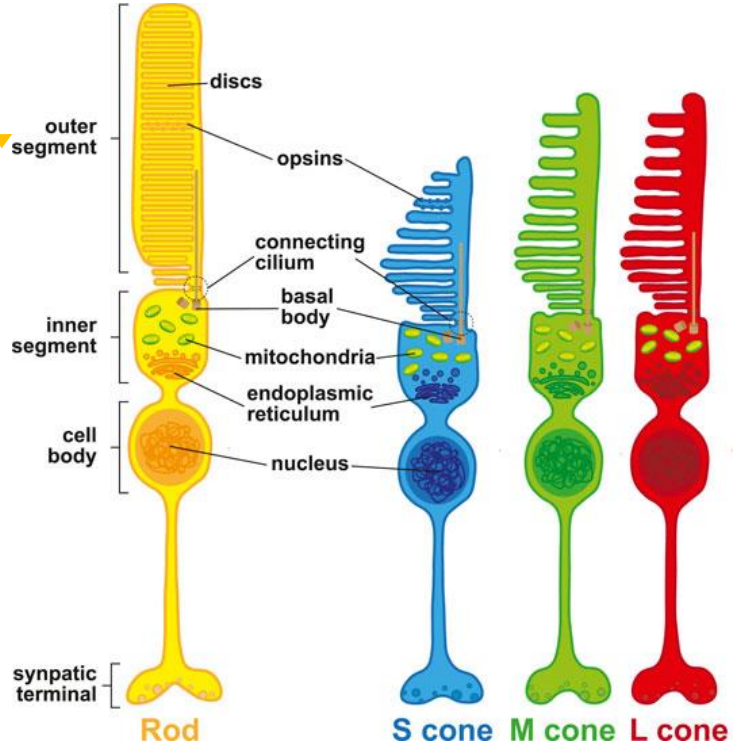


Covers the rear inner wall of the eyeball

- **Pigment Epithelium**: rearmost layer of non-neuronal cells, feed & recycle nutrition from receptors, help reflect/maximize light
- **Receptors**: Rods & Cones, rearmost layer of retina
- **Bipolar cells**: postsynaptic to receptors
- **Ganglions**: axons of the Ganglion cells form the Optic Nerve
- **Interneurons**: horizontal & amacrine cells, perpendicular to pathway, influence above neurons

Visual Receptors

- **Photoreceptors = Rods & Cones**
  - Contain photopigment molecules (Opsin – light-sensitive protein, *and* Retinal – short lipid segment, synthesized from Vitamin A) that react to light ("Isomerize") and alters NT release
  - Rod's outer segment is much larger with more photopigment, also greater in amount (Rods: ~120 million/eye, Cones: ~6 million/eye)
  - Graded Potentials that release inhibitory NTs

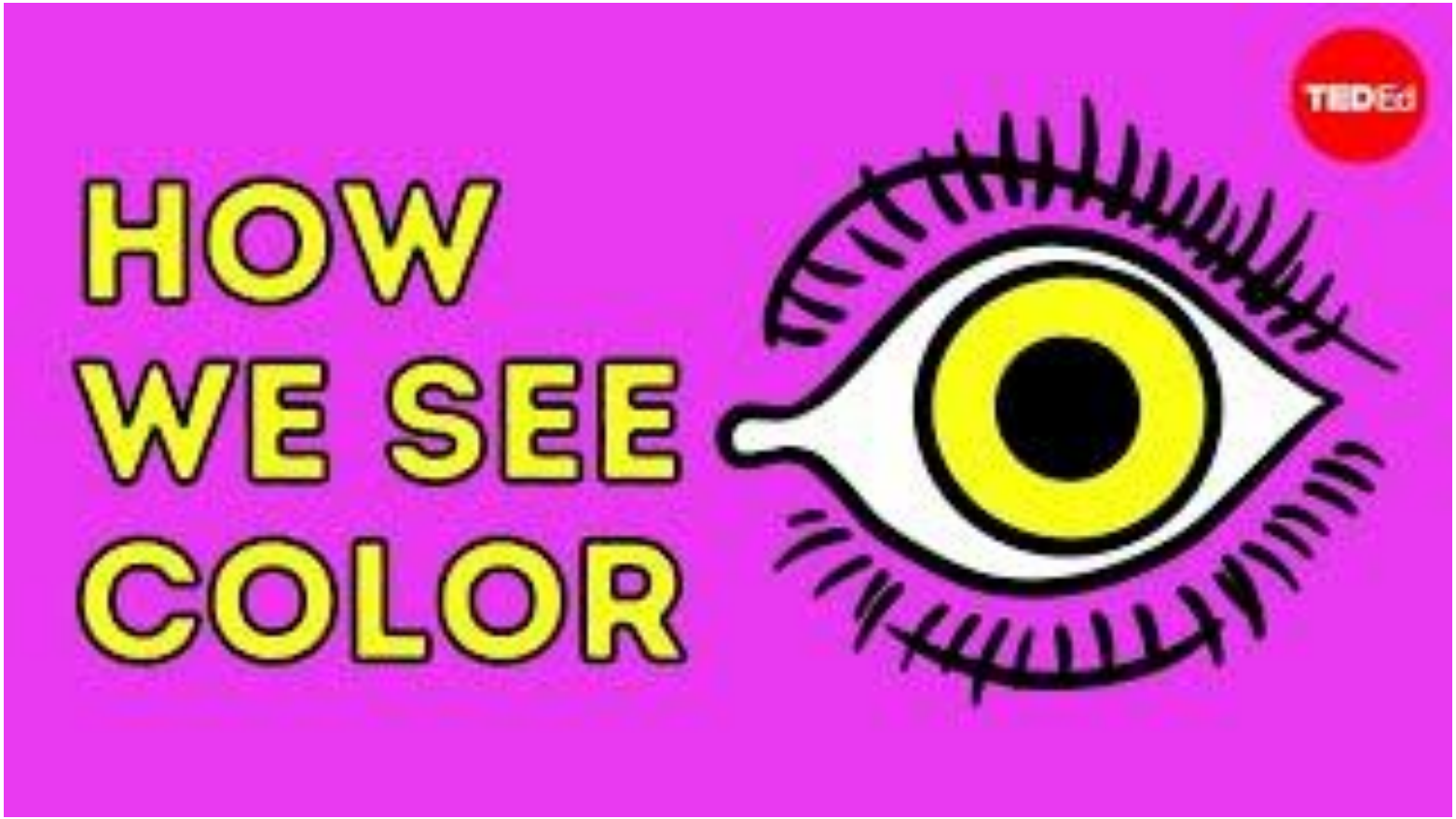


Visual Receptors

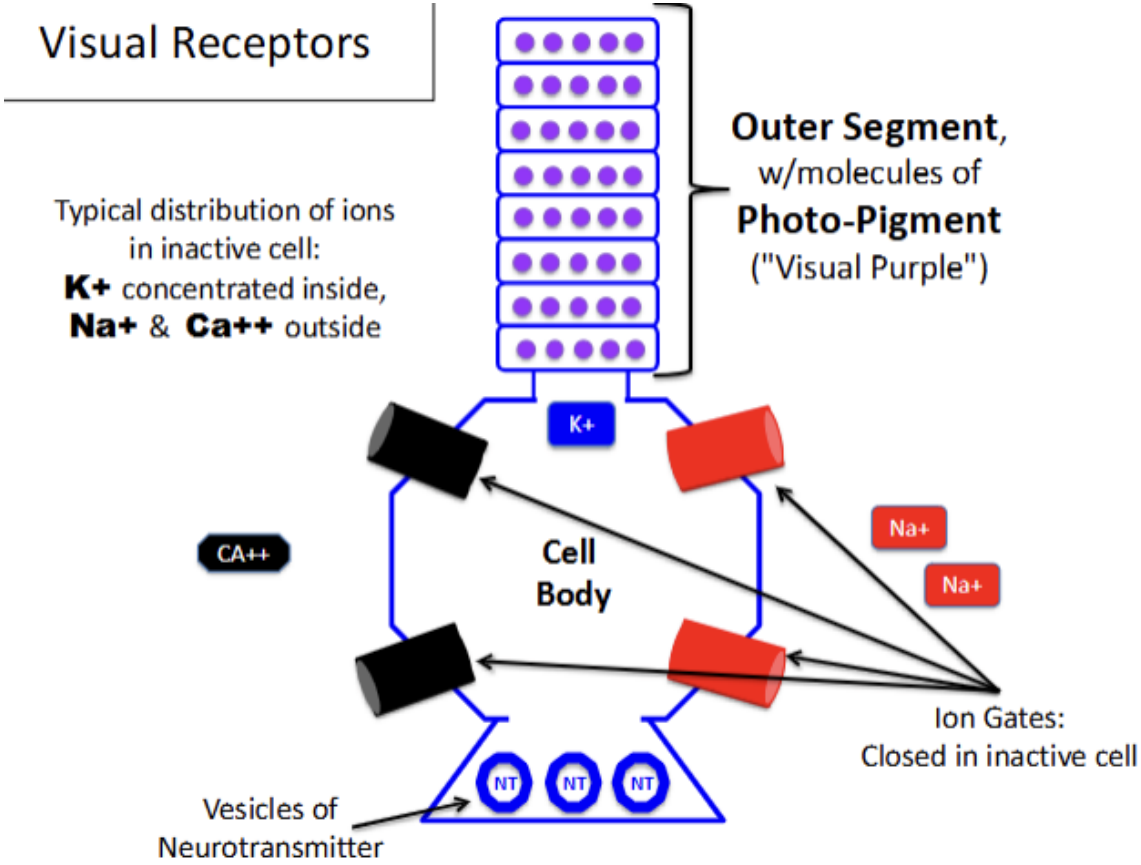
	RODS	CONES
Shape	Outer Segment rod-like	Outer Segment cone-like
Size	Larger (more photopigment)	Smaller (less photopigment)
#	~ 120 million/eye	~ 6 million/eye
Distribution	None in Fovea, highly conc'd in periphery	High concentration in Fovea, dispersed in periphery
Re: Ganglion Cells	High Convergence	Low Convergence
Potential	Graded potentials	Graded potentials
NT	Spontaneously release Inhibitory NT	Spontaneously release Inhibitory NT
Photopigment	1 kind (Rhodopsin)	3 kinds (sensitive to Long, Medium, Short λs)
Code Color	No (dark/light only)	Yes (Long, Medium, Short λs)
Motion Detection	Excellent	Poor
Acuity	Low	High (esp in Fovea)
Sensitivity	High (can operate in dim light)	Not as good (require brighter light)
Pathway	Magnocellular/Dorsal Stream	Mostly Parvocellular/Ventral Stream

Red: Similarities / Yellow: differences

Visual Receptors

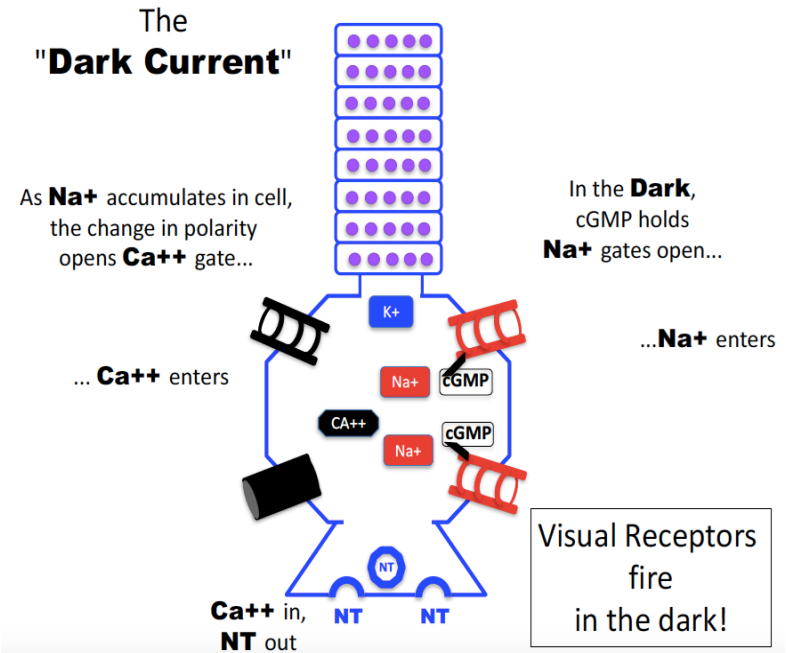


In the Dark


Visual Receptors
Typical distribution of ions in inactive cell:
K+ concentrated inside,
Na+ & Ca++ outside
Outer Segment, w/molecules of Photo-Pigment ("Visual Purple")
K+
CA++
Cell Body
Na+
Na+
Ion Gates: Closed in inactive cell
NT
NT
NT
Vesicles of Neurotransmitter

In the Dark

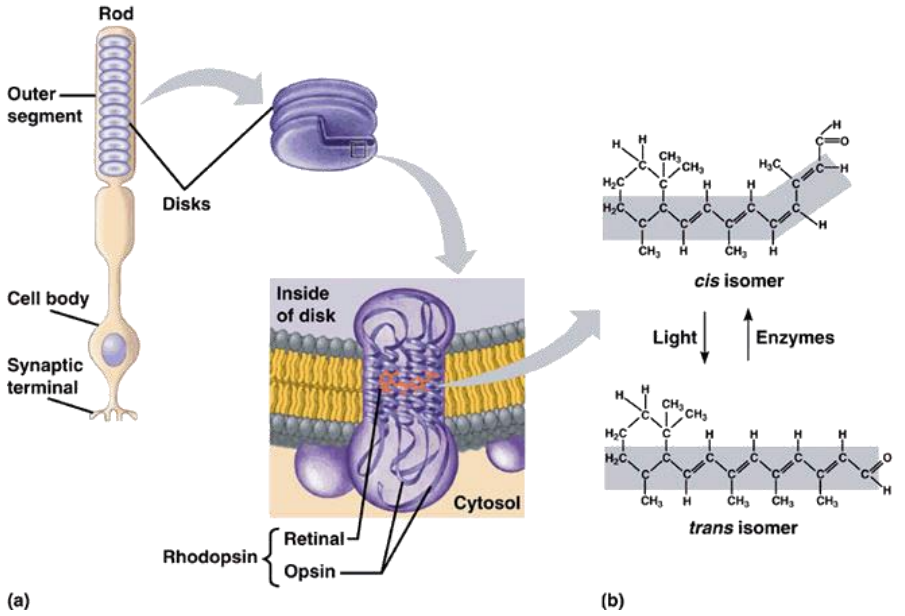
- Light turns Receptor cells OFF, Darkness turns them ON
- In the absence of stimulation (x light), cGMP holds Na+ gates open, Na+ flows in
- Ca++ gates also open, causing continuing release of NT, Ca++ actively pumped out so cycle can repeat
- As photopigments are isomerized, Na+ & Ca+ gates close, increasing Receptor's polarity, decreasing NT release



In The Light

How light is converted to neural signal?

- Photopigment made of Opsin & Retinal, undergo a chemical change (=Isomerization) when they absorb light
- *11-Cis Retinal* changes shape (straightens → now called *All-trans* Retinal) and detaches from Opsin (Opsin changes color from reddish-purple to pink, “bleached”)
- When isomerized, cGMP converts 5’GMP so that Na+ gates are closed → x Ca^{2}+ enters as the Ca^{2}+ gates are closed → x NT release
- Ultimately in the light, the “Dark Current” is shutdown (turned off by the light)

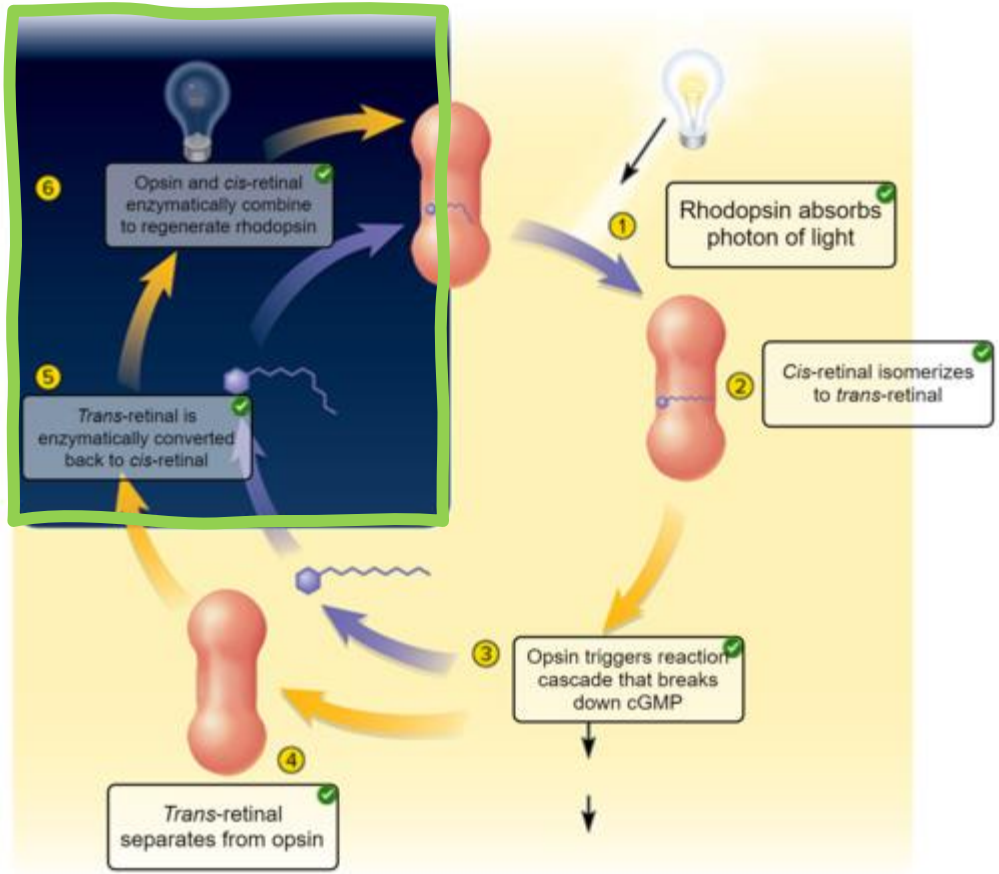


In The Light

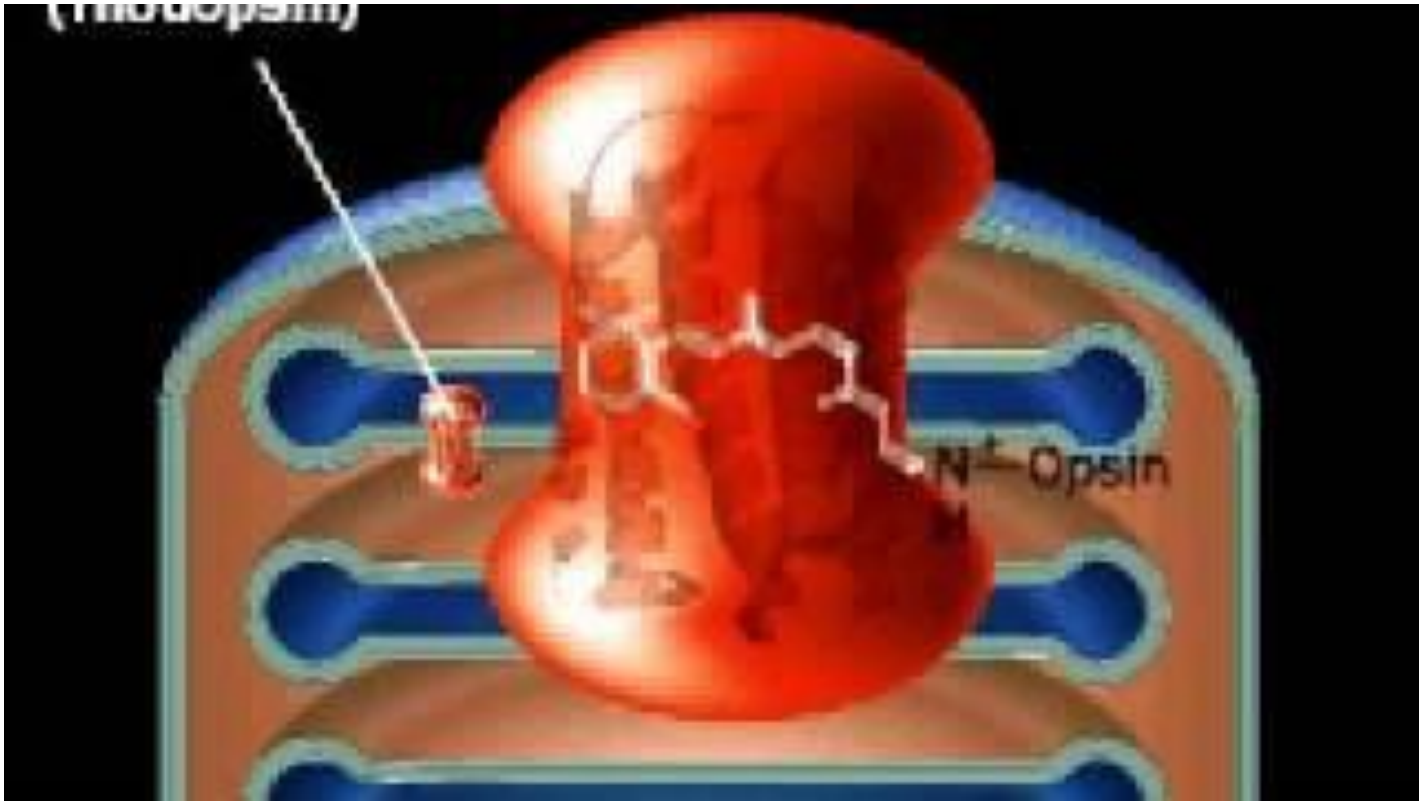
- Photopigment regeneration (recombination of Retinal & Opsin): use enzymes from Pigment Epithelium, Requires time…

e.g. Hard to see indoors at first after bright sunlight (since “Light Adapted”) but as regenerate, sensitivity restored

e.g. Hard to see just after turn off lights, but soon, as more regenerate, sensitivity increased (become “Dark Adapted”)



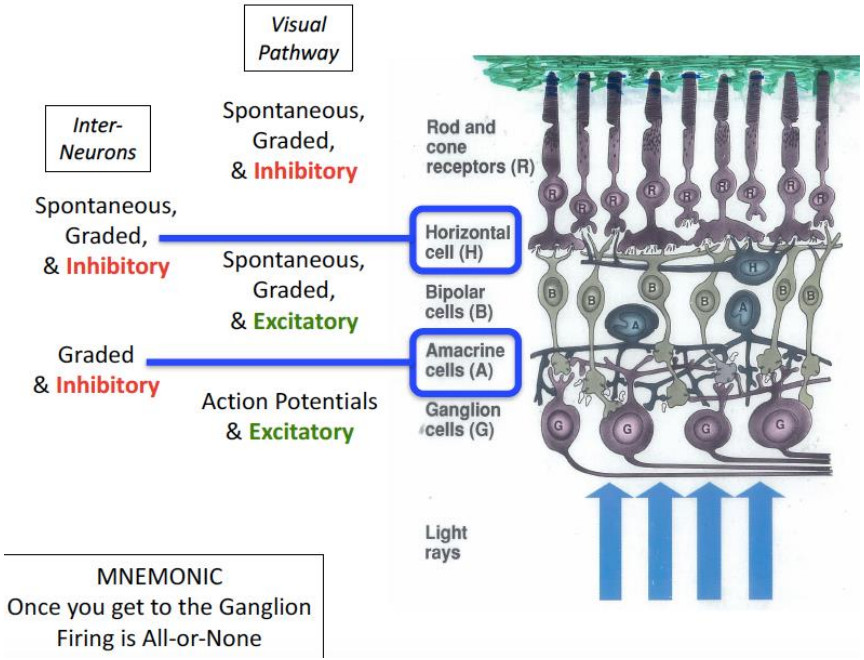
In The Light



Connectivity

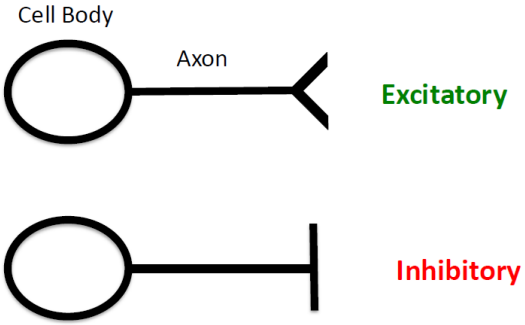
From Receptors To the Brain…

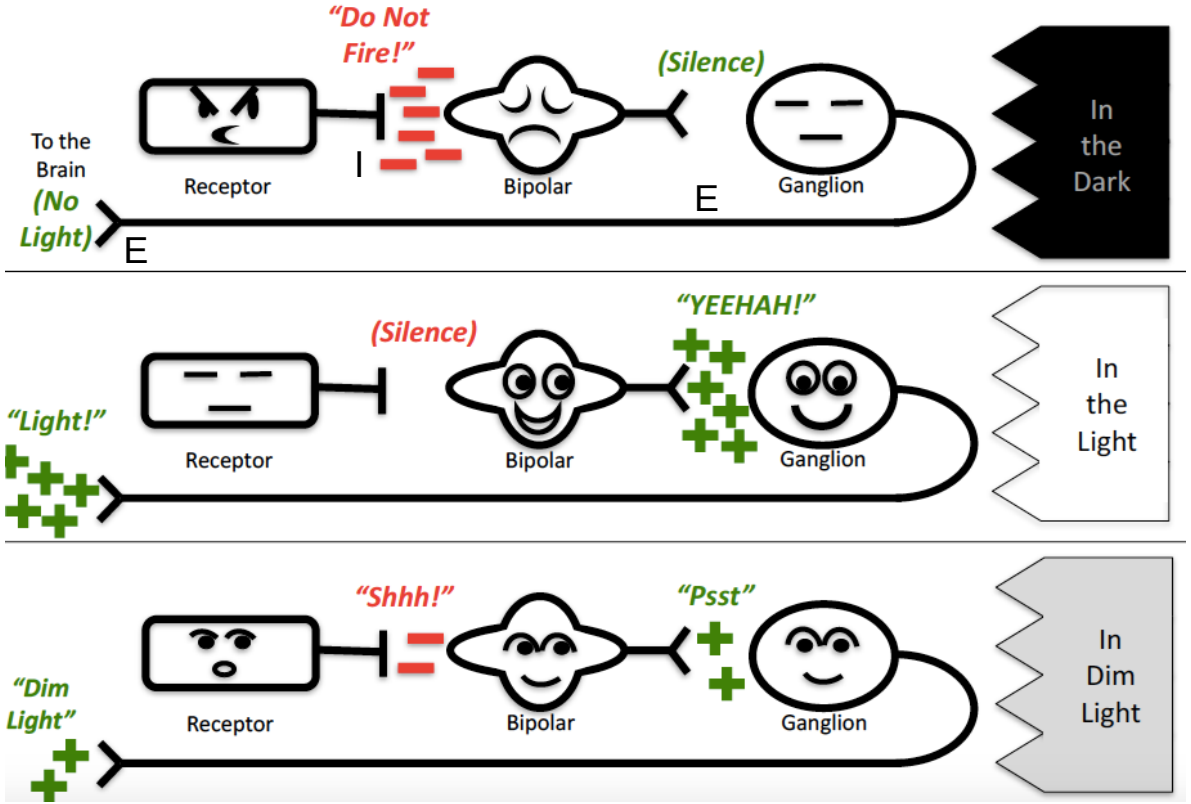
- **Rods and Cones:** Graded potentials with inhibitory NT
- **Bipolars**: Postsynaptic to Receptors
  - Spontaneous firing of Graded Potentials, releases Excitatory NTs
- **Ganglions**: Postsynaptic to Bipolars
  - Fires off Action Potentials, releases Excitatory NTs
- **Interneurons** (**Horizontals** and **Amacrines**)
  - Both send out Graded Potentials, mostly inhibitory NTs (Lateral Inhibitors)
  - Horizontals mainly modify interface of Receptors and Bipolars
  - Amacrines mainly modify interface of Bipolars and Ganglions



MNEMONIC
Once you get to the Ganglion
Firing is All-or-None

Connectivity Patterns





Fill in the Blank

A.

In the **(dark / bright light),** Receptors release enough **(inhibitory / excitatory)** NT to prevent Bipolars from triggering Ganglions

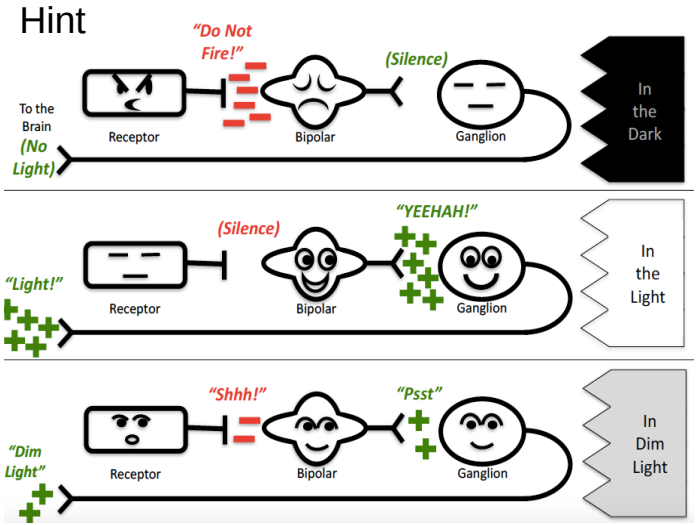
→ Ganglions does not fire

B.

In **(dark / bright light),** Receptors are **(turned on / shut down),** do not inhibit Bipolars, so Bipolars spontaneously release enough excitatory NT to pass Ganglion's threshold for firing

→ Ganglions fire a lot

Hint



Fill in the Blank

A.

In the **dark**, Receptors release enough **inhibitory** NT to prevent Bipolars from triggering Ganglions

→ Ganglions, by not firing, in effect, report to brain: “No light”

B.

In **bright light**, Receptors are **shut down**, do not inhibit Bipolars, so Bipolars spontaneously release enough excitatory NT to pass Ganglion’s threshold for firing

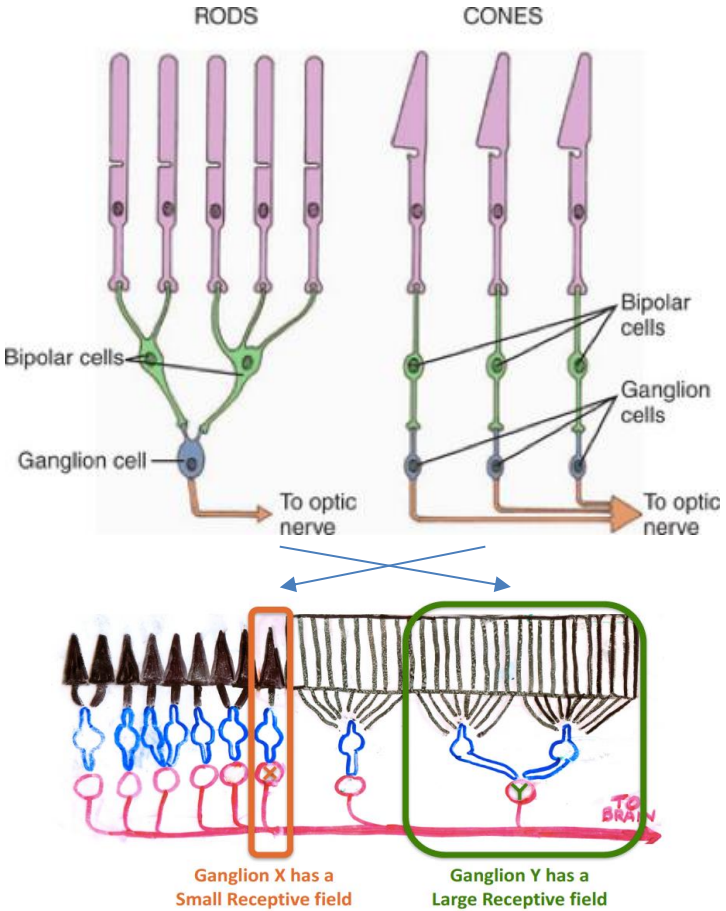
→ Ganglion sends message: “Bright Light!”

Convergence

- Receptors Converge onto Ganglion Cells (varied ways)

- **Cones**
  - **Low** Convergence (6:1 or few:1)
  - **High Acuity**, detailed information is preserved (link w/ smaller Receptive Field – fewer receptors influencing downstream ganglion cell)
  - Fovea Cones have very low convergence (1:1)

- **Rods**
  - **High** Convergence (120:1 or Many:1)
  - **Low Acuity,** details can be lost



Receptive Field

- A set of receptors whose activity influences the activity of a “target” downstream cell

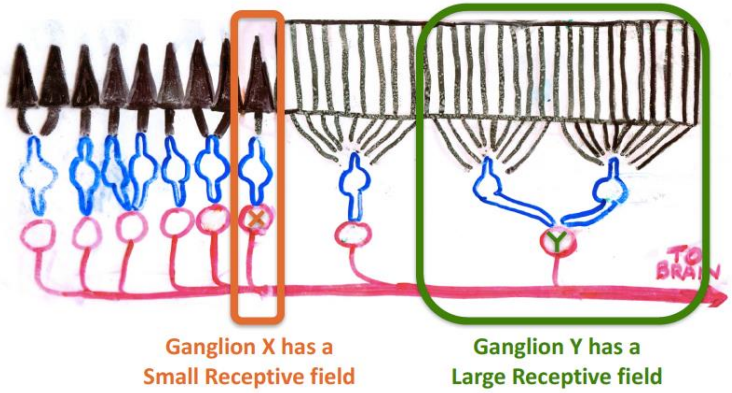
- Can think of this as pixel resolution
  - If you have less convergence (smaller RF), more neurons (pixels) are dedicated to a particular detail (higher DPI)

- Size and type of a Target’s RF is determined by patterns of Convergence and Lateral influences

e.g. Ganglion (target) along path from converging Rods has large RF, while Ganglion along path from Cones has small RF

HIGH RESOLUTION (300 DPI)

LOW RESOLUTION (72 DPI)

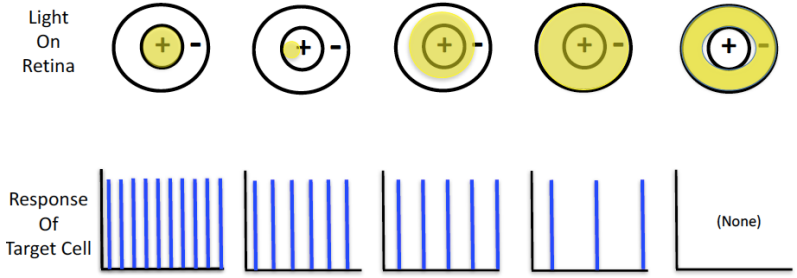


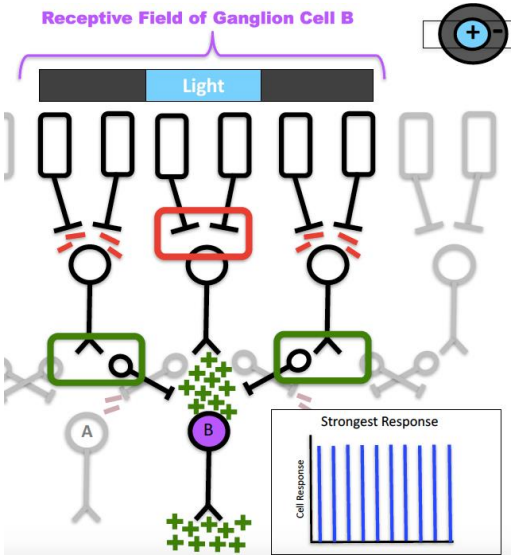
Ganglion X has a Small Receptive field

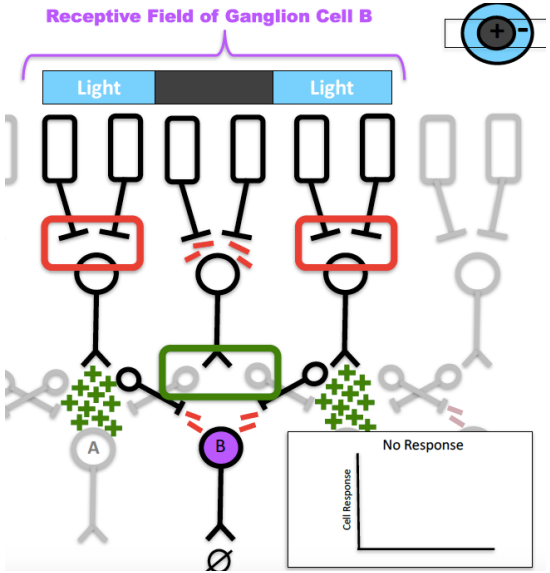
Ganglion Y has a Large Receptive field

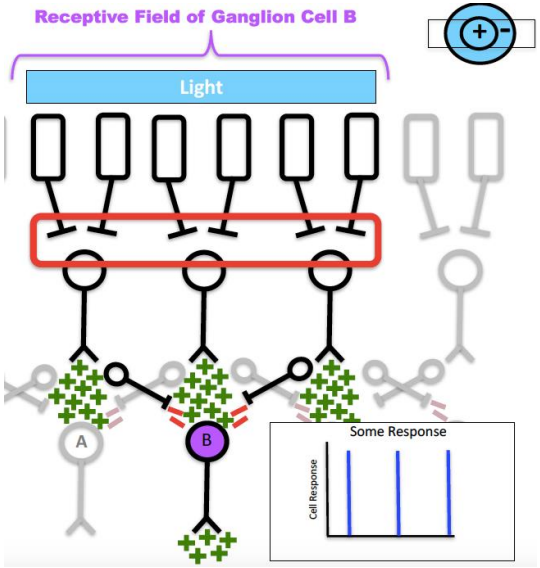
Center-Surround Receptive Fields (RF)

- Excitatory center and inhibitory surround RF
- RF of cells on the retina have Excitatory (+) or Inhibitory (-) activities
- RFs overlap, thus many receptors contribute to multiple RFs









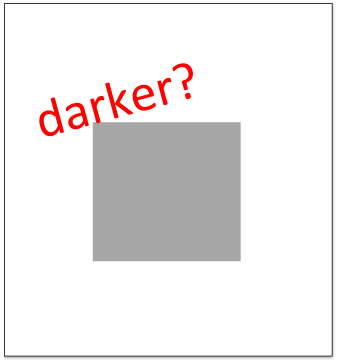
Simultaneous Contrast in the Retina

- Optical Illusion

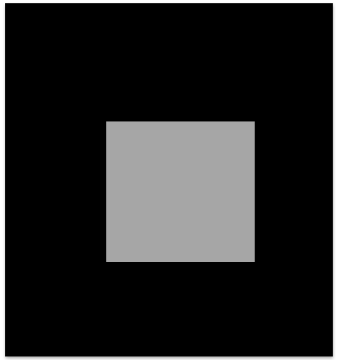
- Due to Lateral Inhibition, the Ganglions “lie to the brain” about the medium gray, making the one located in the center of the white box look darker

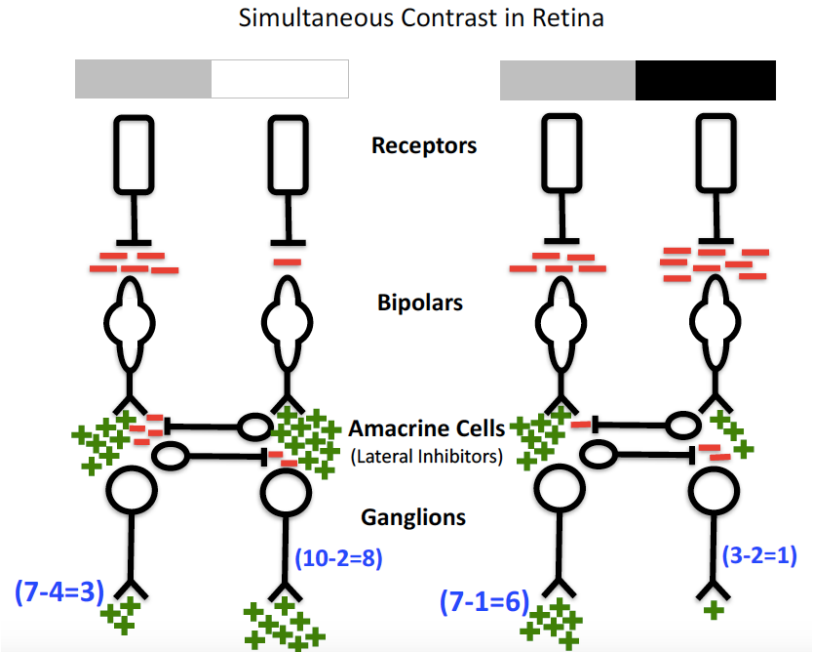
1) More lateral inhibition from the bright surrounding
2) Less lateral inhibition from the dark

1)



2)





Optical Illusions

Visual Crossover

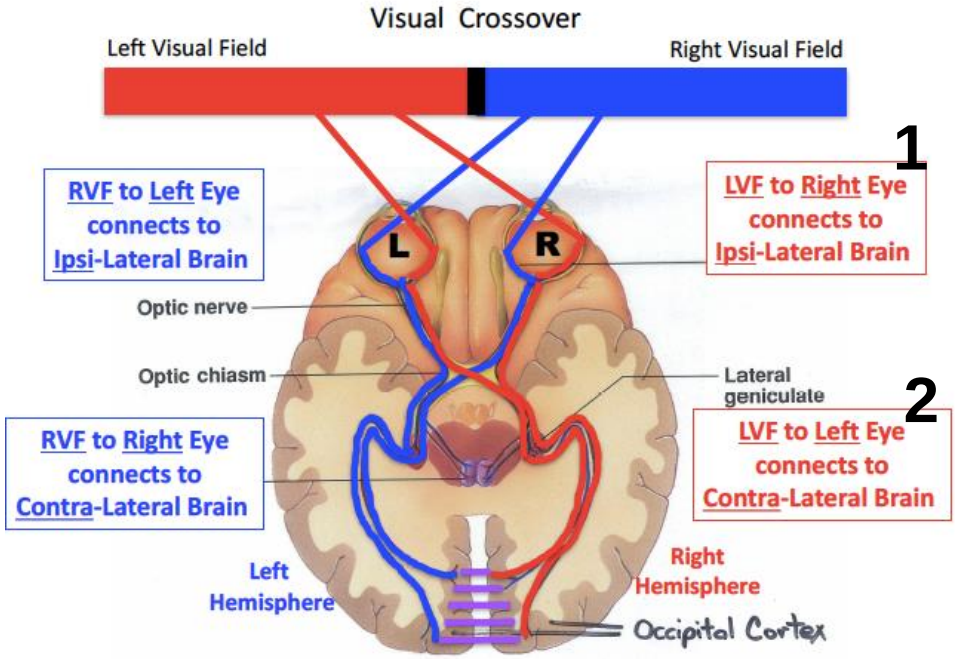
- Each Optic Nerve, from each eye, divides and goes to both sides of the brain

- When you fixate on a single point in environment, any stimulus to the L of that point will fall on the R side of both Retinas (= Left Visual Field, LVF) and vice versa

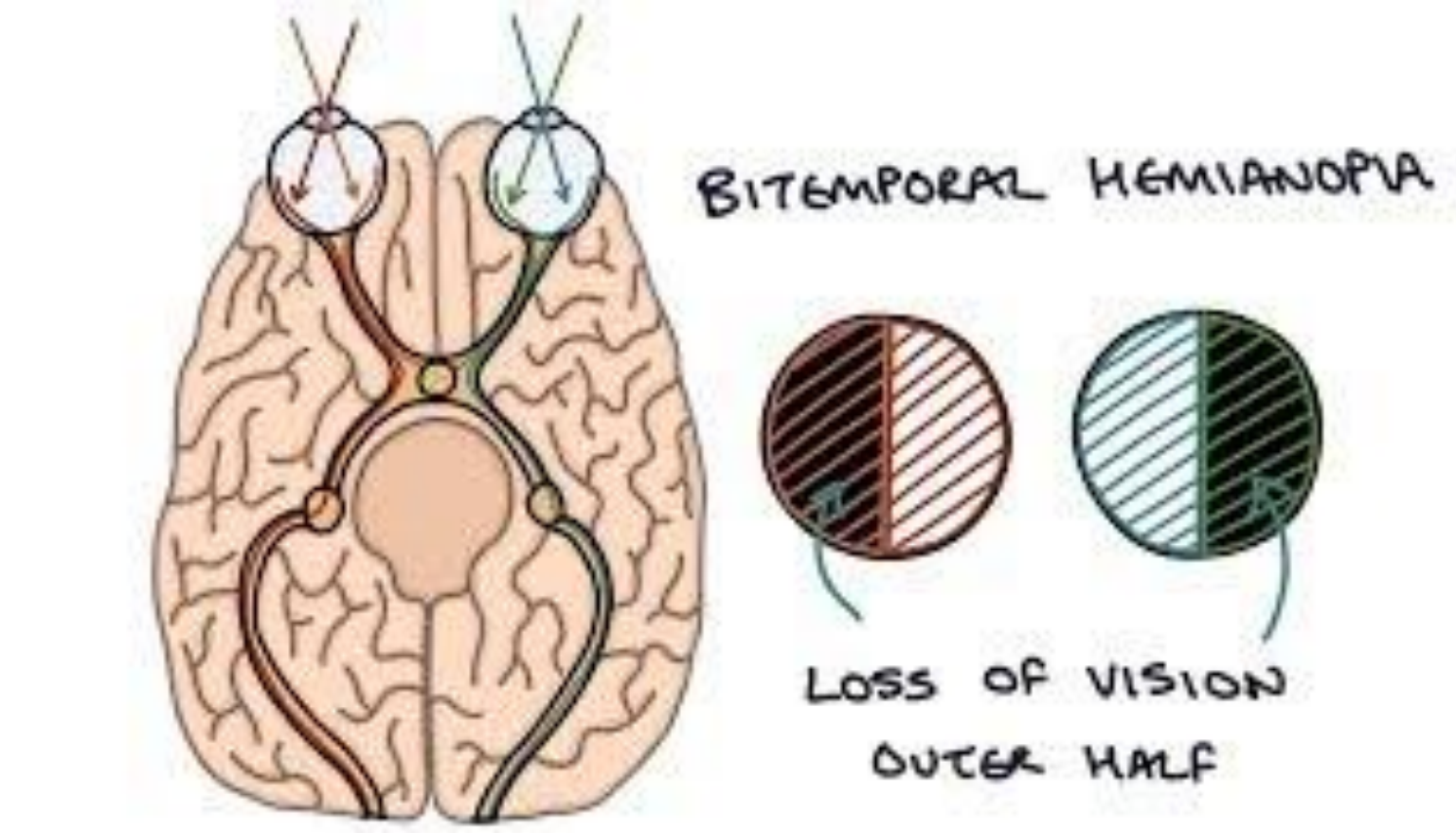
- Info from **LVF**

→ **1.** falls onto the Retina on **R side** of R eye, then to R LGN, R Striate Cortex

→ **2**. falls onto the Retina on **R side** of L eye, cross over at Optic Chiasm, then to R LGN, R Striate Cortex



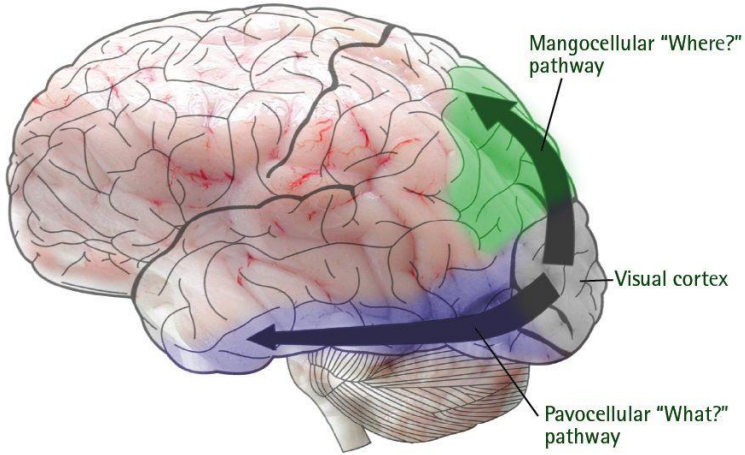
Visual Crossover



Information Pathways

- **Dorsal Pathway (Magnocellular Pathway)**
  - "Where/How" information → for visuo-spatial mapping
  - Motion and Depth
  - Begins at Rods & Cones in periphery of Retina
  - "Magnocellular" Ganglions (Y Ganglions) w/ large RFs

- **Ventral Pathway (Parvocellular Pathway)**
  - "Who/What" information → identification
  - Color and Detail (Contextual information)
  - Begins at Cones in and near Fovea
  - "Parvocellular" Ganglions (X Ganglions) w/ small RFs



LGN

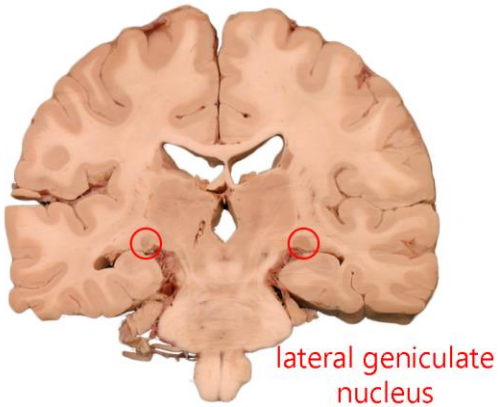
6 layers

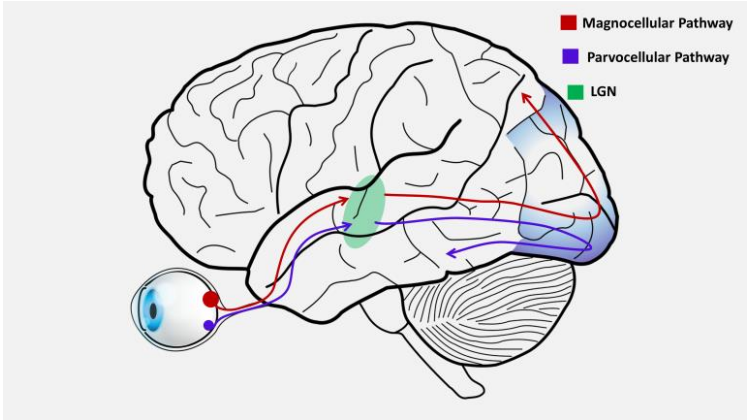
Magnocellular Pathway (Where Pathway) projects to and from layers 1 & 2

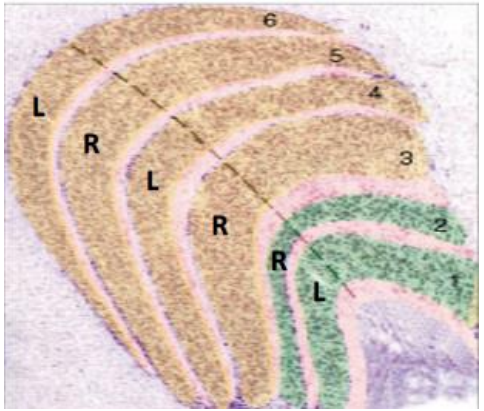
- Bottom 2 layers of LGN of thalamus > V1 > V2 > Medial Temporal Cortex > Medial Superior Temporal Cortex > Posterior Parietal Cortex

Parvocellular Pathway (Who/What Pathway) projects to and from layers 3-6

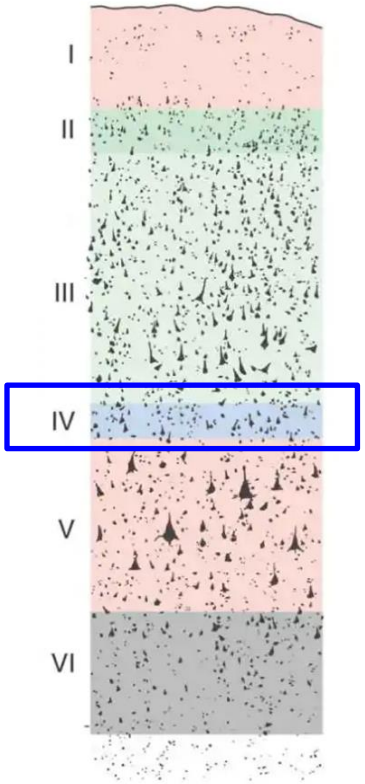
- Top 4 layers of LGN of thalamus > V1 > V2 > V3 > V4 > Inferior Temporal Cortex



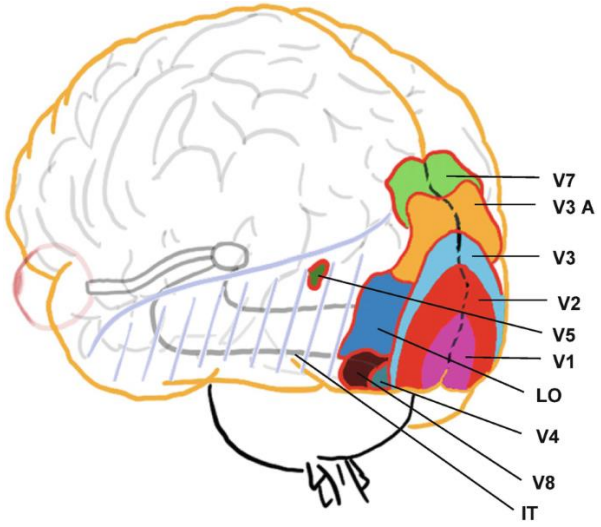




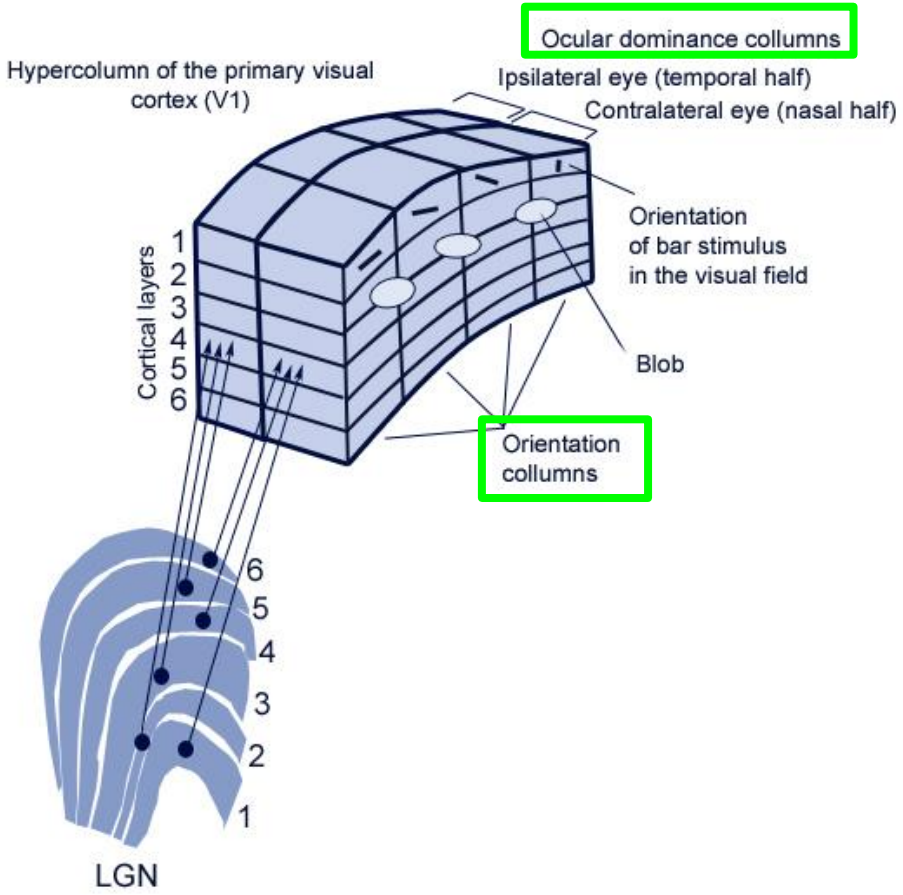
Visual Cortex (Occipital Lobe)



- 6 Layered Cortex
- Layer **4** of the Primary Visual Cortex (V1) receives input from the LGN
- Information is then processed and passed “upwards” to other Visual Cortices (V2-V4) which specialize in processing certain properties (Color, Shape, Orientation, etc)



Columnal Organization

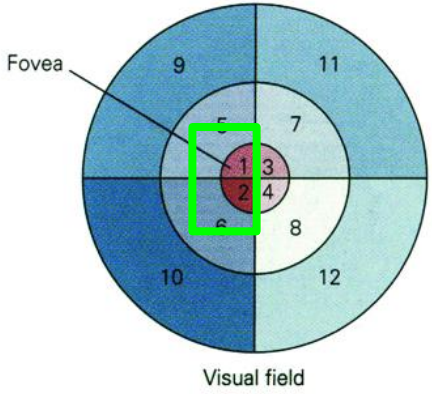


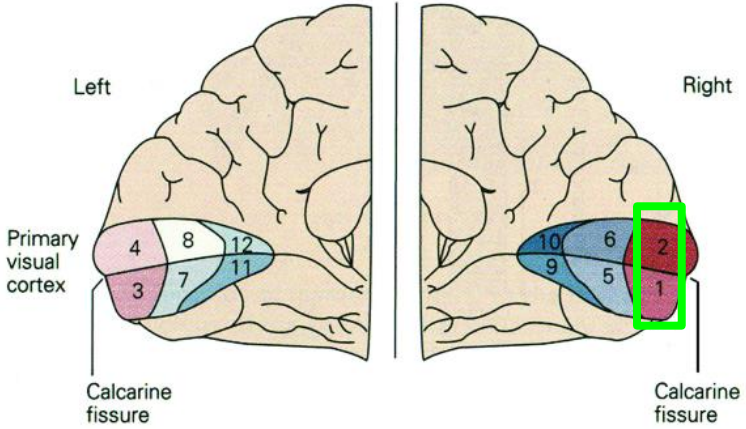
- **Column:** run vertically through the layers of the cortex
  - Each column respond to lines oriented in one particular orientation (same "preferred" stimuli like | or / or \ or —, etc)

- **Hypercolumn:** a set of orientation columns with the same receptive field
  - One Hypercolumn includes columns for 1 full set of Orientations, plus "Blobs" for color processing, from same area of retina
  - Retinotopic Map reproduces retinal layout such that adjacent columns have adjacent RFs in Retina

Columnal Organization

Retinotopic Organization

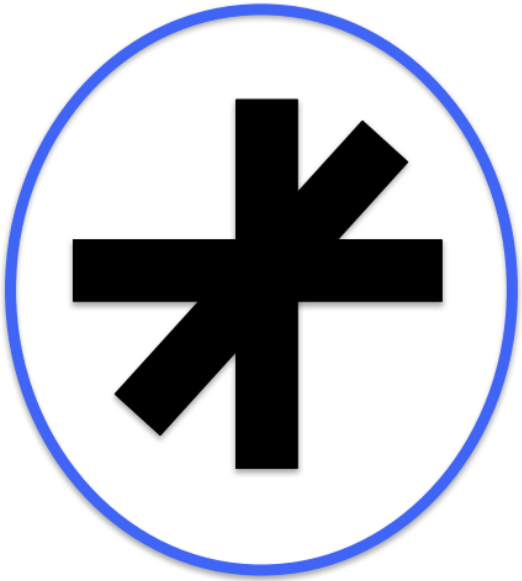




Columnal Organization

Simple Cells in V1

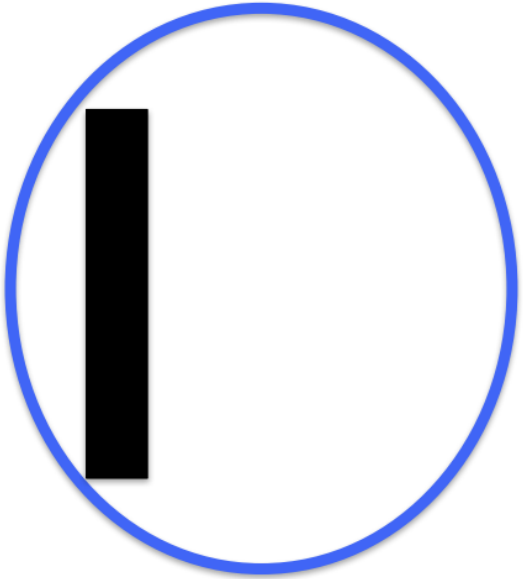
Respond to "bar" in a particular orientation in a given Receptive Field



Receptive Field of Simple Cell in Retina

"Complex" Cells in V2

Respond to **moving** "bar" in particular orientation in given Receptive Field



Receptive Field of Complex Cell in Retina

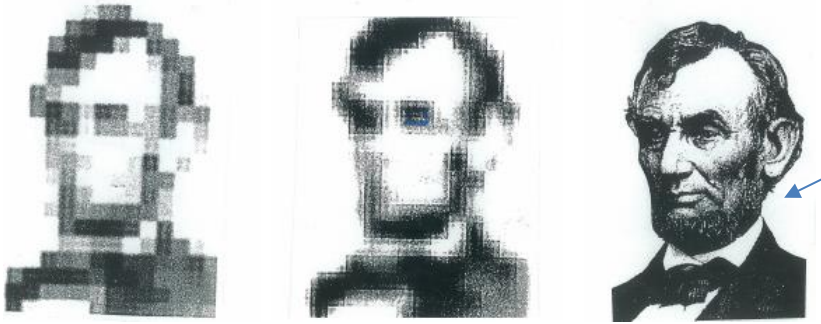
Columnal Organization

Vivid Vision

- To determine details such as shape and texture, detail information is processed in a hierarchical structure **V1 >V2 >V3 >V4**
  - Simple cells of V1 responds best to lines of particular Orientation (Orientation tuned)
  - Complex cells of V2 responds best to moving lines of particular orientation (Motion tuned)
  - V3 integrates visual information
  - V4 is tuned to orientation, spatial frequency, and color

- **Spatial Frequencies (SF)**
  - # of dark-light transitions (changes in contrast) in a given amount of visual space
  - Low SFs for Gross outlines (e.g., general shapes, broad features), High SFs for Fine details – correspond to

Low



High SF

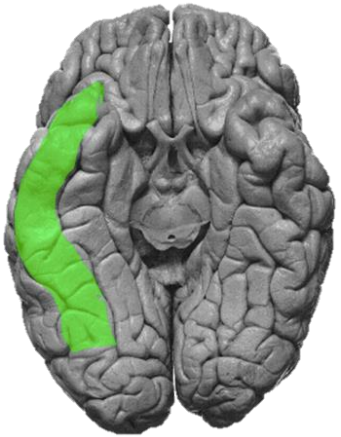
a lot of dark-light transitions in a small area

Fusiform Gyrus

- Face recognition in Inferior Temporal (IT) Cortex
  - Aka Fusiform Face Area (FFA)

- Damage to this area leads to Prosopagnosia, the inability to identify familiar faces (face blindness)

- Other cells in IT react to objects (dog breeds, cars, etc) of which you are an expert (highly practiced) discriminator



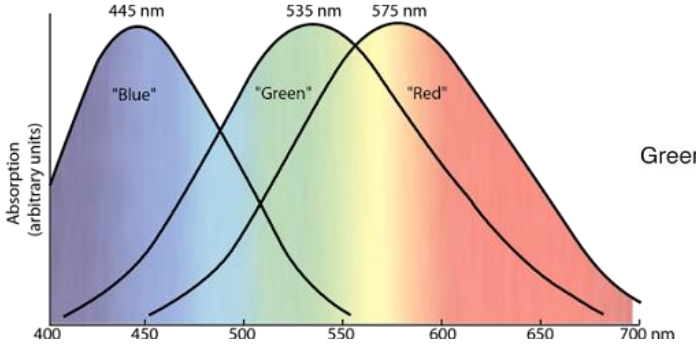
same!

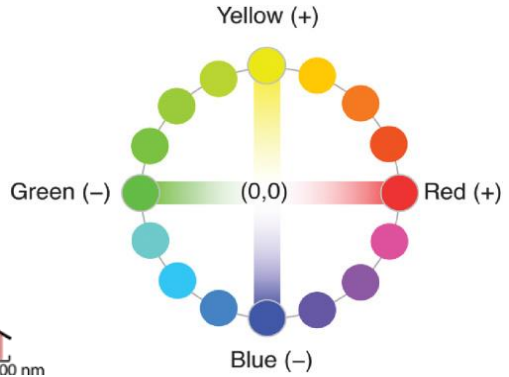
Color Perception

- "Visible light" consists of wavelengths ~350 nm to ~700 nm

- **Trichromatic Color Vision**
  - 3 Cone Types (Blue, Green, Red): each with its own unique type of Opsin (light-sensitive proteins) that responds to specific wavelengths of light

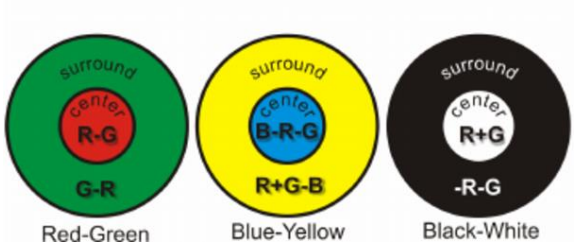
- **Color Opponency**
  - Trichromatic system is recorded into opponent systems (Red vs. Green, Blue vs. Yellow, Black vs. White)
  - Color adaptation: Adapt to Red → See Green as an afterimage

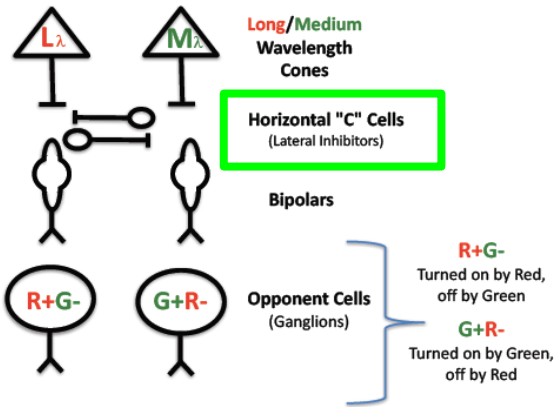


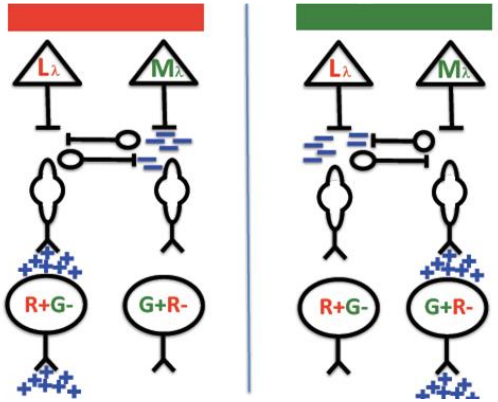


Color Opponency Circuitry

- **Horizontal cells** allow for opponency
- Horizontal “C” cells spontaneously fire, inhibiting neighboring bipolar cells
- **Double Opponent Cells** in Ganglion Cells
  - Most have R+G- Center and G+R- Surround receptive Fields
  - Good for detecting ripe fruit
- Color constancy: Able to recognize colors under varying light conditions (V4 - detects and filters out overall tint of scene)





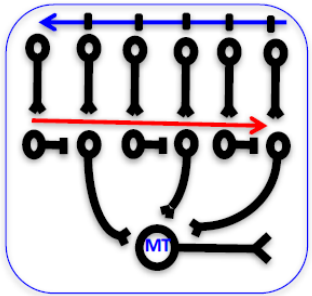


Medial Temporal (MT)

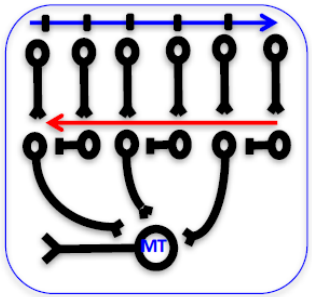
- Along the “Where/How” or “Magnocellular” Pathway
- Includes **direction-sensitive motion detectors**

- **Rely on Uni**directional lateral inhibition
  - runs in **OPPOSITE** direction detected by circuit

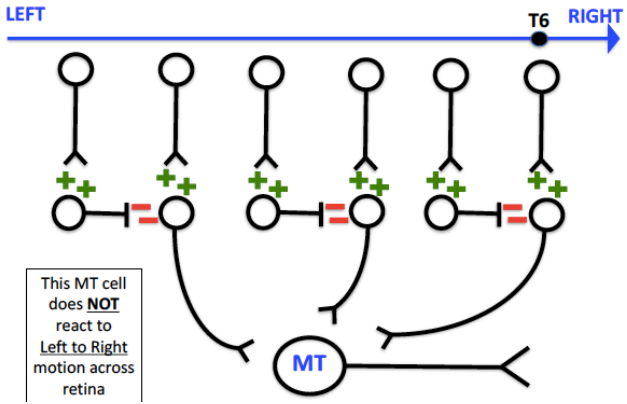
- Feeds to Medial Superior Temporal (MST)
  - Includes “Optic Flow” detectors
  - Responds to the movement of the entire visual field

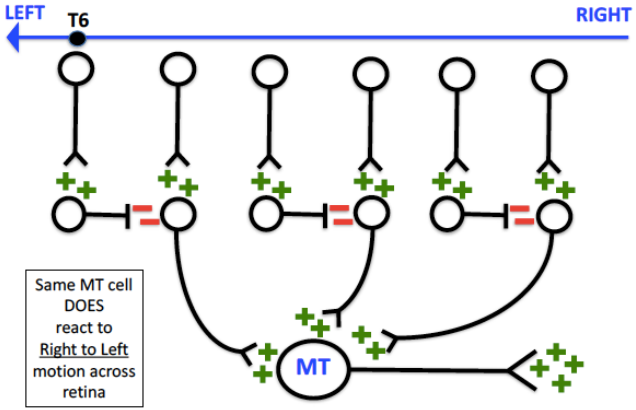


Detects motion
RIGHT to LEFT



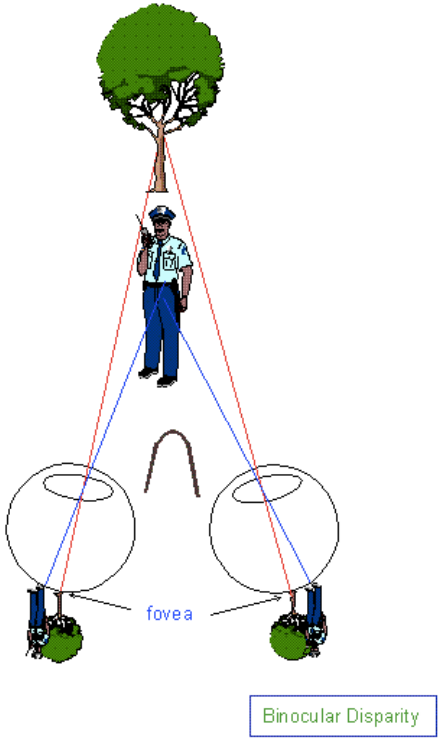
Detects motion
LEFT to RIGHT





Depth Perception

- **Binocular Disparity**: Disparity between the views from each eye allows 3D depth perception
- If both eyes focus on a focal point, the farther any other point is from that point, the greater the disparity in degrees of visual angle between where the points will fall on the two retinas
- In V2, disparity detectors differentially respond to different ranges of disparity
- In MT, the cells respond to different ranges of disparity regardless of receptive field
- Each disparity detector has a “preferred” disparity (responds most strongly) though some overlap between detectors exists



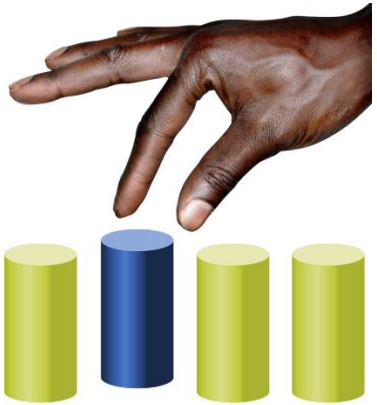
Higher Parietal Cortex

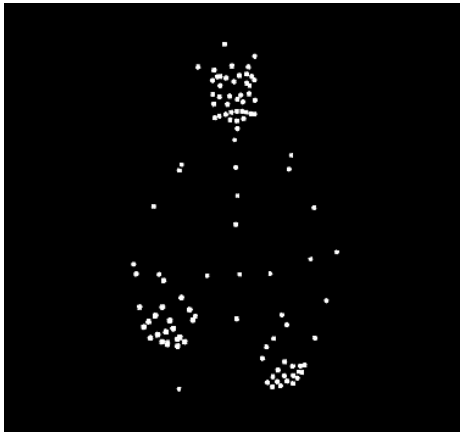
- Integration of visual and somatosensory information

- In Anterior Intra-parietal (AIP) Cortex, "**Canonical cells**" responds to the "affordances" of objects
  - Signals to the premotor cortex to shape the hand in specific motions (reaching out)

- Mirror Cell System
  - Responds to seeing self or other, perform and action
  - Promotes imitation

- Biological Motion Perception
  - Not in Parietal cortex
  - Located in the Superior Temporal Sulcus (STS)






HALF WAY DONE!