# COGS 17

# Week 6

Vision pt. 1

# Reminders!

**Homework Problem Sets**

- Homework #5 is due WED @ 11:59 PM!
- No late homeworks accepted

**Midterm**

- Midterm 2 is 5/15 (Th) from 3-30:4:50 PM! (10 days)
- Can be taken online or in class
- Will be proctored in class

**Extra Credit**

- SONA
- Mnemonics
- Do all HWs → 4 extra credit points

# For Slides + Problem Sets

**Link:**

https://drive.google.com/drive/folders/1DlvXFvEKxhF3ykEaK2_jBsNUgGOb8fS3?usp=drive_link

# Anatomy of the Eye

**Fovea**

- Small central area of high concentration of Cones only, for HIGH DETAIL

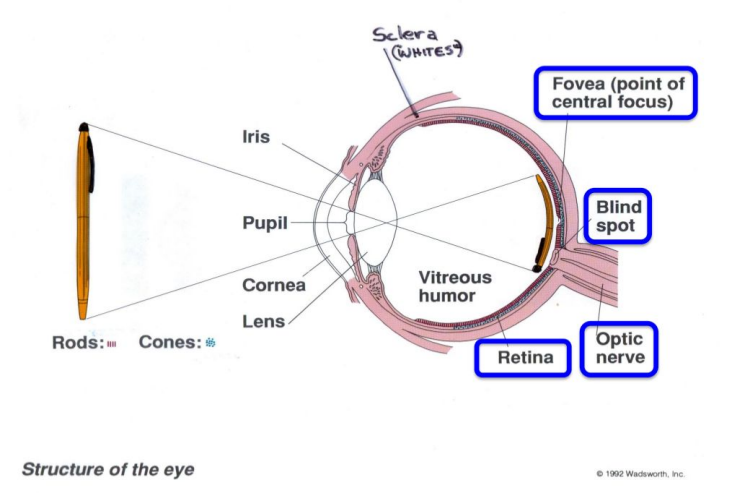
**Retina**

- Senses light, sends info to the brain via Optic Nerve

**Blind spot**

- Area where there are no receptors

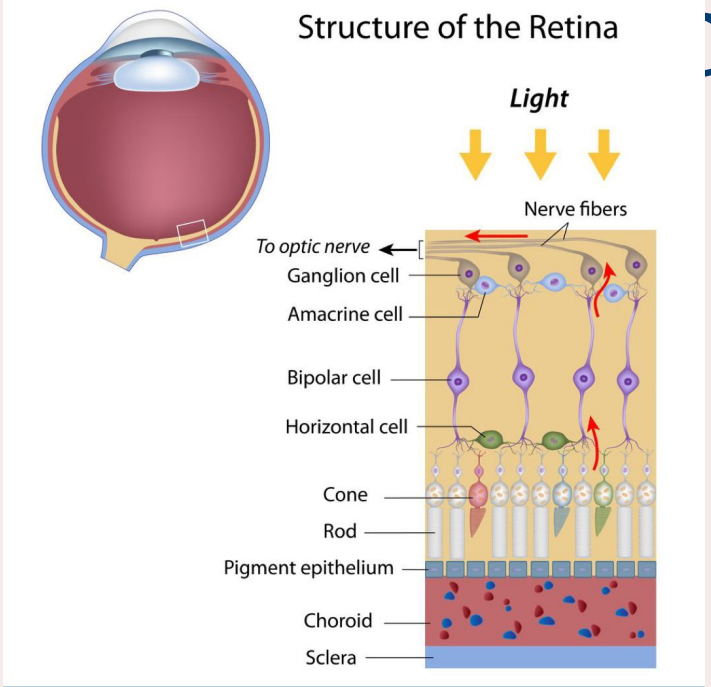
Light needs to pass through the outer layers of the eye before it reaches the receptors
(Cornea > Pupil > Iris > Lens > Receptors)



# The Retina

Multi-layered, covers the rear inner wall of the eyeball

- **Pigment Epithelium**
  - Non-neuronal cells, feed & recycle nutritions 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**
  - Perpendicular to pathway, influence above neurons

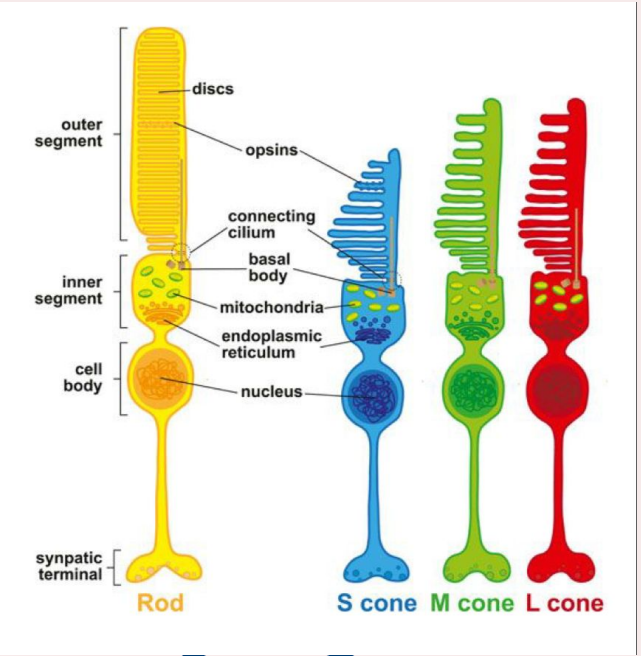


# Visual Receptors

**Photoreceptors = Rods & Cones**

- Rod's outer segment is much larger with higher amounts of photopigments (Opsin and Retinal)
- Both are embedded in the pigment epithelium
- Graded Potentials that release inhibitory NTs

Outer segments of photoreceptors isomerize and convert light into neural signals



# 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

# Retina

**Interneurons: Horizontals and Amacrines**

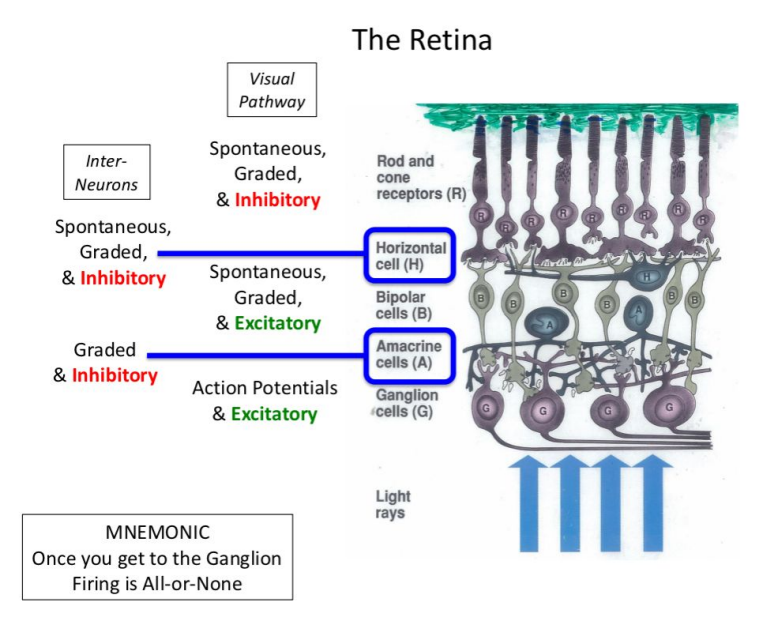
- Both send out Graded Potentials, mostly inhibitory NTs (Lateral Inhibitors)
- Horizontals mainly modify interface of Receptors and Bipolars
- Amacrines mainly modify interface of Bipolars and Ganglions

Bipolars: Postsynaptic to Receptors

- Spontaneuous firing of Graded Potentials, releases excitatory NTs

Ganglions: Postsynaptic to Bipolars

- Fires off APs, releases excitatory NTs



# The “Dark Current”

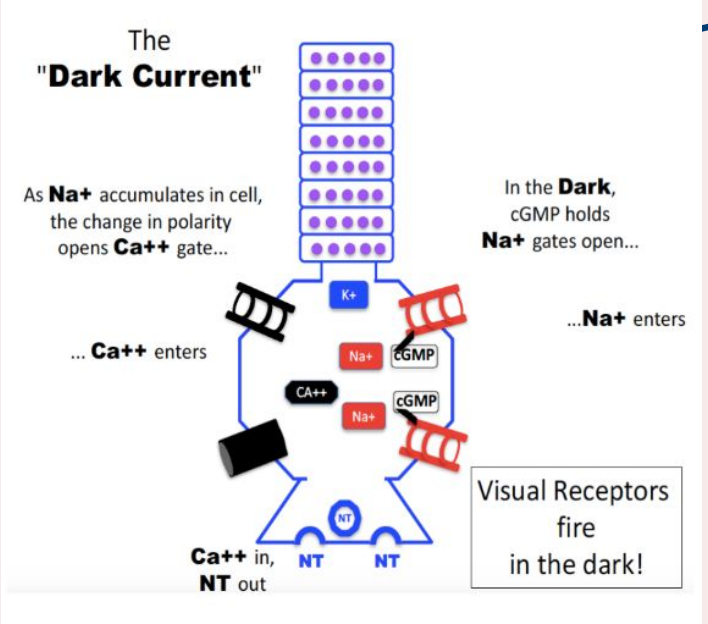
Light turns Receptor cells OFF, Darkness turns them ON

1. cGMP holds Na+ gates open → Influx of Na+
2. Change in polarity leads to Ca++ gates opening →Influx of Ca++
3. NT released

When positive charge accumulates in the cell, Na+ exits via electrostatic pressure

- Builds up outside > Influx into cell again
- Ca++ enters again
- Continuous cycle of ion influx/efflux

Ca+ pump pushes Ca++ out of the cell (requires ATP)

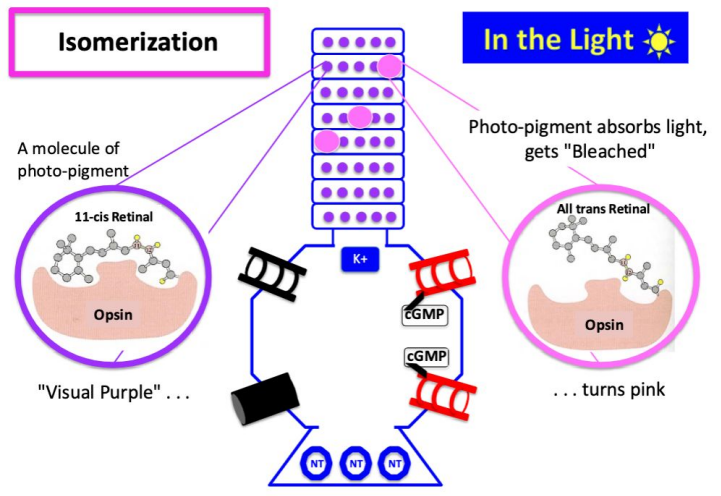


# Isomerization

Converting light into a neural signal

1. Before absorbing light, a molecule of photopigment, 11-cis Retinal, is attached to Opsin (AKA visual purple)
2. In the light, the photopigment absorbs the light and gets “bleached”, causing Retinal to detach from the Opsin where it undergoes a form change to All trans Retinal and turns pink
3. cGMP converts 5’GMP when isomerized so that Na+ gates are closed → no Ca++ enters as Ca++ gates are closed
4. No NT is released

Ultimately when in the light, the “Dark Current” is shut down (turned off by the light)

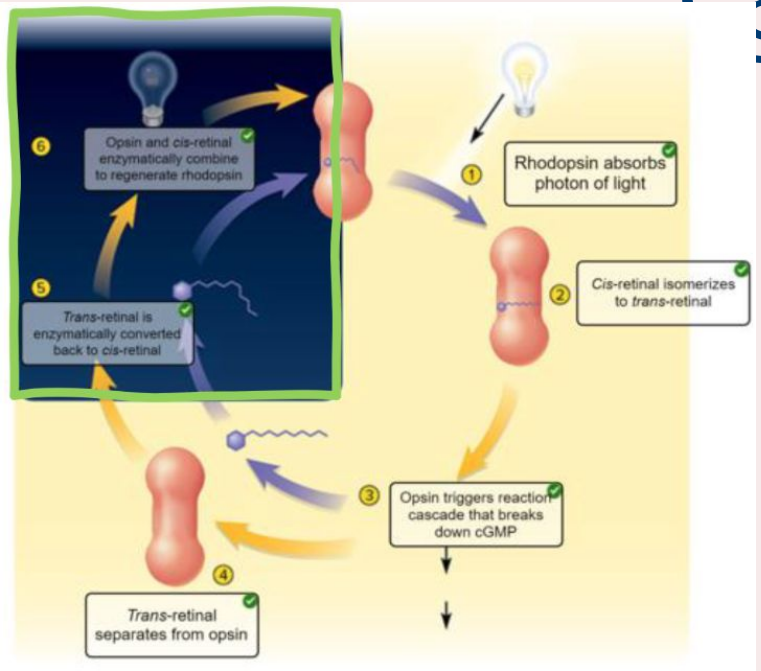


# Isomerization

Photopigment regeneration: using enzymes from Pigment Epithelium, preparing to respond to the next photon

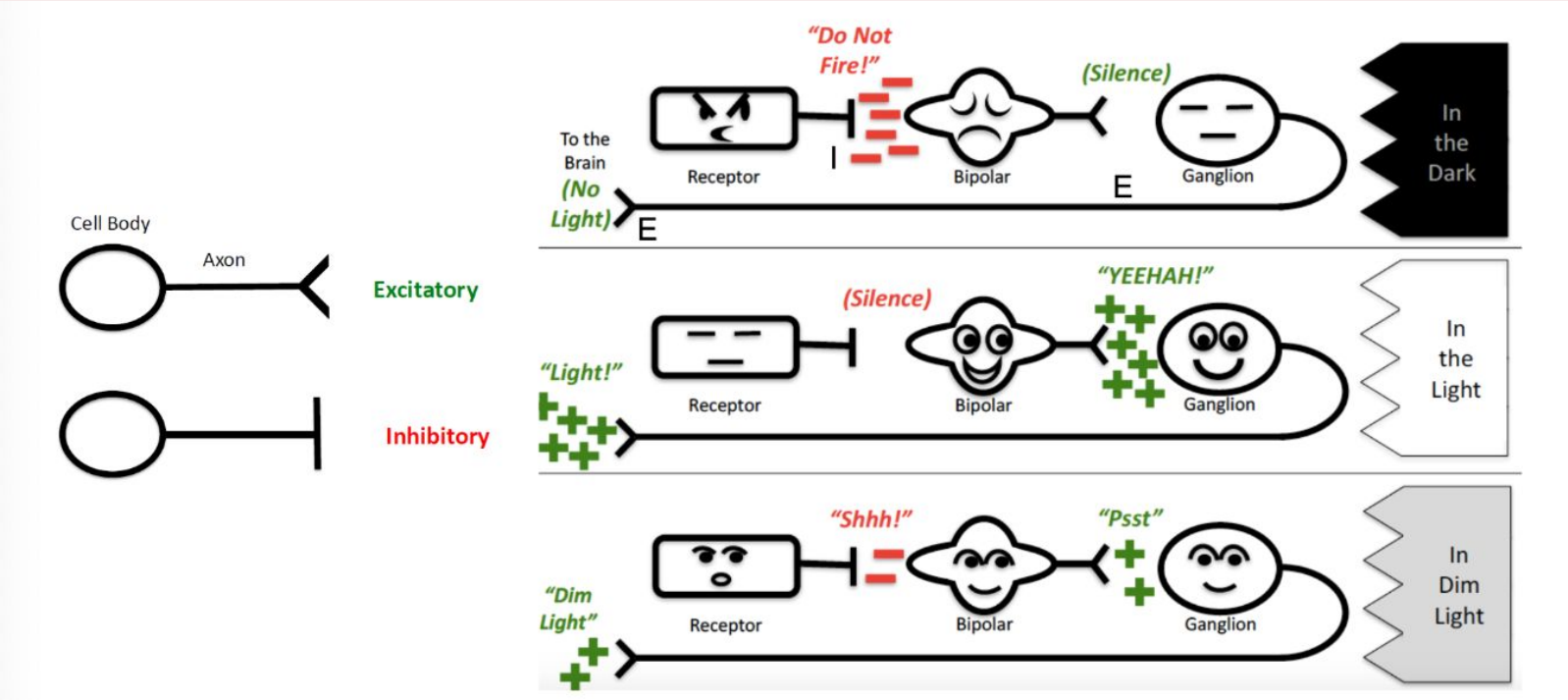
Ex. Hard to see indoors at first after bright sunlight (since “Light Adapted”) but as photopigments regenerate, sensitivity is restored

Ex. Hard to see just after turning off the lights, but soon, as more photopigments regenerate, sensitivity is increased (becomes “Dark Adapted”)



# Connectivity Patterns

Play a critical role in information-transmission



# Convergence

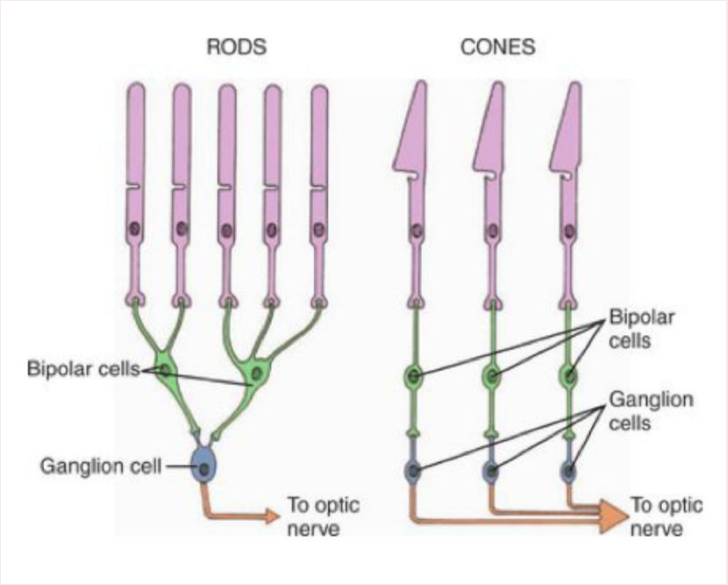
Receptors converge onto Ganglion cells (varied ways)

**Cones**

- Low convergence (6:1 or few:1)
- High acuity, detailed information is preserved
- Fovea cones have very low convergence (1:1)

**Rods**

- High convergence (120:1 or many:1)
- Low acuity, details can be lost



# Receptive Field

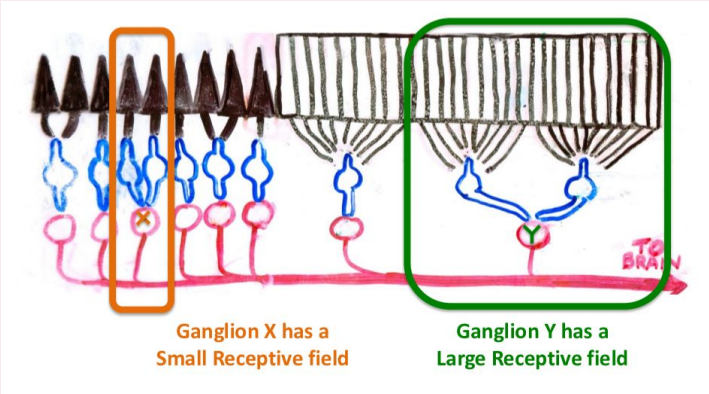
A set of receptors whose activity influences the activity of a “target” downstream cell

When a cell has a smaller receptive field → better acuity

Can think of this as a pixel resolution

- If you have less convergence (smaller receptive field), more neurons (pixels) are dedicated to a particular detail (higher DPI)

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

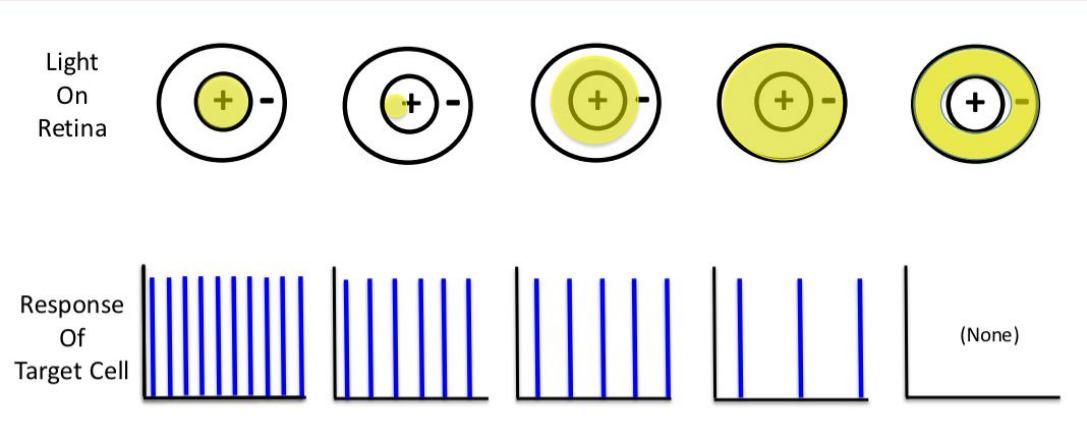


# Center-Surround Receptive Fields

**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



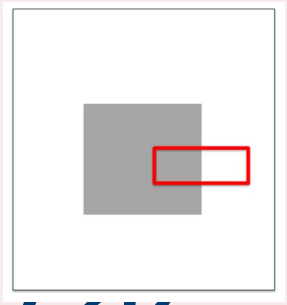
# Simultaneous Contrast in the Retina

**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)



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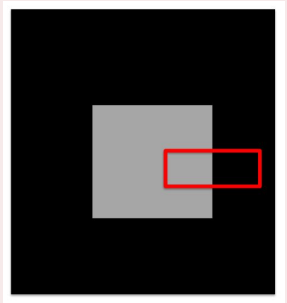
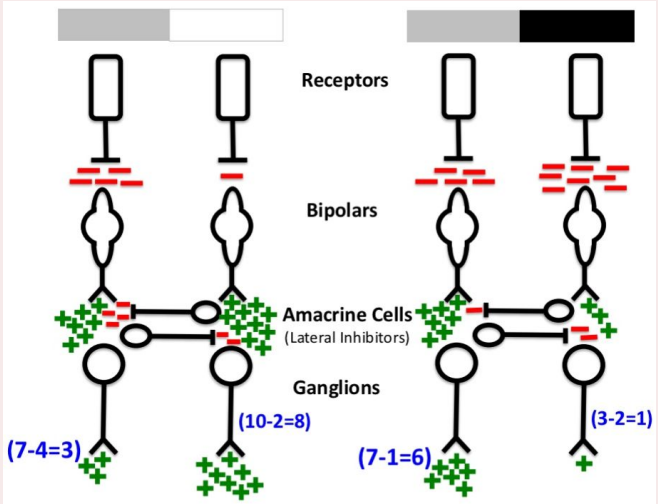




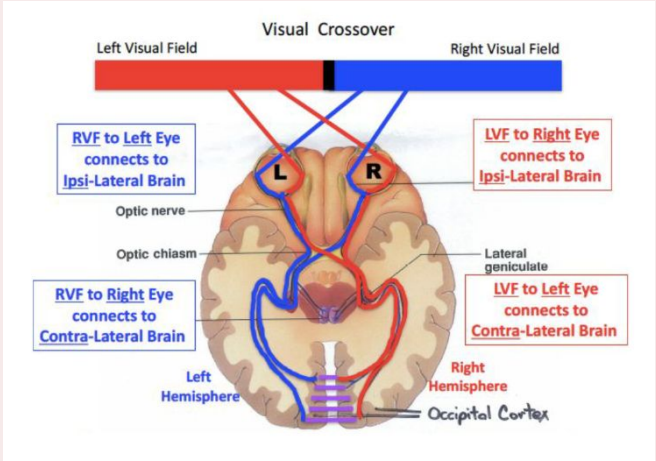
# Visual Crossover

The visual field is split into the left and right

The optic nerve from each eye splits and forms connections to both sides of the brain based on the visual field

- Crosses via the **Optic Chiasm**

When you fixate on a single point in environment, any stimulus to the left of that point will fall on the right side of both retinas (= LVF) and vice versa

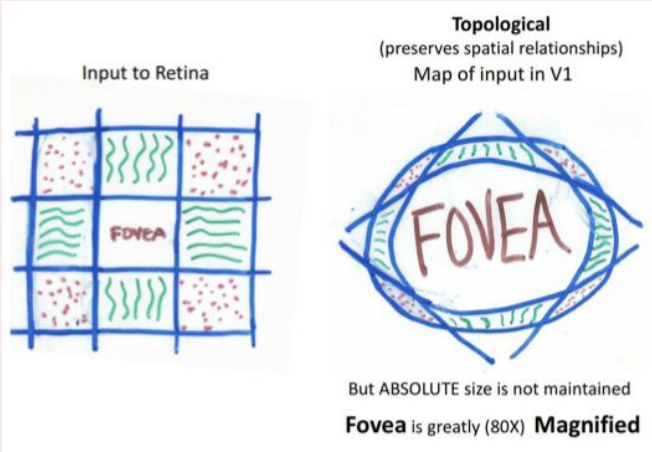


# Visual Crossover

**Magnification Factor:** Cortical cells with small receptive fields have a disproportionately higher projection to the visual area

- **Fovea** makes up 0.01% of the retina, but accounts for 8% of V1 mapping

Visual Imagery: Similar cortical activation when seeing an object as when imagining it



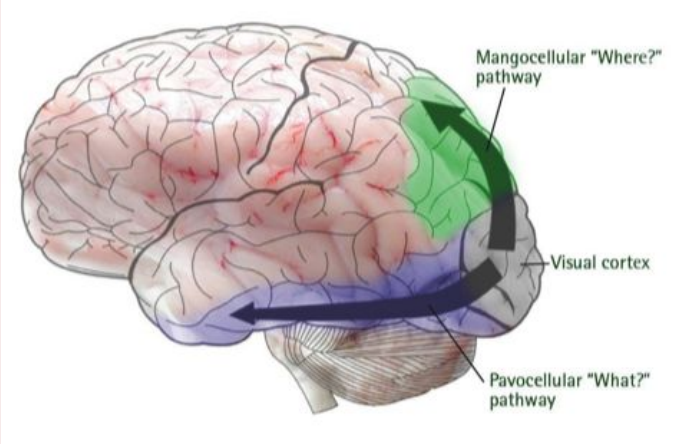
# Information Pathways

**Dorsal Pathway (Magnocellular Pathway)**

- "Where/How" information → for visuospatial mapping
- Motion and Depth
- Begins at Rods & Cones in periphery of Retina
- Large "Magnocellular" Ganglions (Y Ganglions)
- **Pathway:** LGN > V1 > V2 > Medial Temporal Cortex > Medial Superior Temporal Cortex > Posterior Parietal Cortex

**Ventral Pathway (Parvocellular Pathway)**

- "Who/What" information → identification
- Color and Detail (Contextual information)
- Begins at Cones in and near Fovea
- Small "Parvocellular" Ganglions (X Ganglions)
- **Pathway:** LGN of thalamus > V1 > V2 > V3 > V4 > Inferior Temporal Cortex



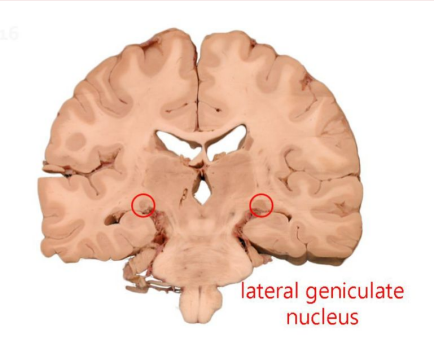
# Lateral Geniculate Nucleus

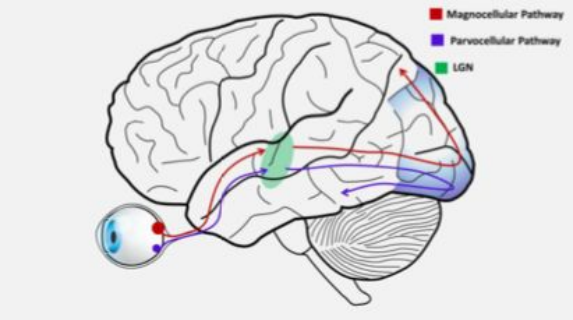
LGN is organized into 6 layers

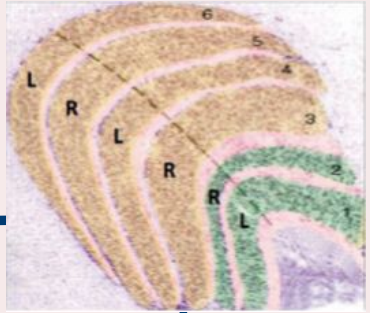
**Magnocellular Pathway (Where Pathway)** projects to and from layers 1 & 2

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

Some axons from the Magnocellular Pathway go first to the Superior Colliculus in the Tectum of the Midbrain. From there, this sub-pathway goes on to the LGN



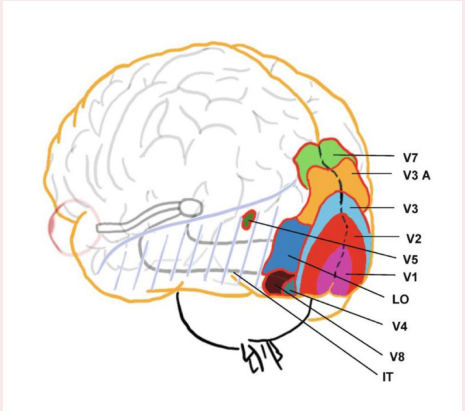



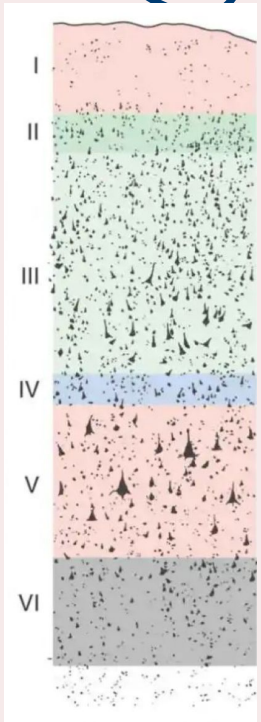
# Visual Cortex (Occipital Lobe)

6 Layered Cortex

**Layer 4 (IV)** 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.)



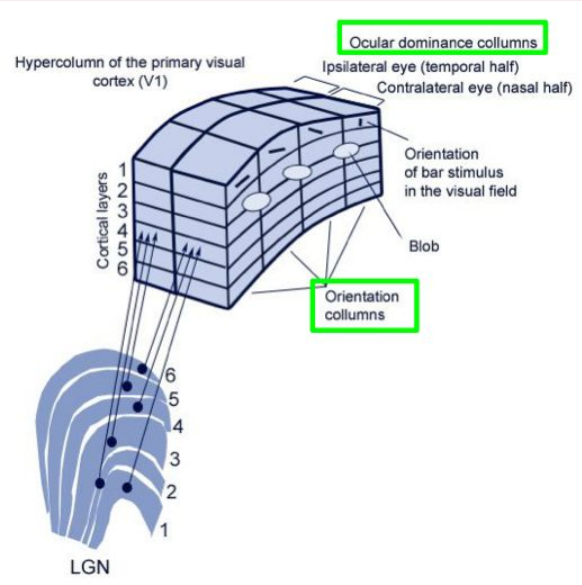
# Columnar Organization

**Column**: runs vertically through the layers of the cortex

- Each column responds to lines oriented in one particular orientation (same “preferred” stimuli like | or / or | or —, etc.)

**Hypercolumn**: set of orientation columns with the same receptive field

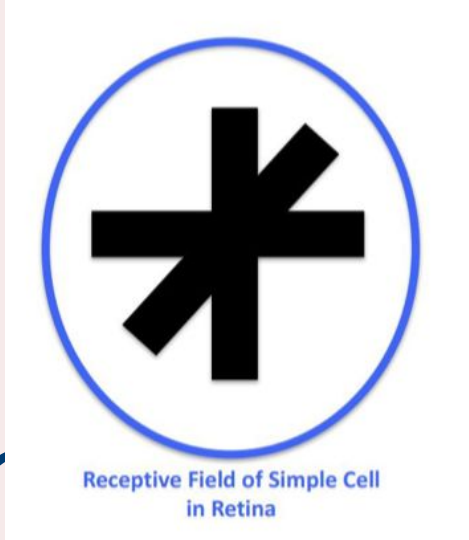
- Comes in pairs: Left or Right eye dominant
- Adjacent hypercolumns have adjacent receptive fields → Retinotopic map: A topological map that preserves spatial relationships from the information received



# Columnar Organization

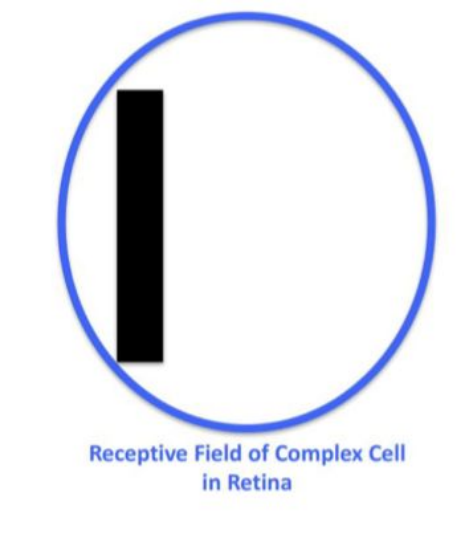
**Simple Cells** in V1

- Respond to “bar” in a particular orientation in a given RF




**Complex Cells** in V2

- Respond to **moving** “bar” in particular orientation in given RF



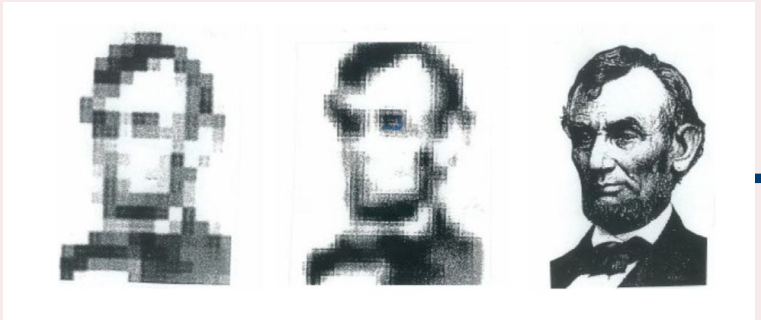
# Vivid Vision

To determine details such as shape and texture, detail info 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 a 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, High SFs for Detail

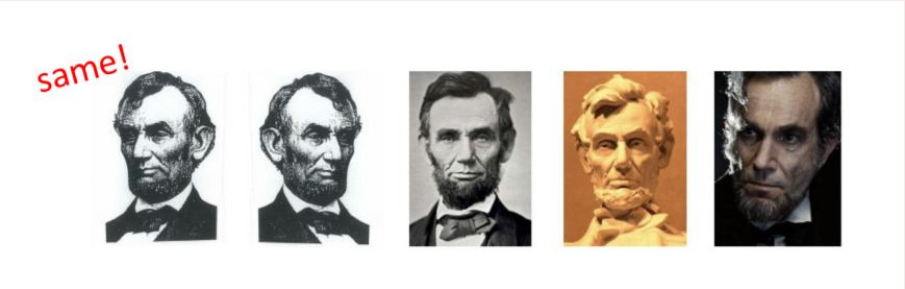


# Fusiform Gyrus

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 discriminator



# Color Perception

“Visible light” consists of wavelengths ~350 nm to ~700 nm

**Trichromatic Color Vision**

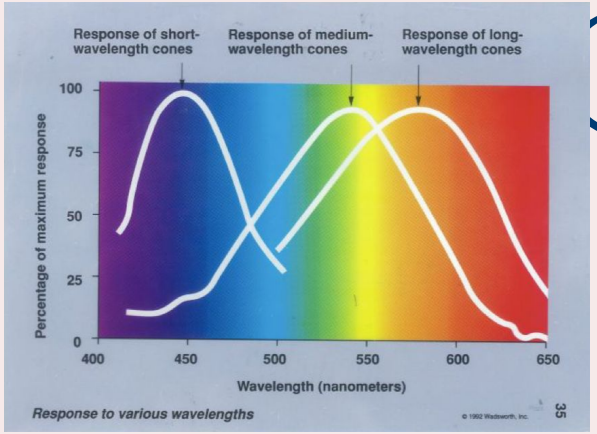
- 3 Cone Types (Blue, Green, Red): each with its own unique type of Opsin that responds to specific wavelengths of light

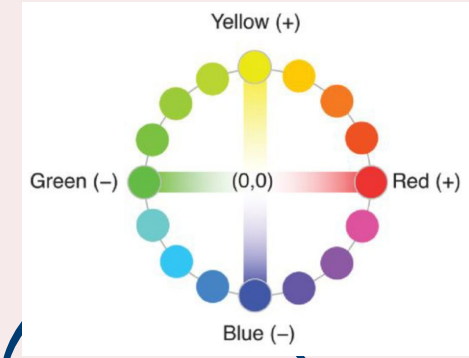
**Color Opponency**

- Trichromatic system is recorded into opponent systems
- Adapt to Red > Green after image. Adapt to Green > Red after image (same as Yellow vs. Blue)

“Blobs”

- In each pair of hypercolumns, there are columns that process colors



# Color Opponency Circuitry

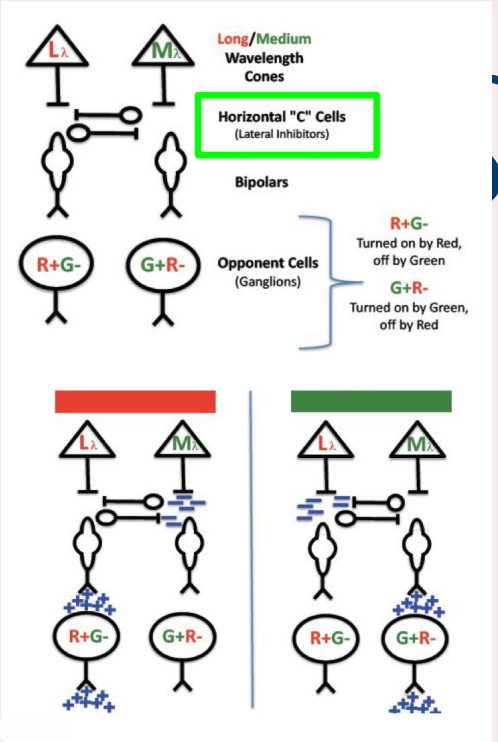
**Horizontal cells** allow for opponency

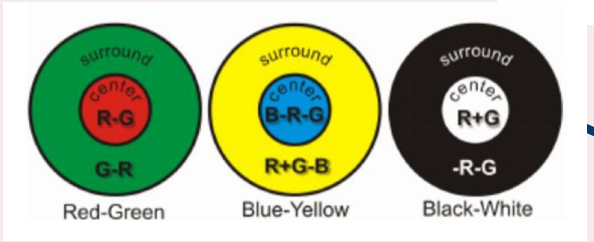
Horizontal “C” cells spontaneously fire, inhibiting neighboring bipolar cells

**Double Opponent Cells** in Ganglion Cells

- Most have R+G- Center and G+R- Surround RFs
- 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)

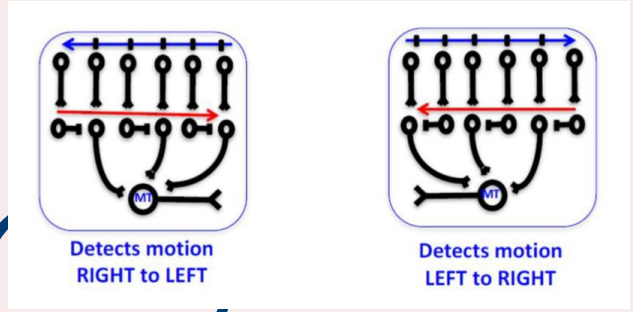
Along the “Where/How” or “Magnocellular” Pathway

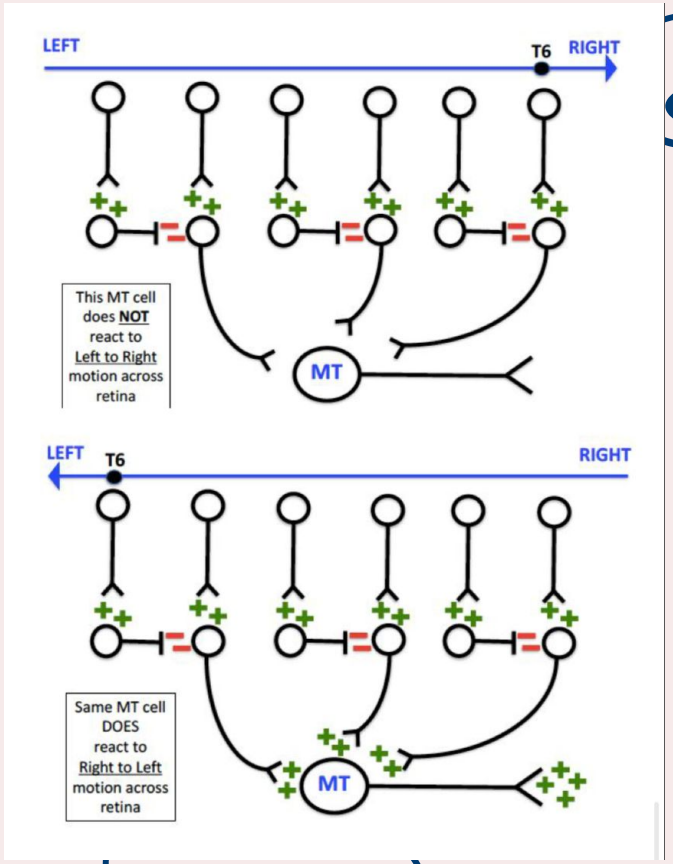
Includes **direction-sensitive motion detectors**

**Uni**directional lateral inhibition → runs in **OPPOSITE** direction detected by circuit

Feeds to Medial Superior Temporal (MST)

- Includes “Optic Flow” detectors
- Responds to movement of the entire visual field



# Depth Perception

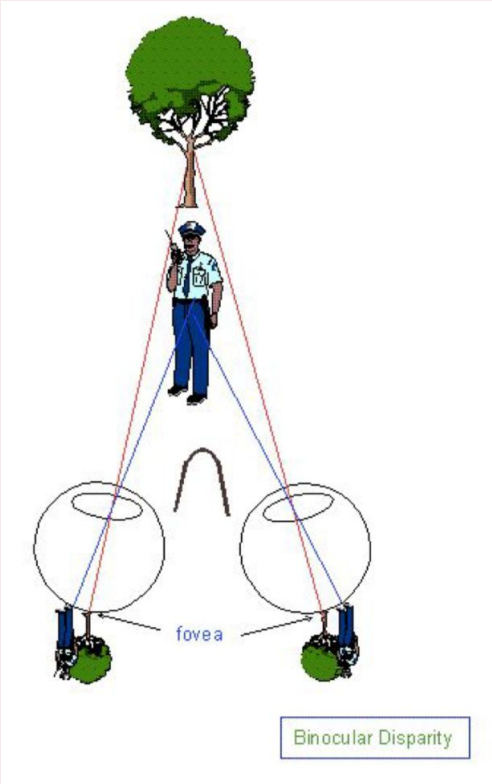
**Binocular Disparity:** Disparity between the views from each eye allows 3D depth perception

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 RF

Each disparity detector has a “preferred” disparity to which it responds the most to. Some overlap 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)