

# EYE Components

Wednesday, November 12, 2025 7:18 PM

**Sclera : white part**

**Cornea : the cover OF EYE**

**Iris : color part : it is muscles to control shape of the pupil**

**Lens : change the shape to see far and near stuff**

**Ciliary muscles : control the Lens size , to see far and small stuff**

**Choroid : suply oxygin to the retina**

**Retina : detect light intensity , wave length / color**

**Fovea :**

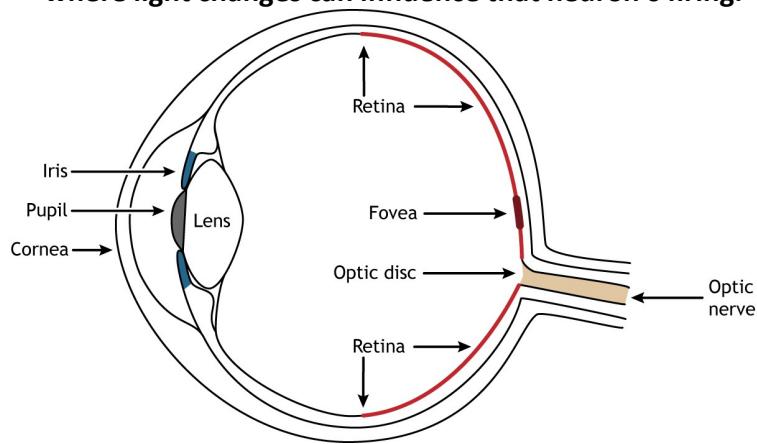
- Rods : light intensity
- Cones : color

**Photoreceptors : Rods and Cones**

**Optic neurv : send dignls to the brain**

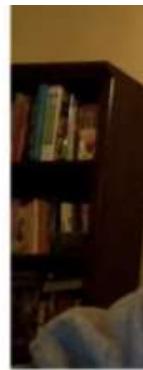
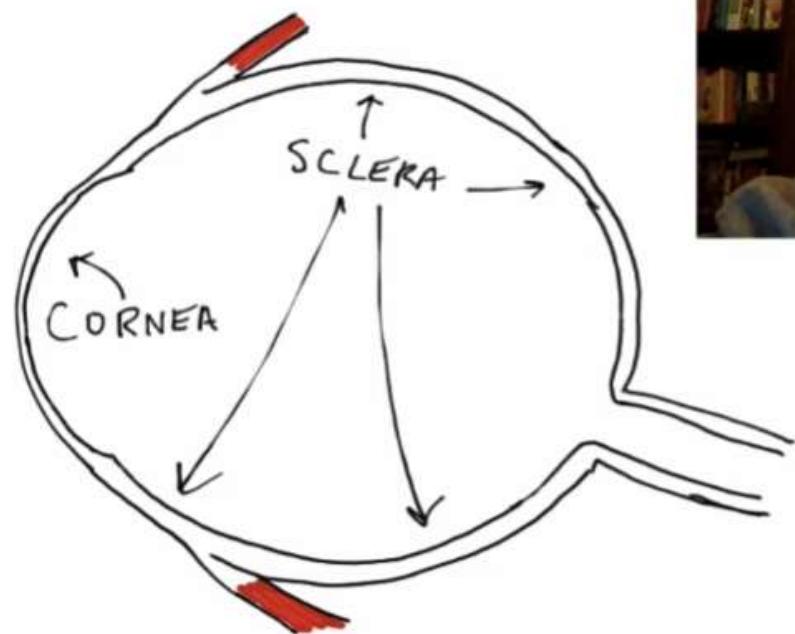
A receptive field isn't a physical spot on the retina; it's a *functional concept*.

A neuron's receptive field = the region of the retina (or the visual world) where light changes can influence that neuron's firing.



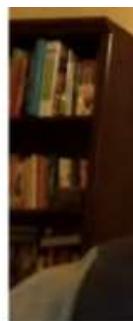
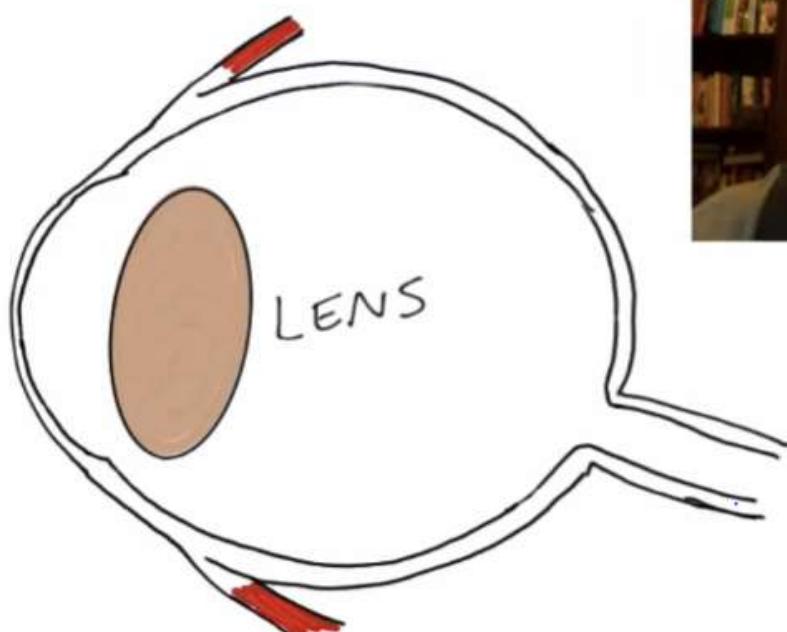
# EYE DIAGRAM

Lateral



Medial

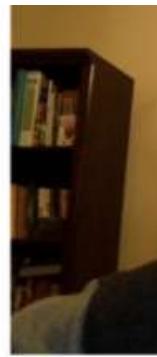
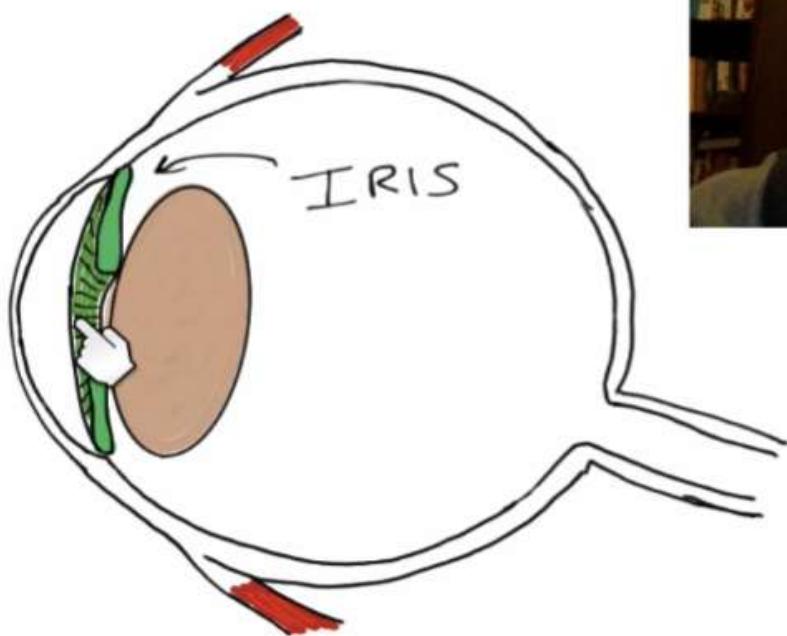
Lateral



Medial

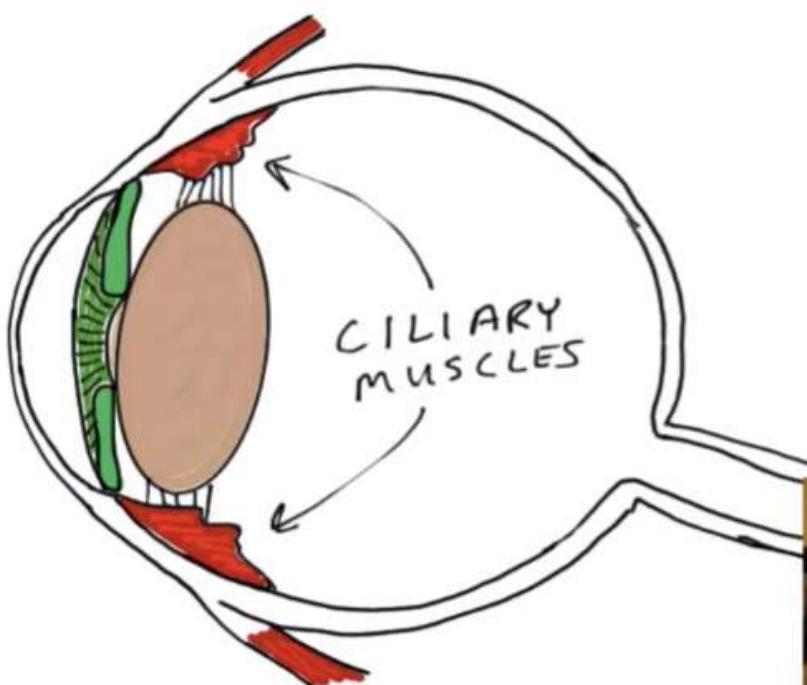
# EYE DIAGRAM

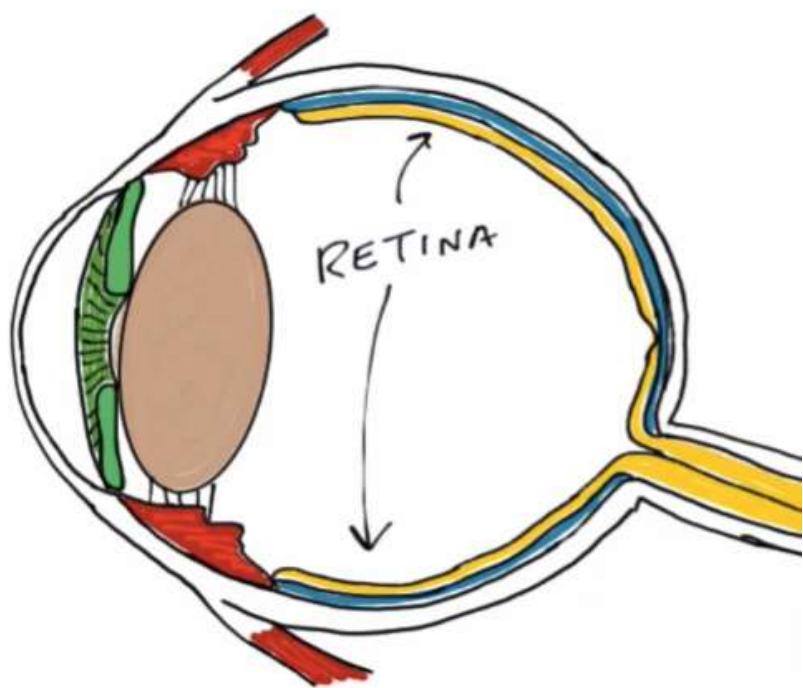
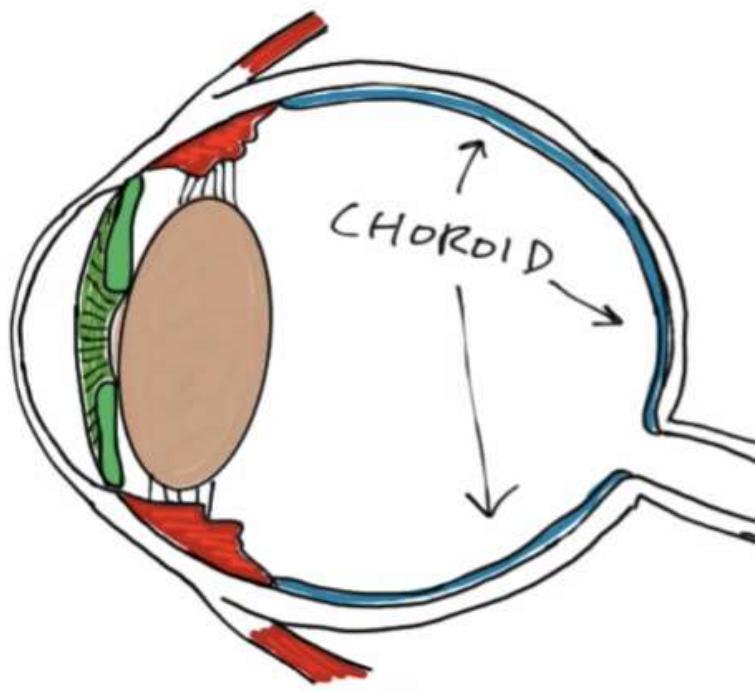
Lateral



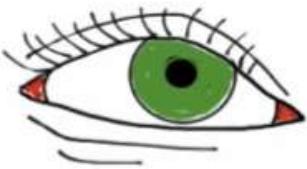
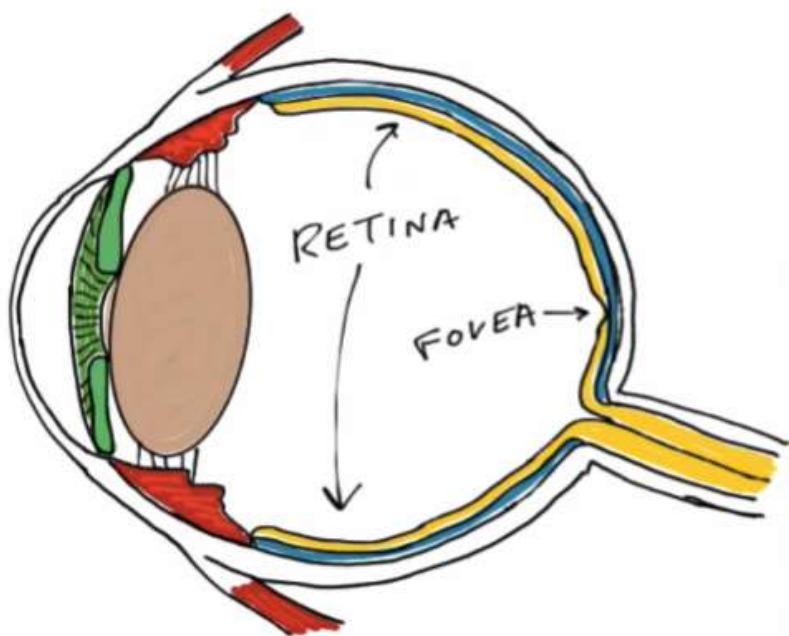
Medial

Lateral





Lateral



rods → light intensity

cones → color



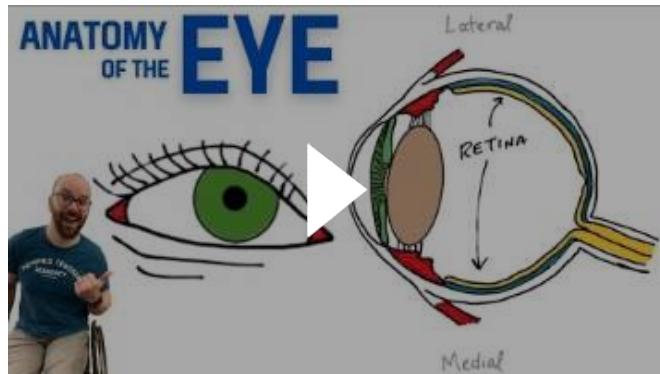
optic nerve



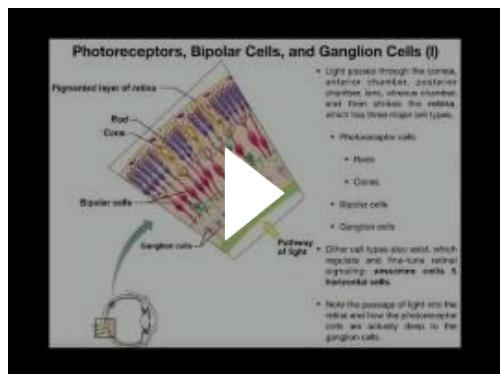
# Explanation

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<https://openbooks.lib.msu.edu/neuroscience/chapter/vision-the-retina/>  
<https://www.youtube.com/watch?v=Cnk-jO2Wfas>



[Anatomy | Vision \(Part 1\) | Retina, Photoreceptors, Bipolar Cells, & Ganglion Cells](#)



Light → Cornea → Lens → Retina → Optic Nerve → LGN (in Thalamus) → V1 (Primary Visual Cortex) → IT (Inferior Temporal Cortex)

## Level

**Retina**

## Function

Converts light to electrical signals (first neural layer).

**LGN (Lateral Geniculate Nucleus)**

Sorts and relays visual info to the brain.

**V1 Cortex**

Detects basic features (edges, orientations).

**Higher cortices (V2, V4, IT)**

Combine features into shapes and objects.

## Inside the Retina

The retina has **five main neuron types**, stacked in layers:

Light  
↓  
**Photoreceptors (Rods, Cones)**  
↓  
Bipolar cells  
↓  
Ganglion cells (X, Y, W types)  
↓  
Optic nerve → Brain

## • Rods and cones

These are at the very back of the retina:

- **Rods:** detect light intensity (brightness)
- **Cones:** detect color (red, green, blue wavelengths)

They **do not detect edges** themselves; they just convert light into signals.

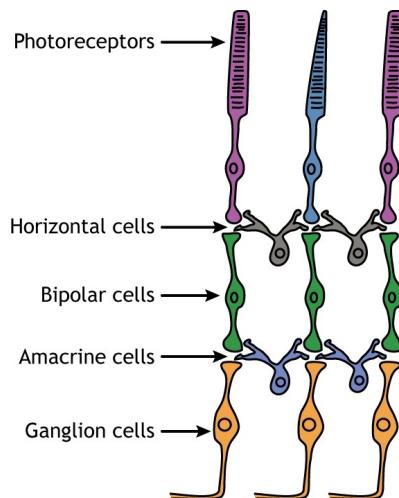
## Ganglion cells — where edges begin

This is where the **X, Y, and W** cells appear.

Ganglion cells receive input from bipolar cells and **compare signals from nearby photoreceptors**.

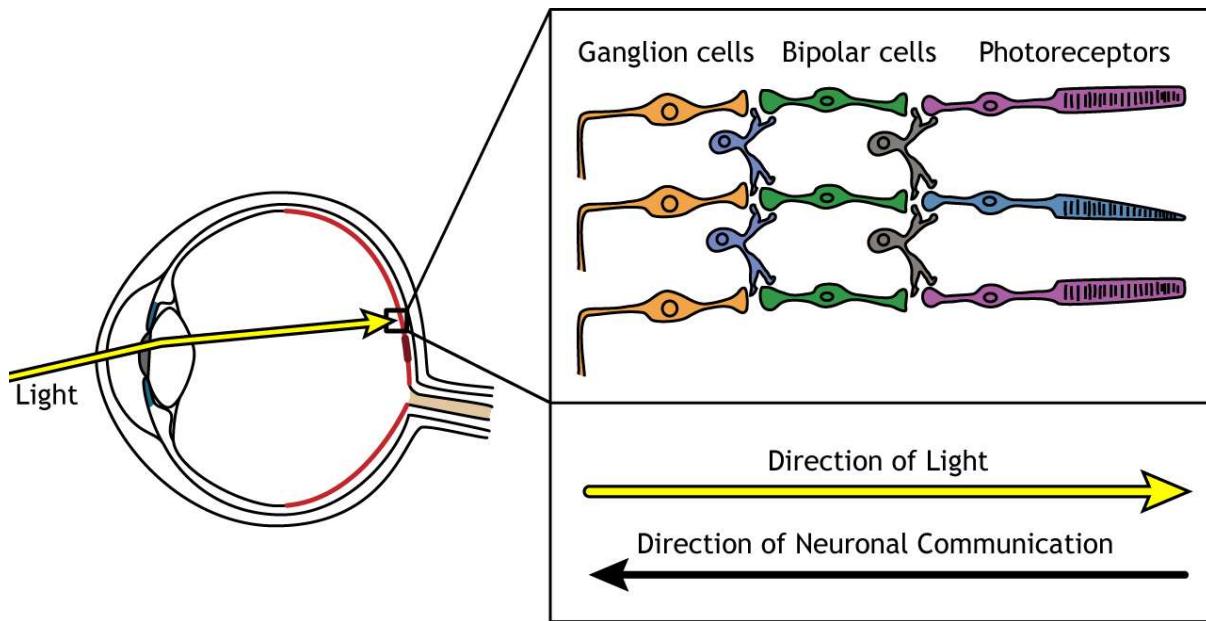
Each one sees a small patch of the retina — that's called its **receptive field**.

## There are 5 primary types of cells in the retina

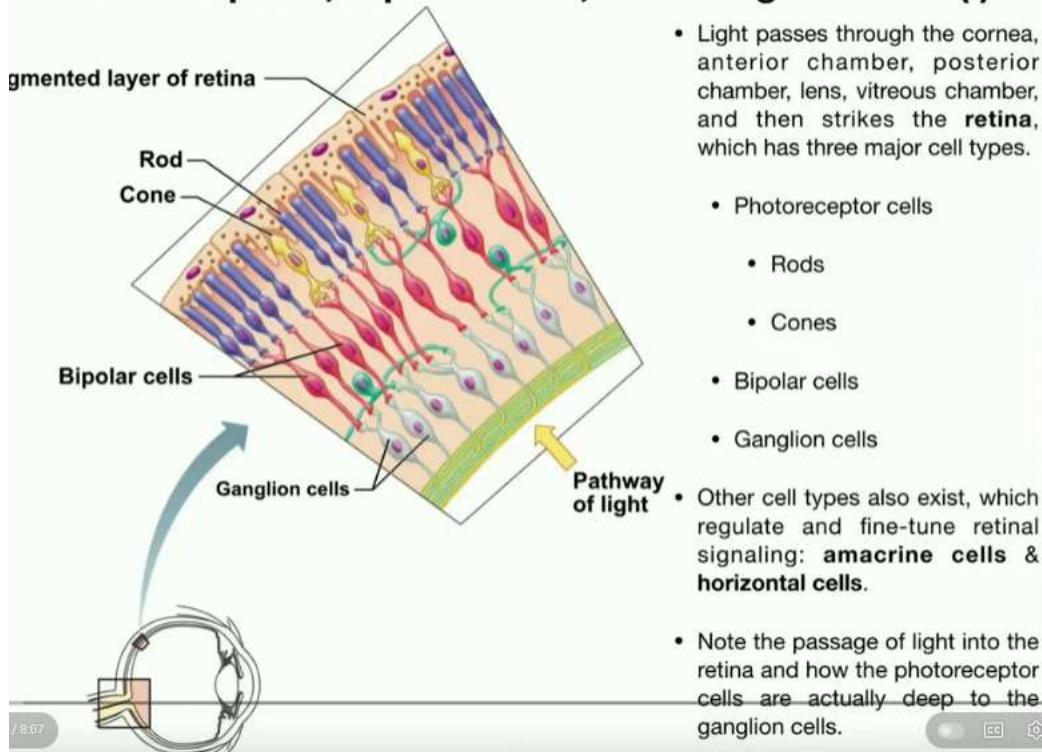


### Direction of Information

When light enters the eye and strikes the retina, it must pass through all the neuronal cell layers before reaching and activating the photoreceptors. The photoreceptors then initiate the synaptic communication back toward the ganglion cells.



### Photoreceptors, Bipolar Cells, and Ganglion Cells (I)



#### Receptors

The photoreceptors are the specialized receptors that respond to light  
There are two types of photoreceptors: rods and cones.

Rods are more sensitive to light, making them primarily responsible for vision in low-lighting conditions like at night.

Cones are less sensitive to light and are most active in daylight conditions.  
The cones are also responsible for color vision.

## The ganglion cells are literally the bridge between the retina and the optic nerve.

Light → Photoreceptors (rods & cones)



Bipolar cells



Ganglion cells ← (these are the X, Y, and W types)



Optic nerve



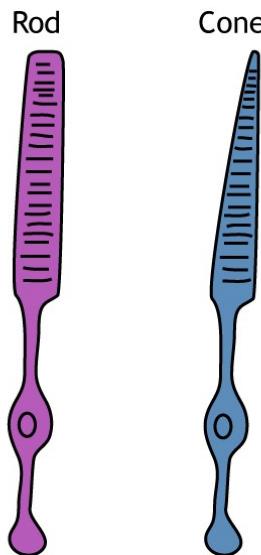
Brain (LGN → V1 → IT)

- They receive signals from bipolar cells (which carry data from photoreceptors).
- Each ganglion cell compares brightness in its center vs surrounding area → detects contrast (that's where edge detection begins).
- When they detect a change (like an edge), they fire an electrical impulse — an action potential.

- The axons (long tails) of all ganglion cells gather together at the back of the eye, in a region called the optic disc.
- These bundled axons form the optic nerve.
- That's why the optic disc has no photoreceptors — it's a blind spot (only axons pass there).
- The optic nerve then sends those signals directly to the LGN (Lateral Geniculate Nucleus) in the thalamus, and from there to V1 (primary visual cortex).

## What happens in the retina before X/Y/W fire

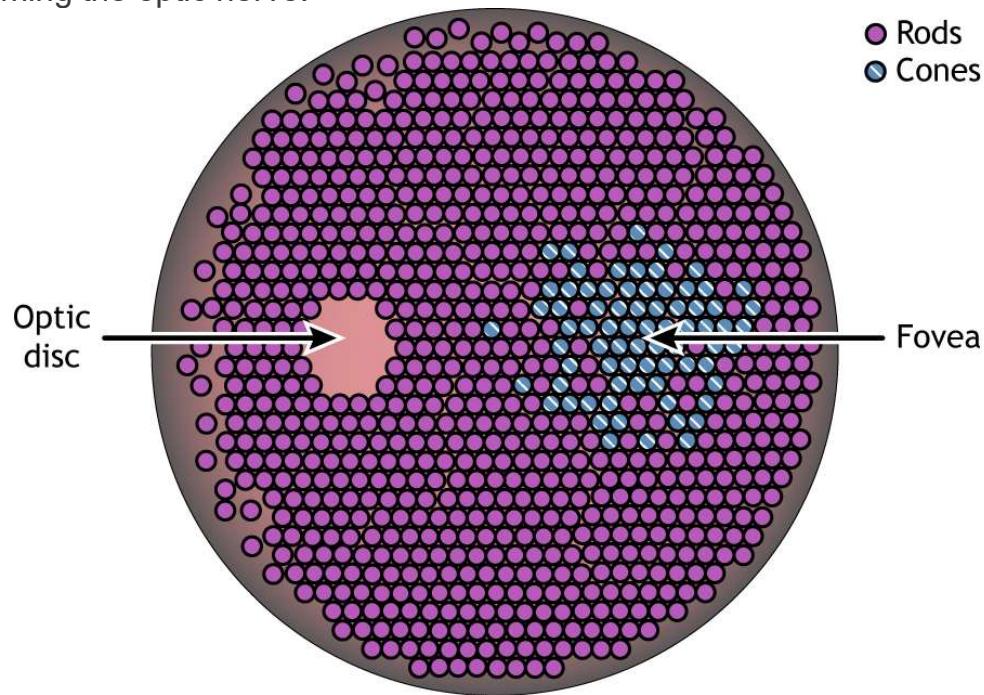
1. Photoreceptors detect photons → convert to electrical signals.
2. Bipolar cells collect those signals and organize them (some excitatory, some inhibitory).
3. Ganglion cells (X, Y, W) receive that input from many bipolar cells and perform contrast detection through center–surround antagonism.



### Receptor Density

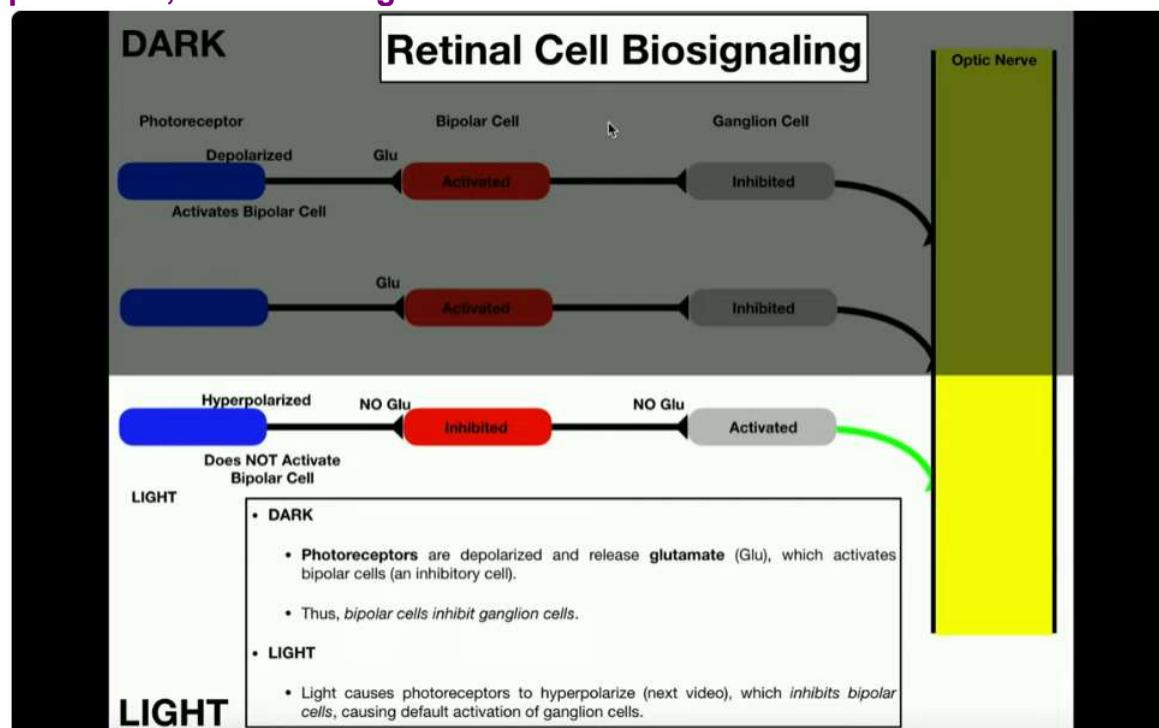
In addition to having different visual functions, the rods and cones are also distributed across the retina in different densities. The cones are primarily

found in the fovea, the region of the retina with the highest visual acuity. The remainder of the retina is predominantly rods. The region of the optic disc has no photoreceptors because the axons of the ganglion cells are leaving the retina and forming the optic nerve.



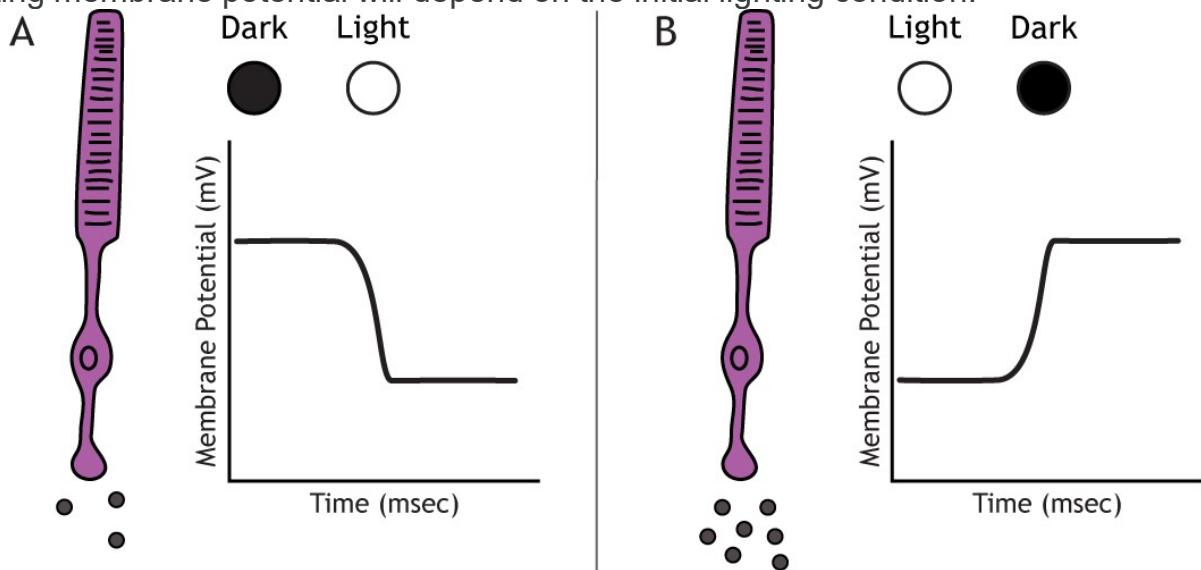
#### Phototransduction

**Photoreceptors hyperpolarize in response to light, do not fire action potentials, and release glutamate**



The photoreceptors are responsible for sensory transduction in the visual system, converting light into electrical signals in the neurons

Photoreceptors do not fire action potentials; they respond to light changes with graded receptor potentials (depolarization or hyperpolarization). Despite this, the photoreceptors still release glutamate onto the bipolar cells. The amount of glutamate released changes along with the membrane potential, so a hyperpolarization will lead to less glutamate being released. Photoreceptors hyperpolarize in light and depolarize in dark. In the graphs used in this lesson, the starting membrane potential will depend on the initial lighting condition.



When the photoreceptor moves into the light, the cell hyperpolarizes. Light enters the eye, reaches the photoreceptors, and causes a conformational change in a special protein called an opsin. This change activates a G-protein called transducin, which then activates a protein called phosphodiesterase (PDE). PDE breaks down cGMP to GMP, and the cGMP-gated cation channels that were open in the dark close. The decrease in cation flow into the cell causes the photoreceptor to hyperpolarize.

[Video Player](#)

# GC/center–surround antagonism

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## Ganglion Cells are in biology

In the human (and mammalian) visual system, **retinal ganglion cells (GCs)** are the first neurons that actually *send visual signals to the brain* through the optic nerve.

They sit at the output layer of the retina and receive processed signals from photoreceptors (rods & cones) through intermediate cells.

Their job: **detect contrast and edges** — they don't care about color or brightness itself, but *changes in brightness*.

## What “antagonism” means

“Antagonism” here means **opposite effects** — when one region excites the neuron and the other region suppresses it.

So a ganglion cell reacts not just to *light itself*, but to *differences in light* between two zones:

- the **center** of its receptive field
- the **surround** area around that center

## The structure

Imagine a small circular patch on your retina — that's one **receptive field** of a ganglion cell.

It has:

- a **center zone** (few photoreceptors)
- a **surround zone** (ring of nearby photoreceptors)

Each ganglion cell comes in one of two types:

1. **ON-center / OFF-surround**
2. **OFF-center / ON-surround**

## How it reacts (example)

### ON-center cell

- Light on center → excited (fires more)
- Light on surround → inhibited (fires less)
- Light on both equally → cancels out → weak signal

### OFF-center cell

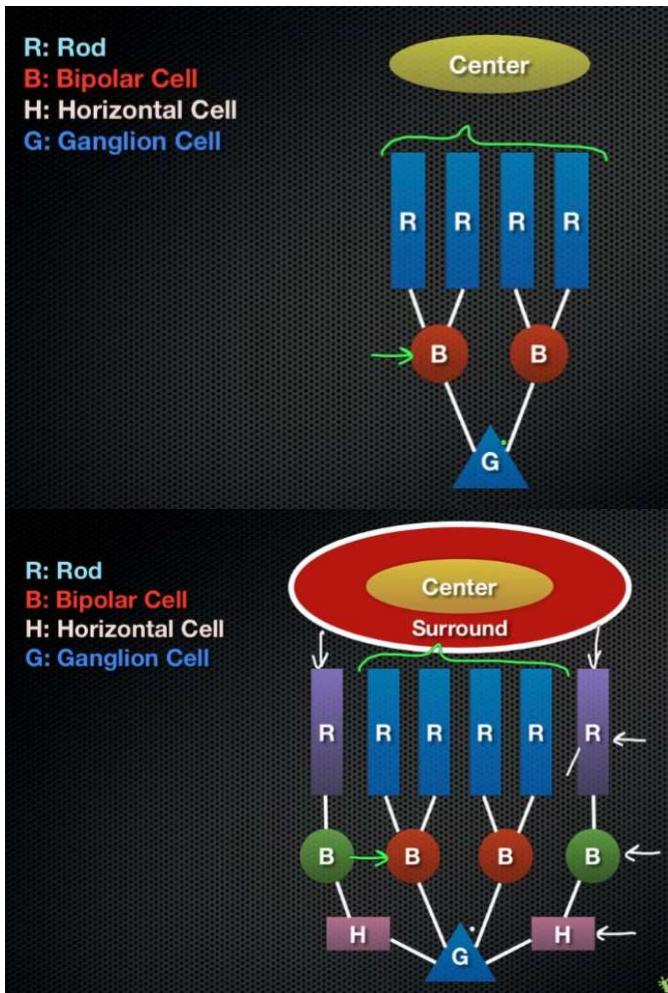
- Light on center → inhibited
- Light on surround → excited

Each bipolar cell passes an *excitatory* or *inhibitory* signal to ganglion cells depending on whether the light hits its center or surround area.

So the ganglion cell receives two types of input:

- **Center** (from direct bipolars)
- **Surround** (from lateral inhibition through horizontal cells)

That's where the “subtraction” comes from — ganglion cells literally compute *center minus surround brightness*.



## 2. X Cells (Parvocellular Pathway)

### Biology:

- Tiny receptive field → small patch of the retina.
- They care about **fine details** and **slow, steady changes**.
- The subtraction (center – surround) is very localized, giving precise edges.
- They respond linearly (double brightness → double firing rate).

### CNN analogy (red block):

$1 \times 1$  conv → center

$3 \times 3$  conv → surround

subtract(center, surround)

Result → fine, local edge map that removes flat textures.

## 3. Y Cells (Magnocellular Pathway)

### Biology:

- Larger receptive field → see a wider zone.
- Contain nonlinear “subunits” that fire only for big changes.
- Respond very fast to motion and strong contrast.

### CNN analogy (teal block):

$1 \times 1$  conv → center  
 $5 \times 5$  dilated conv → wide surround  
subtract(center, surround)

The *dilation* enlarges the receptive field, just like the big, nonlinear Y cells.  
Output → coarse, high-contrast or motion-like edges.

## 4. W Cells (Koniocellular Pathway)

Biology:

- Fewer in number; respond irregularly.
- Sensitive to flicker, global brightness, and micro-eye movements (**microsaccades**).
- Their signals help the brain stabilize images during small eye motions.

CNN analogy (blue block):

$1 \times 3$  conv → horizontal context  
 $3 \times 1$  conv → vertical context  
combine

That cross-shape aggregation smooths and stabilizes the map, simulating how W-cells blend horizontal + vertical information to maintain global context.

## What happens after ganglion cells fire

All three kinds send their axons into the **optic nerve**:

- X cells → **Parvocellular layers** of LGN
- Y cells → **Magnocellular layers** of LGN
- W cells → **Koniocellular layers** (thin layers between the others)

Then LGN → V1 cortex, where neurons start detecting **oriented edges, lines, and shapes**.

Later areas (V2, V4, IT) combine those signals into full object recognition.

## 5. Putting It Together

- X-cells → small receptive field → fine edges
- Y-cells → large receptive field → thick, high-contrast edges
- W-cells → motion context → smoothed, stable edges

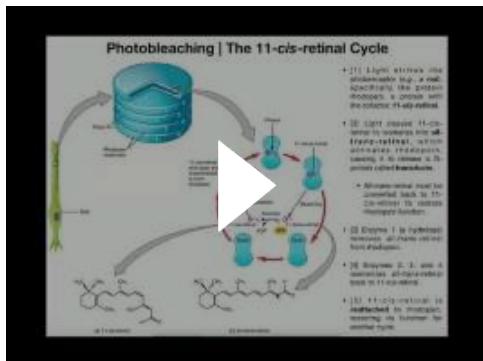
In the real eye, those three sets of ganglion cells send separate streams (X = detail, Y = motion, W = context) through the **optic nerve** → **LGN** → **V1**, where the brain fuses them. حيث يقوم الدماغ بدمجهم.

In **XYW-Net**, the encoder's X/Y/W modules do the same, and the decoder's ITM blocks mimic that fusion. الالندماج

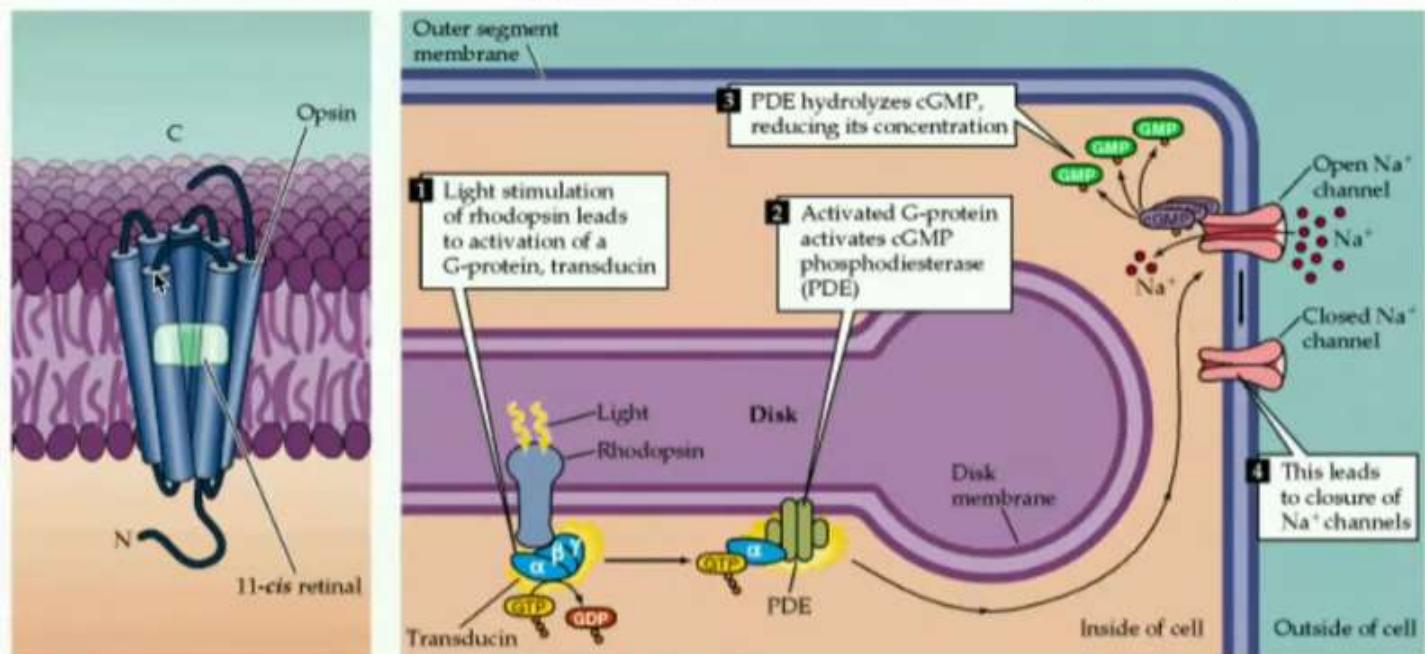
# Advanced Photo Receptors

Wednesday, November 12, 2025 6:15 PM

## Anatomy | Vision (Part 2) | Photoreceptor Signaling & Photobleaching



## Photoreceptor Biosignaling via Transducin, a G-protein



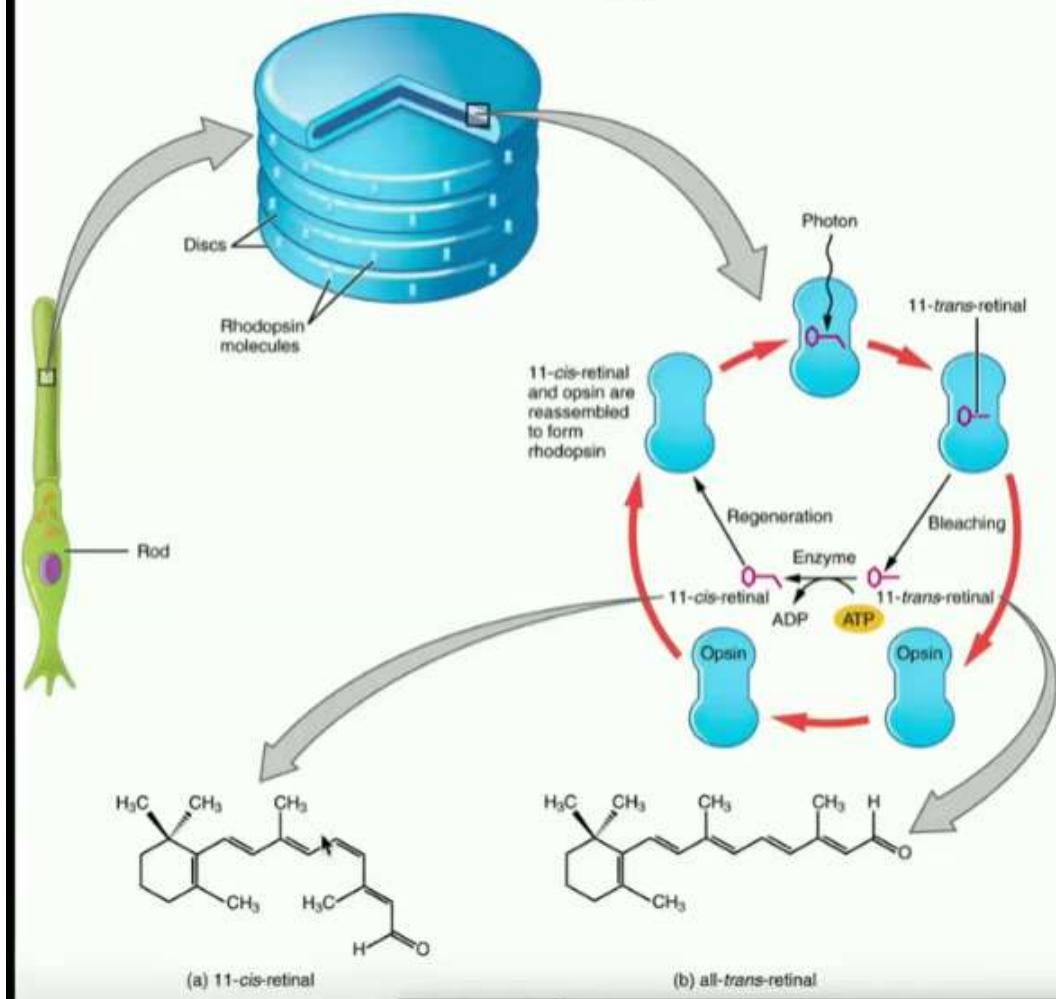
- Note that for the photoreceptor to be depolarized (DARK), 1) cGMP must be present, and 2) ligand-gated  $\text{Na}^+$ -channels must be open.
- [1] Light strikes the photoreceptor (e.g., a rod), specifically the protein rhodopsin, a protein with the cofactor, 11-cis-retinal.
- [2] Light causes 11-cis-retinal to isomerize into all-trans-retinal, which activates rhodopsin, causing it to release a G-protein called transducin.
- [3] Transducin activates the enzyme, cGMP phosphodiesterase, which hydrolyzes cGMP to GMP.
- [4] This causes ligand-gated  $\text{Na}^+$ -channels to close, hyperpolarizing the photoreceptor.

## Photobleaching | The 11-cis-retinal Cycle



- [1] Light strikes the photoreceptor (e.g., a rod), specifically the protein

# Photobleaching | The 11-cis-retinal Cycle



- [1] Light strikes the photoreceptor (e.g., a rod), specifically the protein rhodopsin, a protein with the cofactor, **11-cis-retinal**.
- [2] Light causes 11-cis-retinal to isomerize into **all-trans-retinal**, which activates rhodopsin, causing it to release a G-protein called **transducin**.
  - All-trans-retinal must be converted back to 11-cis-retinal To restore rhodopsin function.
- [3] Enzyme 1 (a hydrolase) removes all-trans-retinal from rhodopsin.
- [4] Enzymes 2, 3, and 4 isomerizes all-trans-retinal back to 11-cis-retinal.
- [5] 11-cis-retinal is **reattached** to rhodopsin, restoring its function for another cycle.