PHGY 210,2,4 - Physiology

SENSORY PHYSIOLOGY

Vision

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SENSORY PHYSIOLOGY

Vision

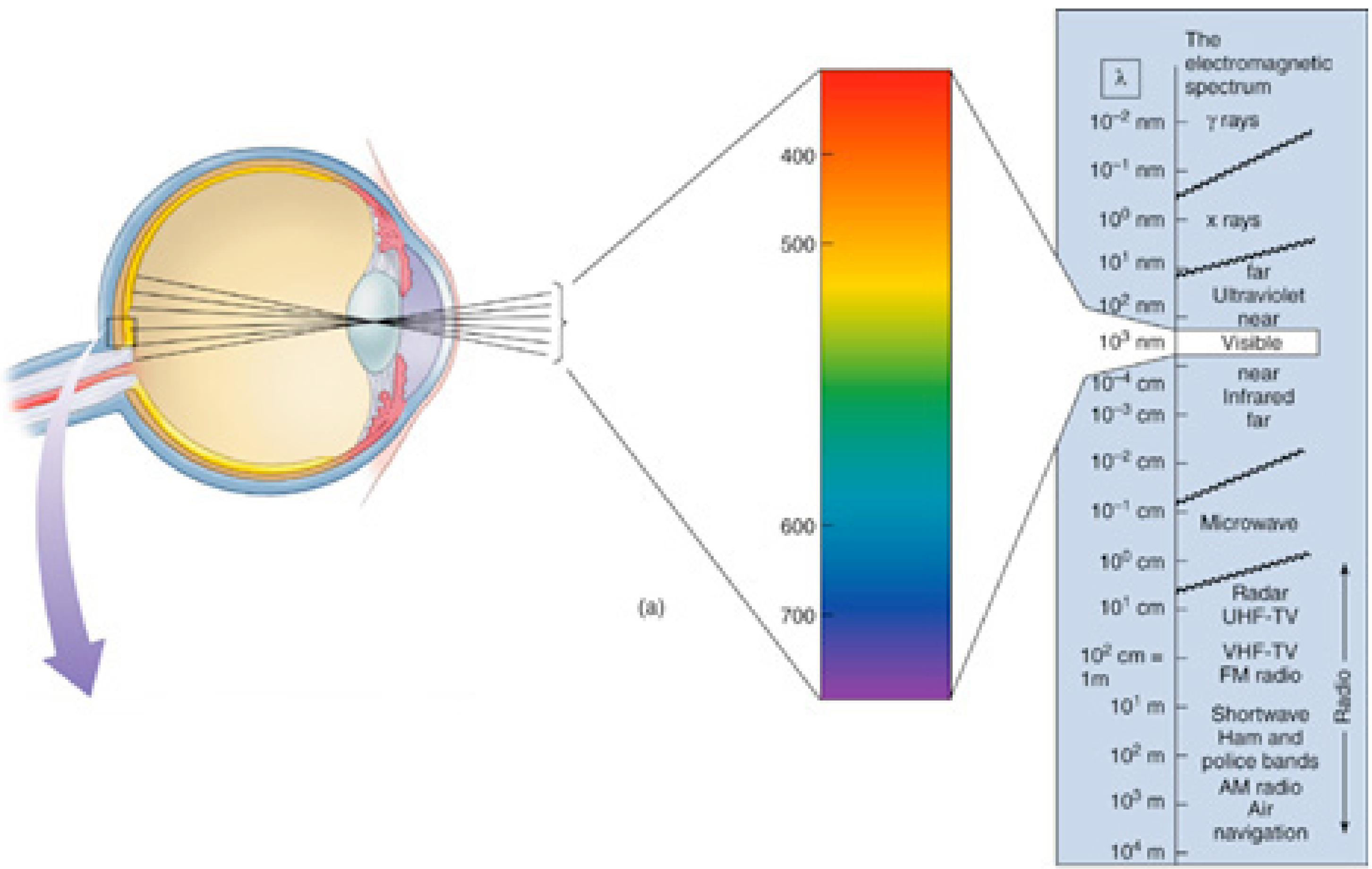
Reading

Rhoades & Pflanzer (4th edition)

Chapter 8: *The Visual System* (p. 273-288)

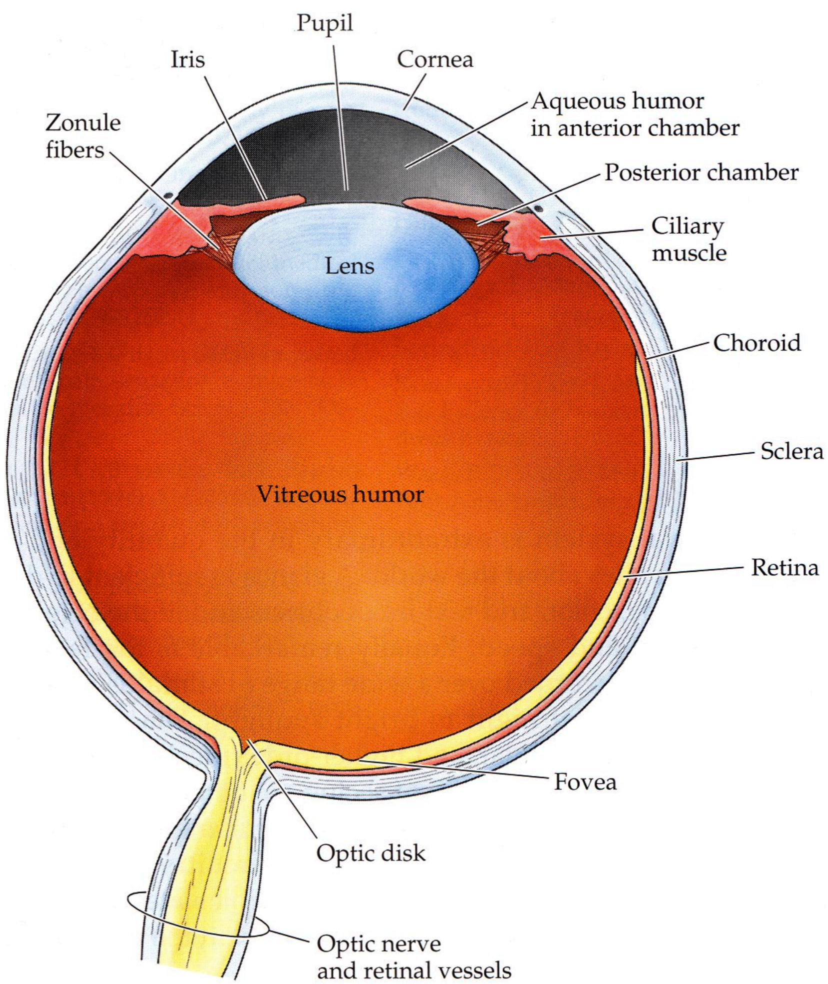
Visible Light

Visible light is composed of electromagnetic waves with wavelengths between 400–750 nanometers (nm).



Ocular Anatomy

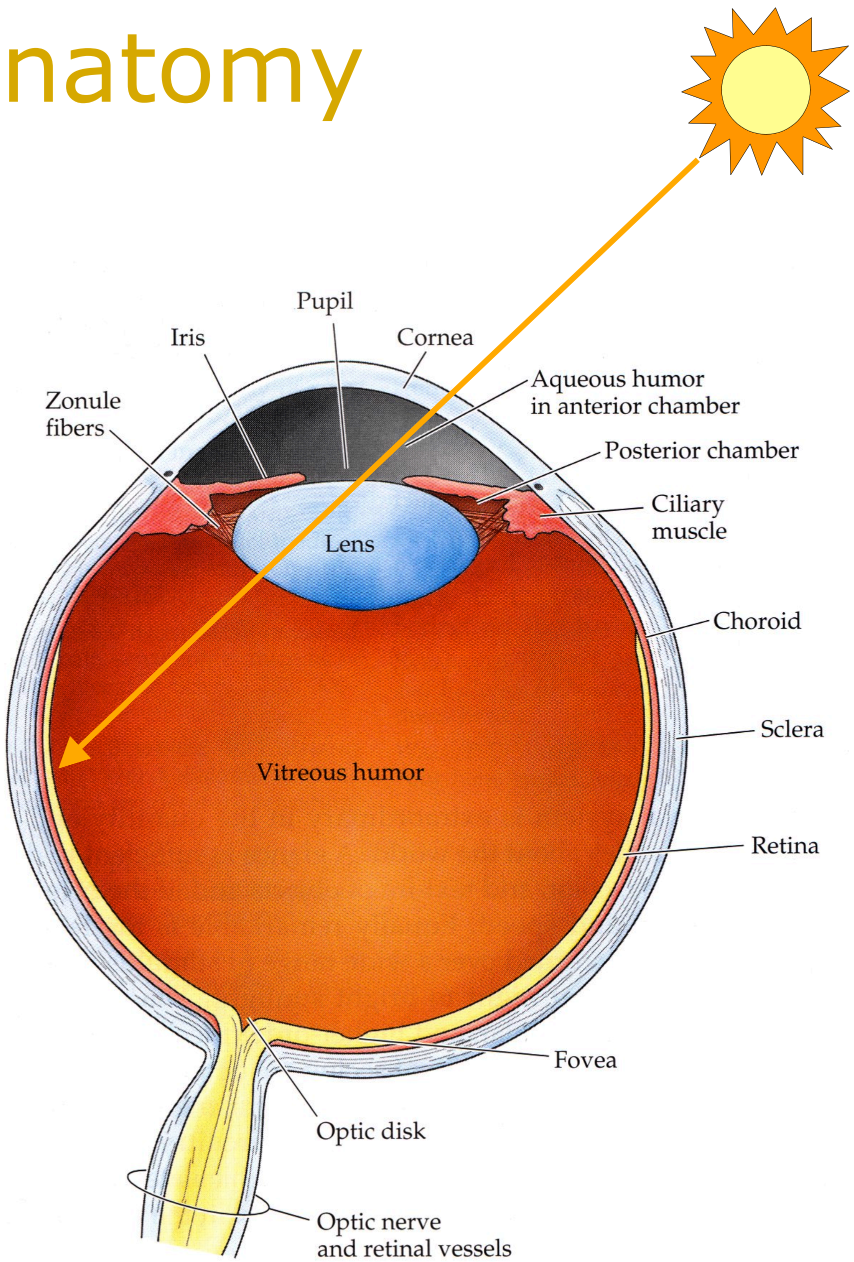
The eye is a fluid-filled sphere enclosed by three layers of tissue:
1) The outer layer is composed of the *sclera* and the *cornea*.
2) The middle layer includes the *iris*, the *ciliary body*, and the *choroid*.
3) The inner layer is the actual *retina* containing the *photoreceptors*.



Ocular Anatomy

En route to the retina, light successively travels through:

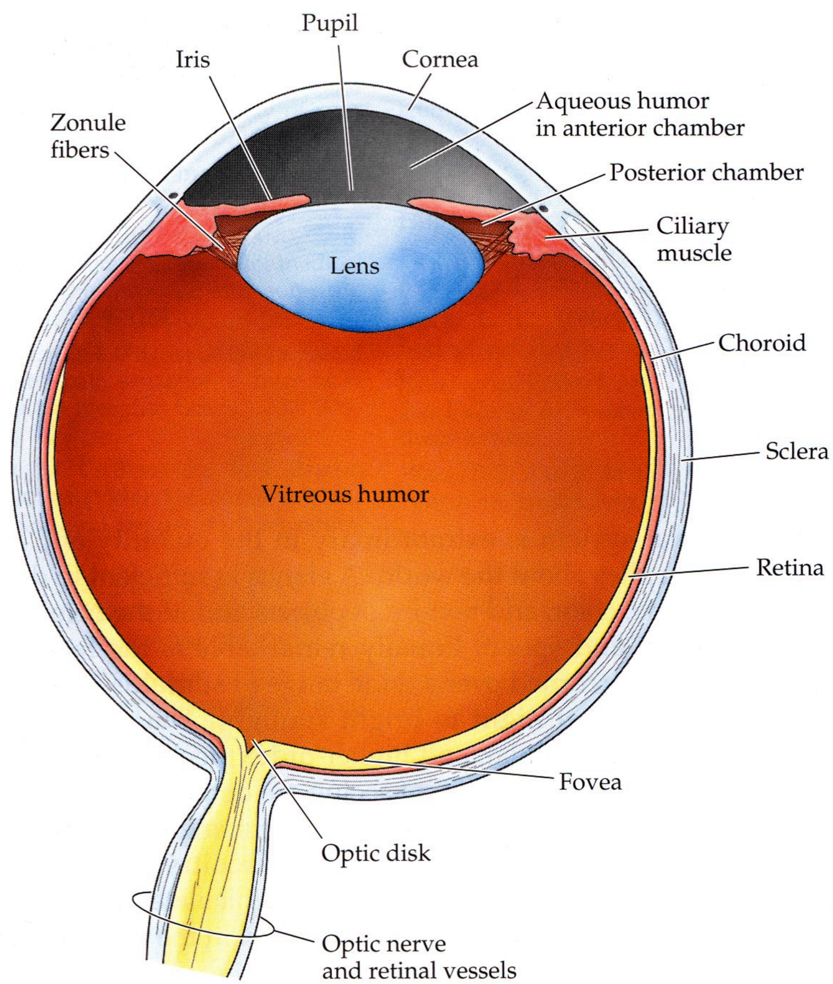
1) the *cornea*
2) the *aqueous humor* of the anterior chamber
3) the *pupil*
4) the *lens*
5) the *vitreous humor*



Ocular Anatomy

The **iris** contains a musculature controlling the **pupil** size.

Its function is to modulate the amount of light that enters the eyes.



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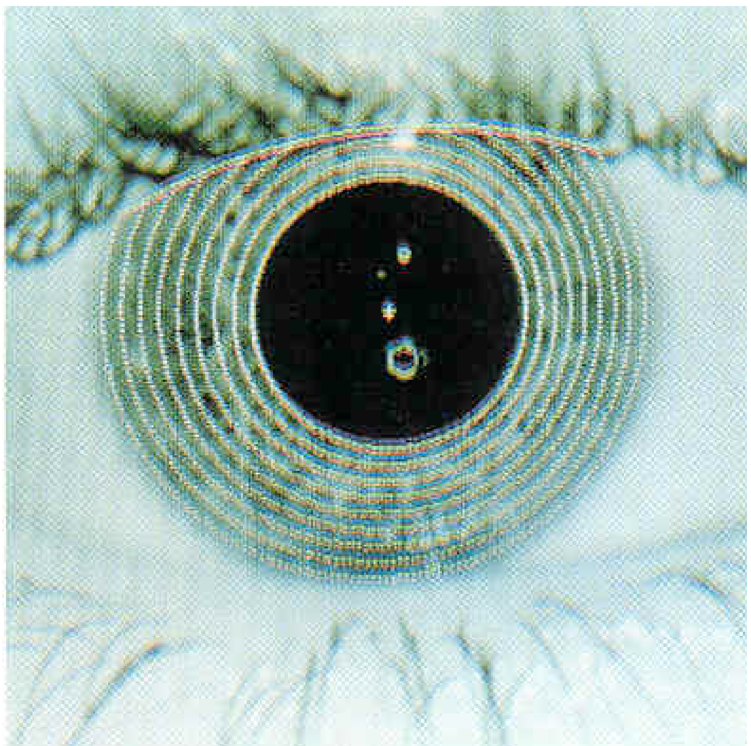
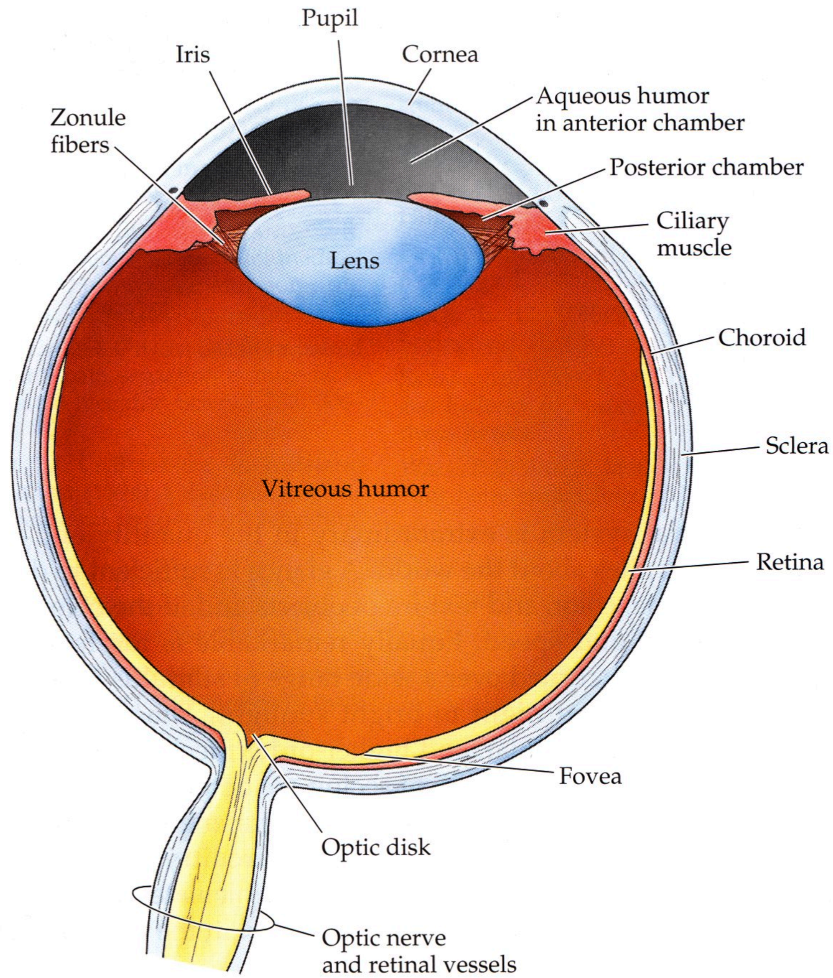
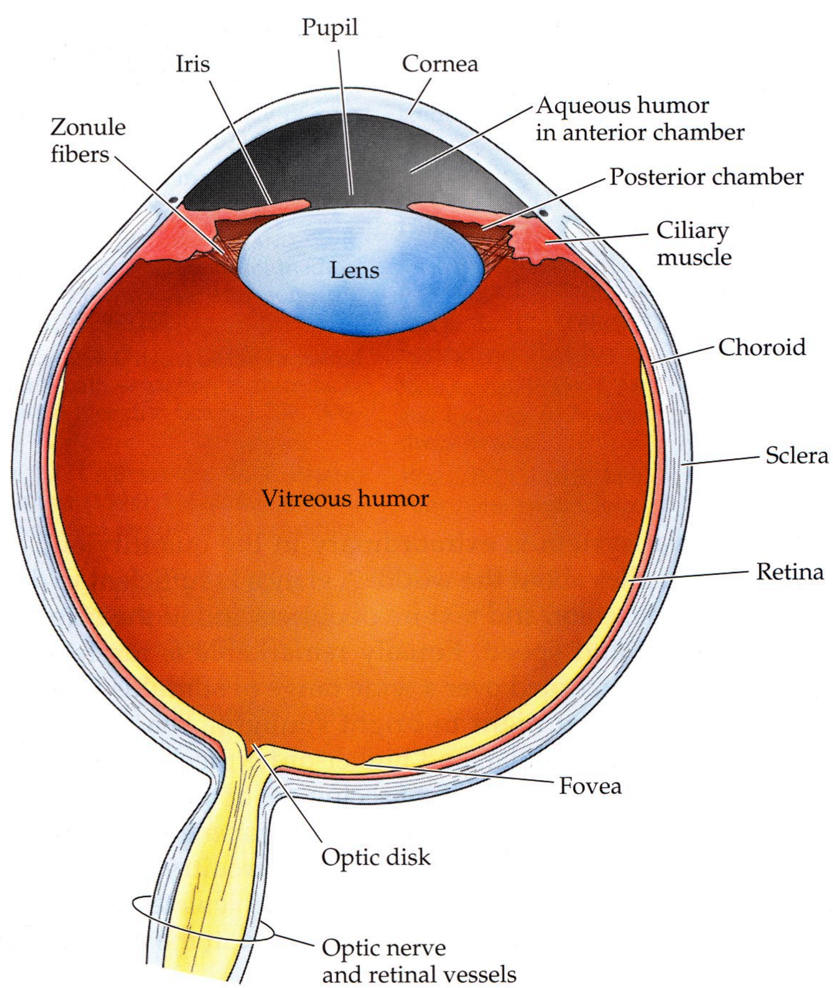




Ocular Anatomy

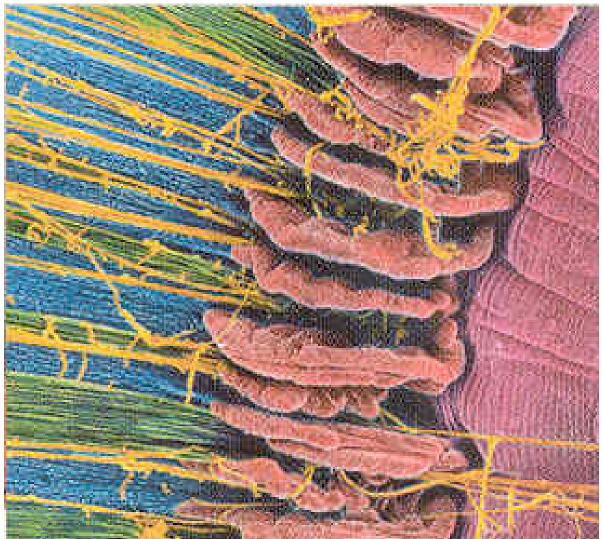
The *ciliary body* encircles the **lens**. It contains a musculature that adjusts the refractive power of the *lens*.

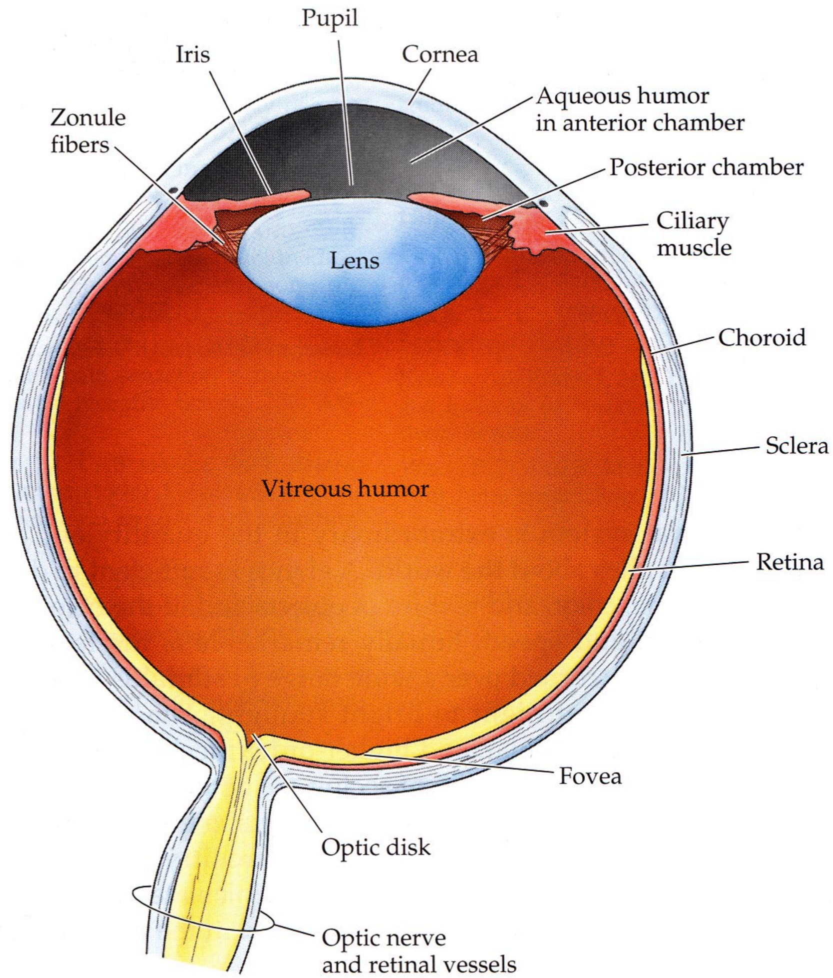
Together with the **cornea**, the *lens* help focusing the image on the *retina*.



Ca

Ocular Anatomy



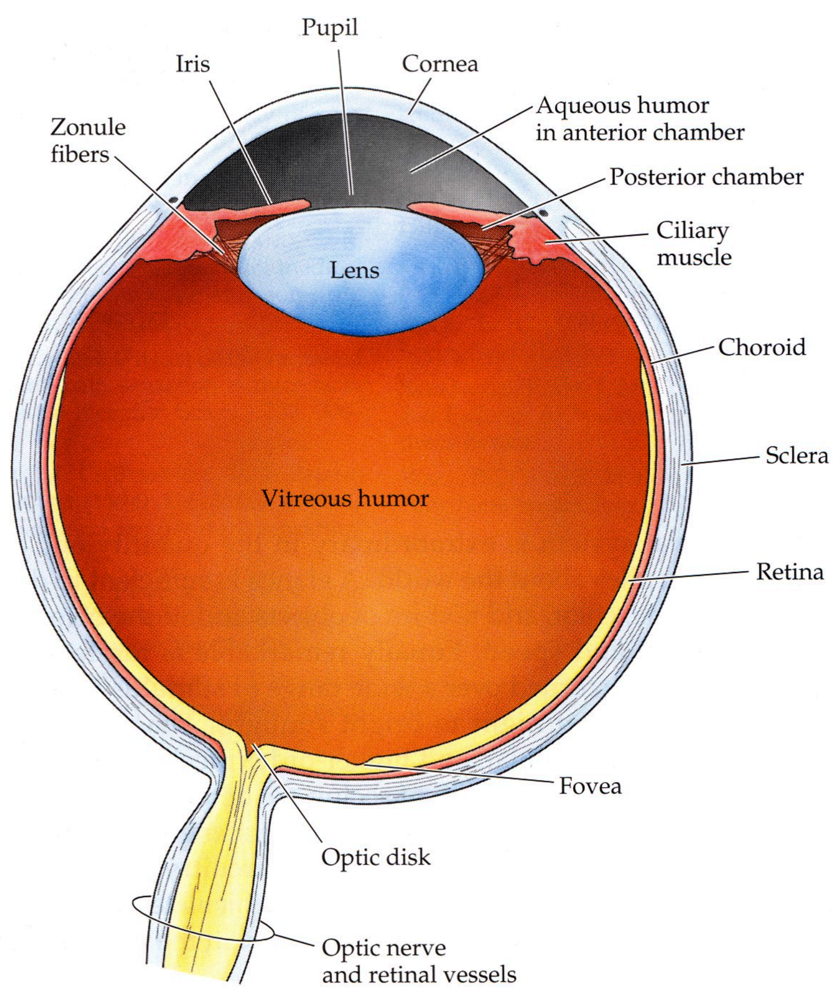


Ca

Ocular Anatomy

The **aqueous humor** is a clear, watery liquid in the *anterior chamber* produced by the *ciliary body* in the *posterior chamber*.

It regulates the intraocular pressure.



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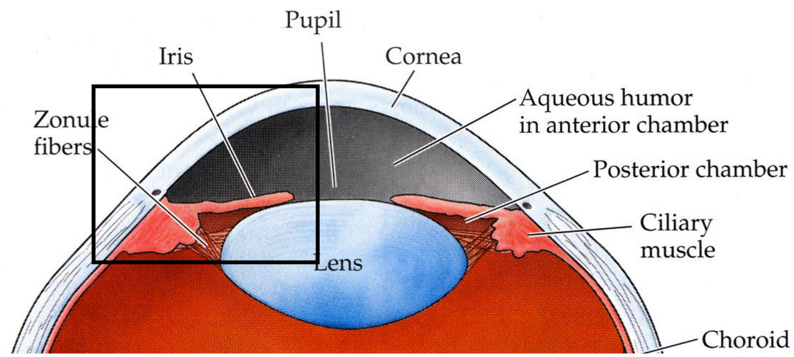
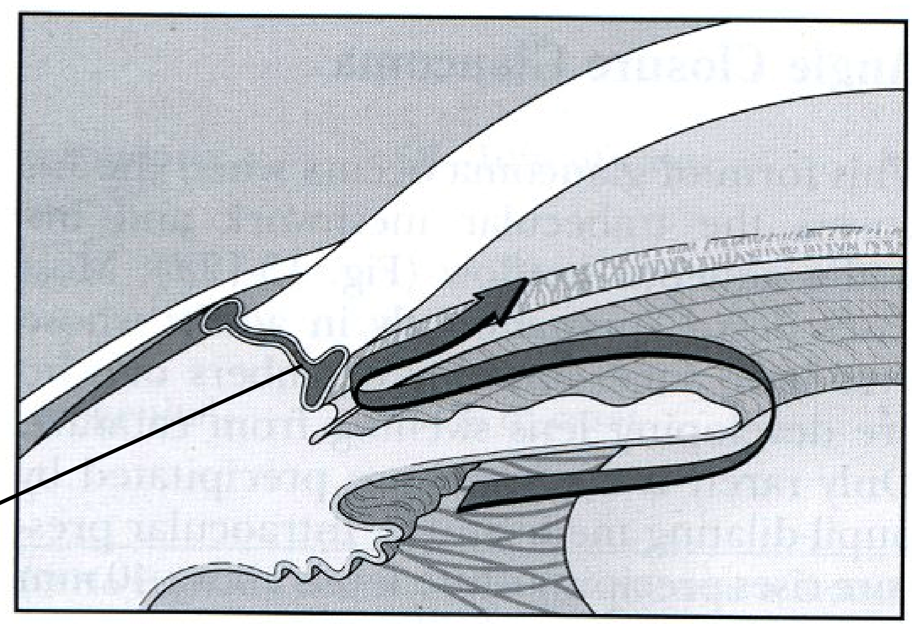


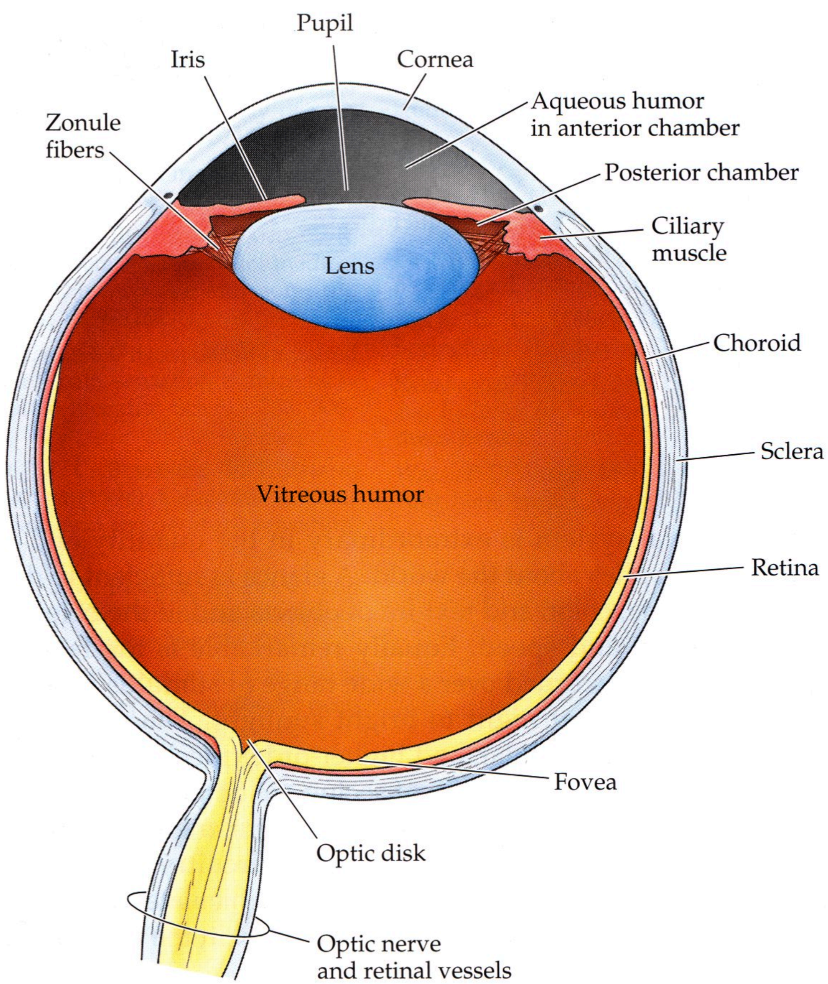


Schlemm's canal

Ocular Anatomy

The **vitreous humor** is a thick gelatinous substance between the back of the *lens* and the *retina*.

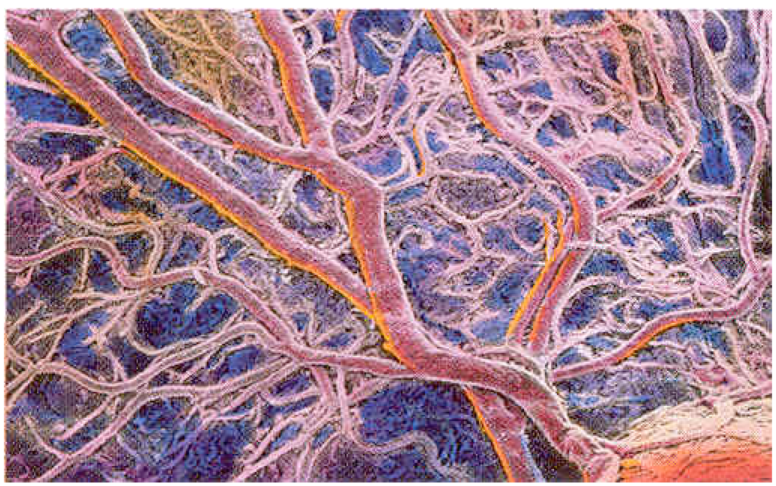
It accounts for the size and shape of the globe.

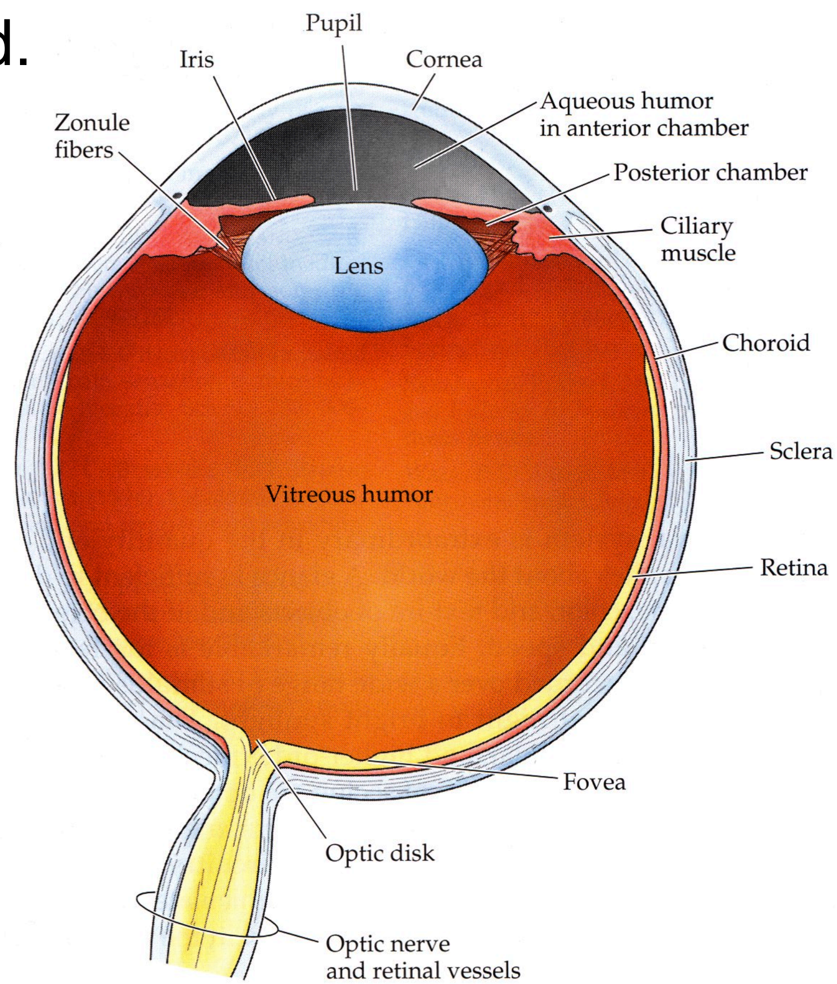


Ocular Anatomy

The **choroid** is a capillary bed.

It supplies oxygenation and metabolic sustenance to the cells in the *retina*, including the photoreceptors.

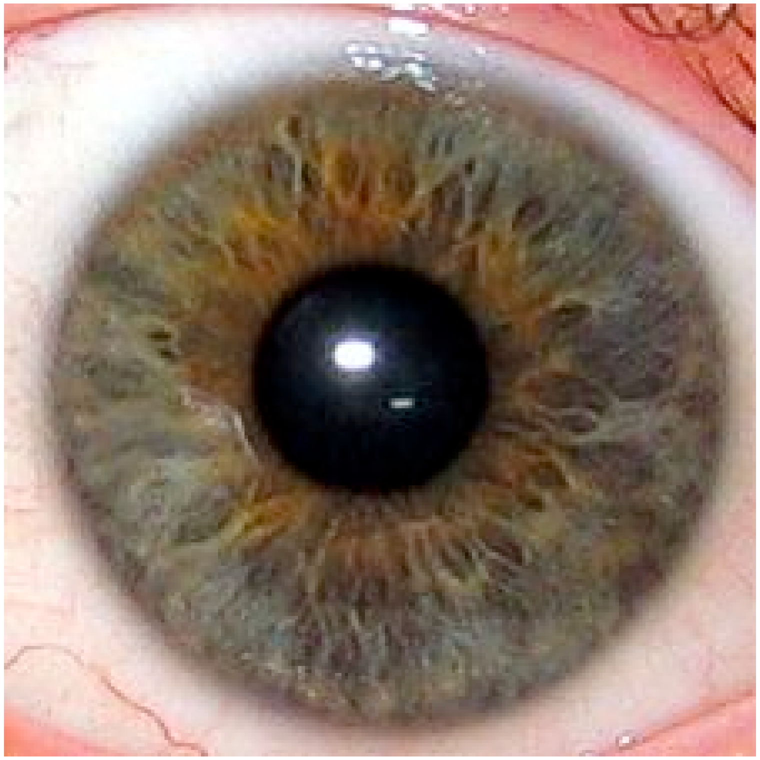




Control of Incoming Light

The amount of light that enters the eyes is modulated by changing the size of the pupil.

This control originates from the brain stem.



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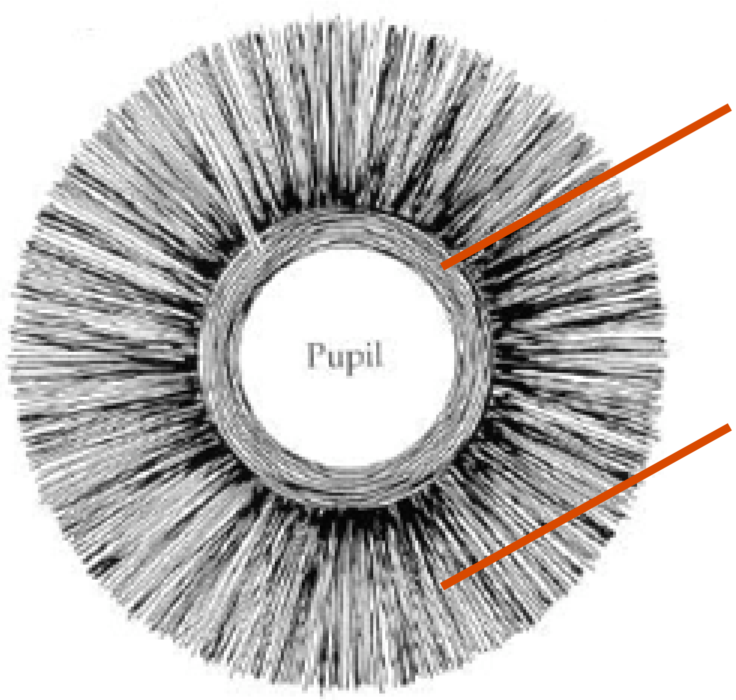


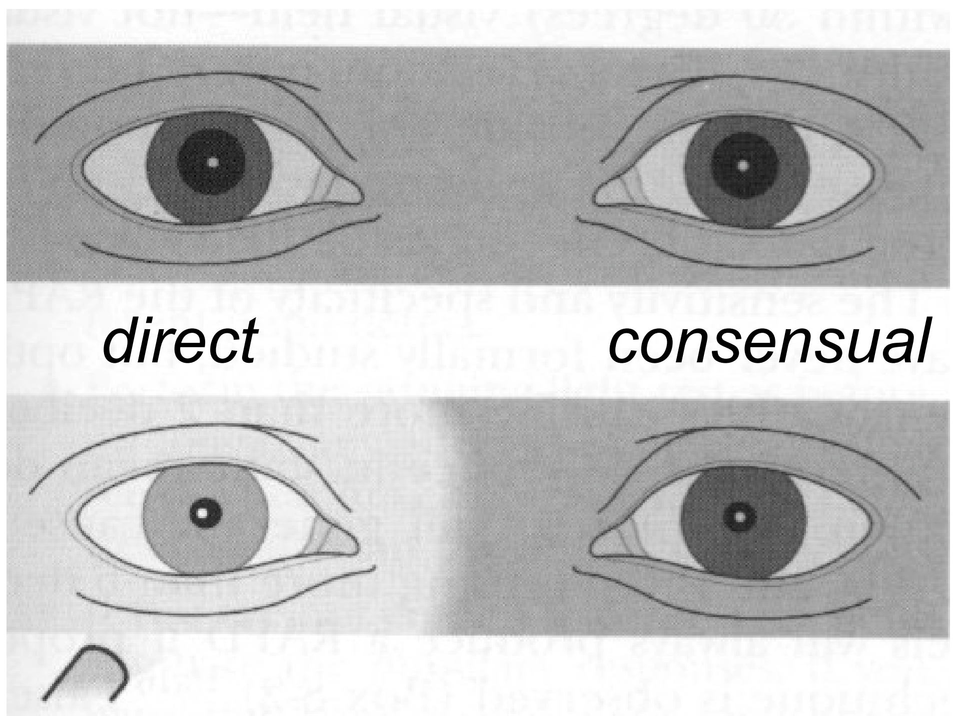
Circular (*constrictor*) **muscles** act to decrease the pupil size under *parasympathetic* control.

Radial (*dilator*) **muscles** act to increase the pupil size under *sympathetic* control.

Pupillary Light Reflexes

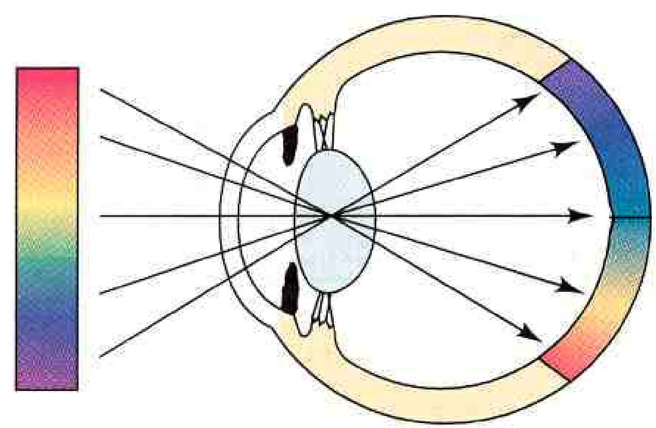
Shining a light into each eye can elicit a **direct** and a **consensual** *pupillary light reflex*.

This light reflex tells us about the state of a patient's visual pathways and helps identify the cause of structural coma.



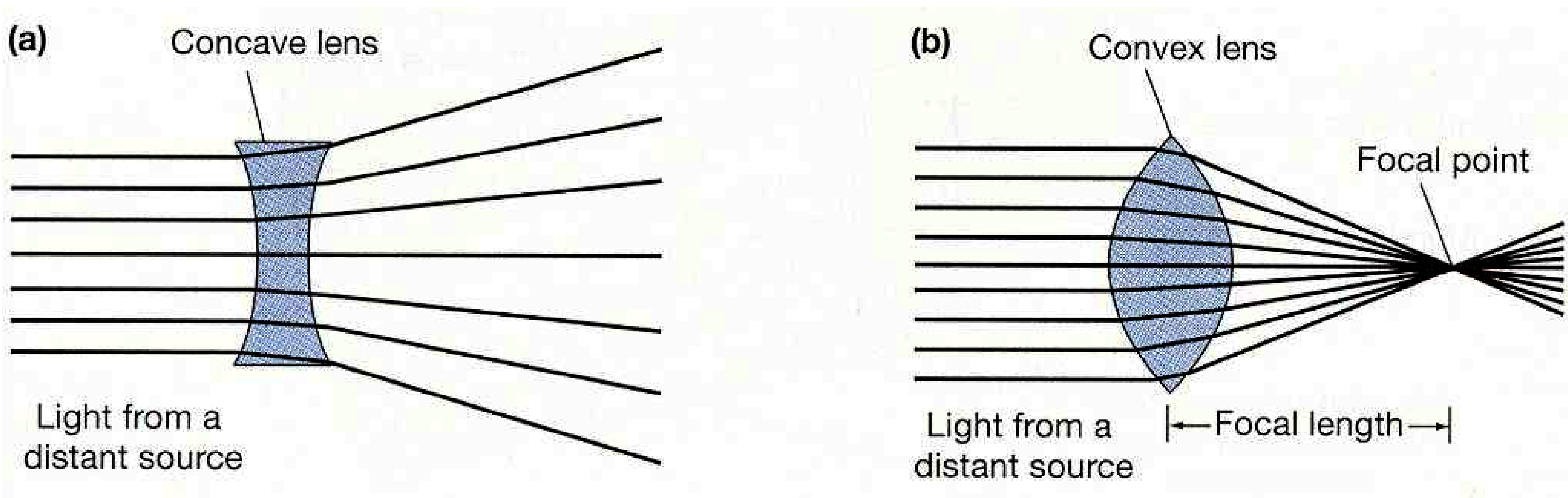
Retinal Image Formation

The ability to focus an image on the retina depends on the refractive power of both the **cornea** and the **lens** as well as on the **shape** of the eye globe.



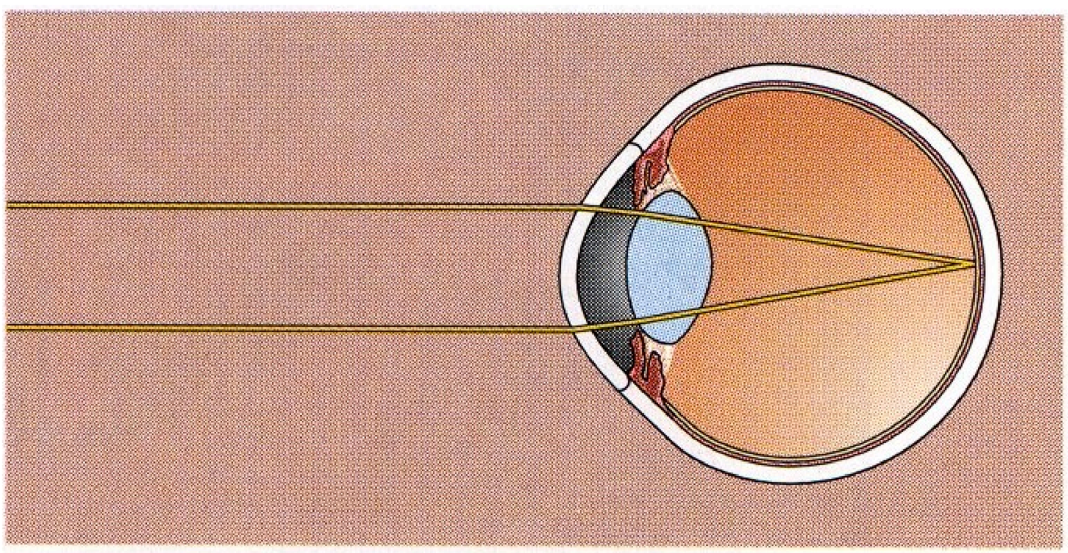
Retinal Image Formation

The *angle of refraction* depends on:
1) the difference in density of the two milieus
2) the angle at which the light meets the surface.



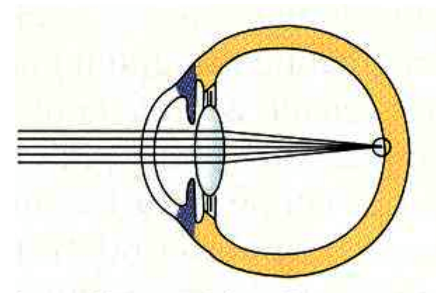
Retinal Image Formation

When the eye is able to bring distant objects to point focus on the retina without the need of a refractive aid, the eye is said to be in a state of **emmetropia**.

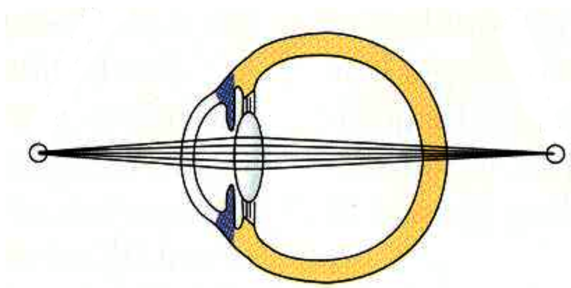


Retinal Image Formation

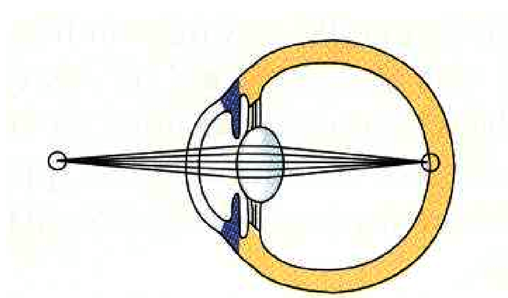
When an object is distant, the light rays are essentially parallel and brought to a focus on the retina.



If the object moves closer, the focal point then moves behind the retina.

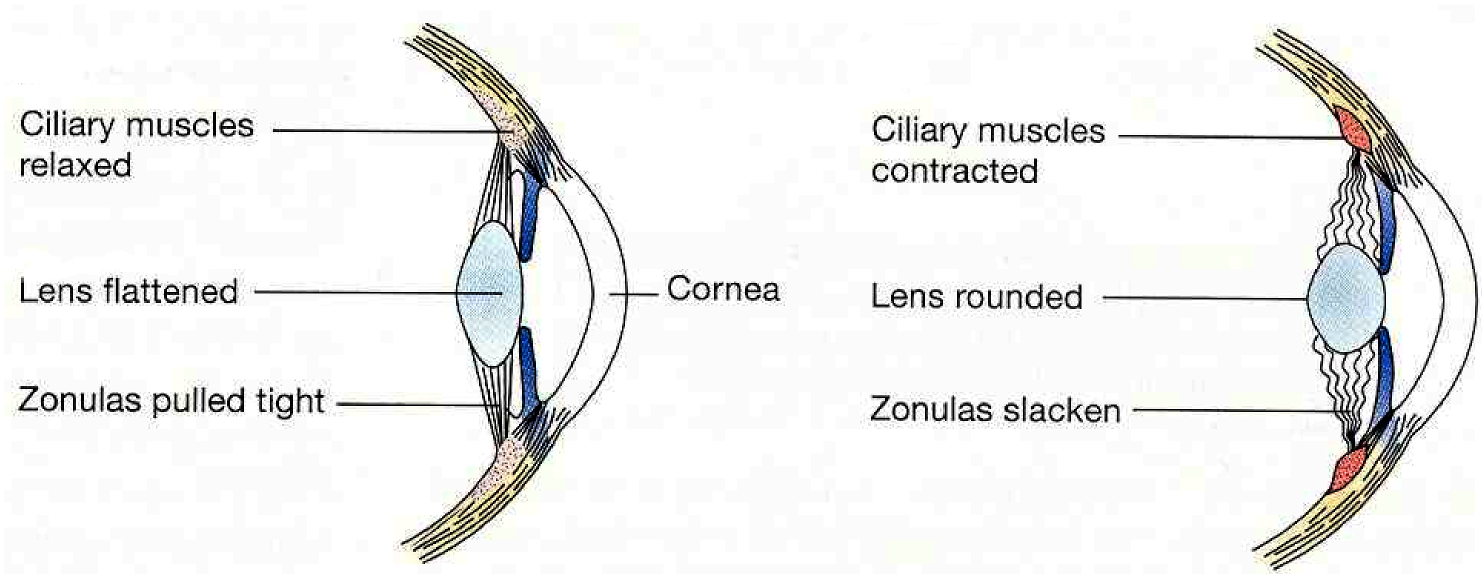


To bring the image into focus on the retina, the lens refractive power must be increased. This is the process of **accommodation**.



Retinal Image Formation

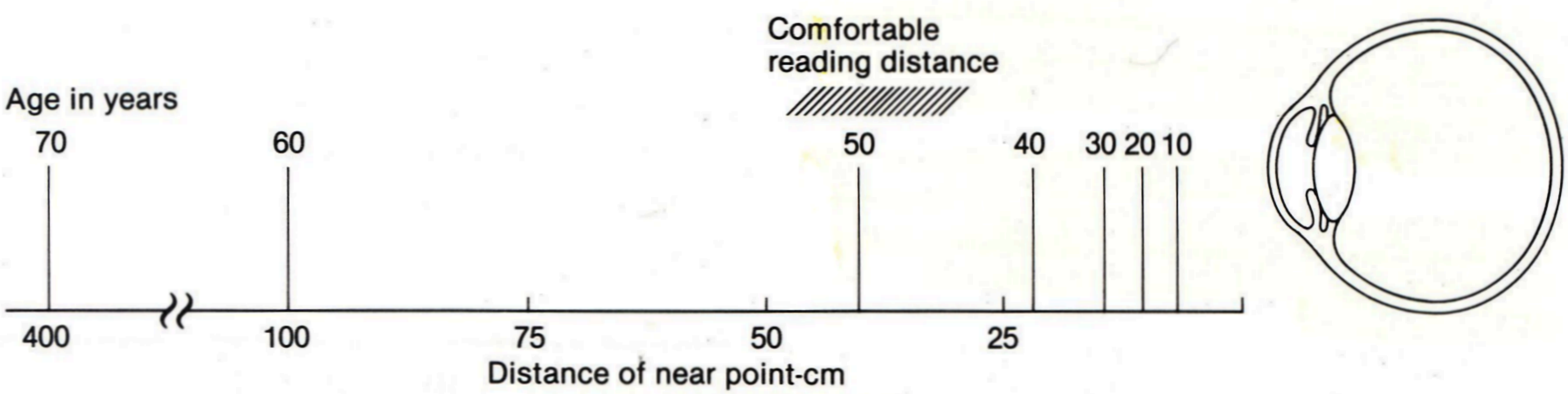
The lens changes its shape through the action of inelastic fibers called **zonulas**. Contraction in *ciliary muscles* relaxes these zonulas, which then allow the lens to assume its natural rounded shape.



Retinal Image Formation

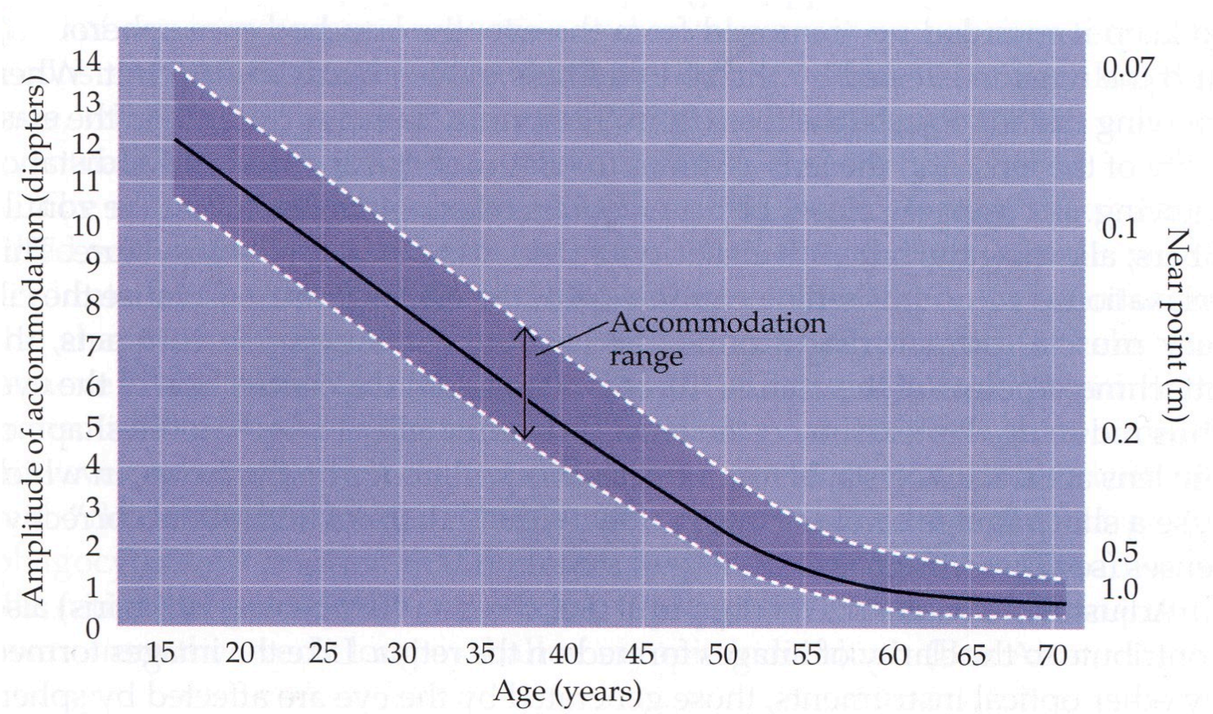
Accommodation has its limits!!!

The closest distance at which your lens can focus on objects is called the **near point** of accommodation.



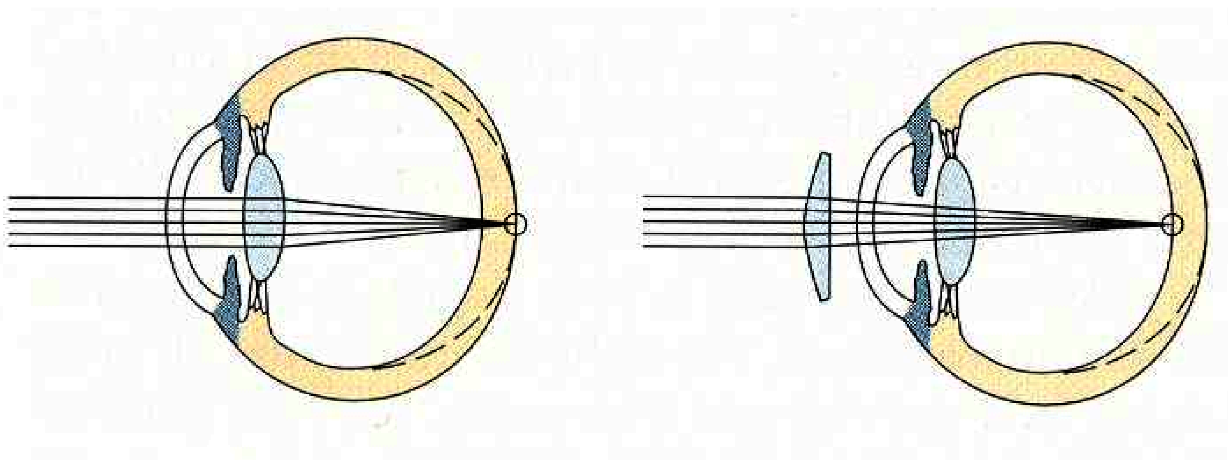
Problems in Retinal Image Formation

Our lens hardens with age and ciliary muscles weaken.
This gradual decreased ability in accommodation
is called **presbyopia**.



Problems in Retinal Image Formation

The solution to **presbyopia** is a corrective (**convex**) lens
that augments the focusing power
to bring the retinal image to a focus on the retina.

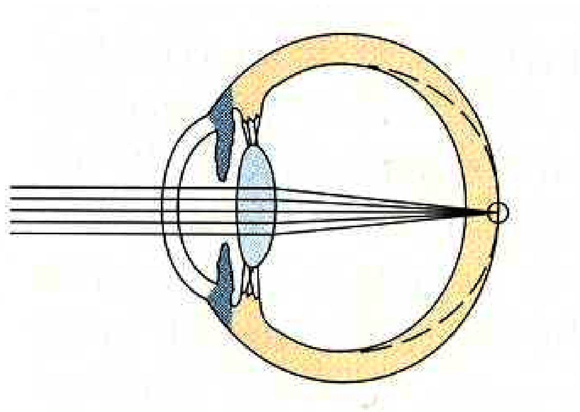


Presbyopia Presbyopia (corrected with a convex lens)

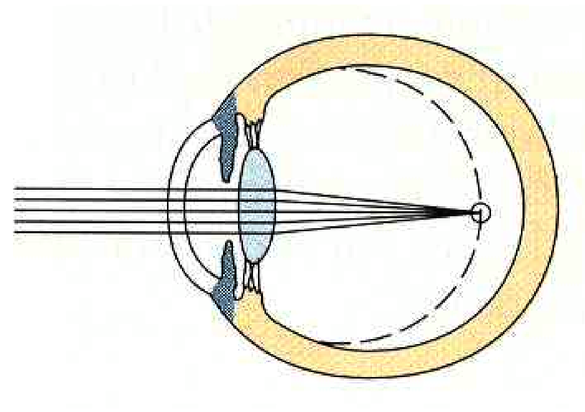
Problems in Retinal Image Formation

Most of us (~70%) have a refractive error (*ametropia*), in which light rays come to a point focus either behind the retina (**hyperopia**) or in front of it (**myopia**).

Hyperopia (*farsighted*)

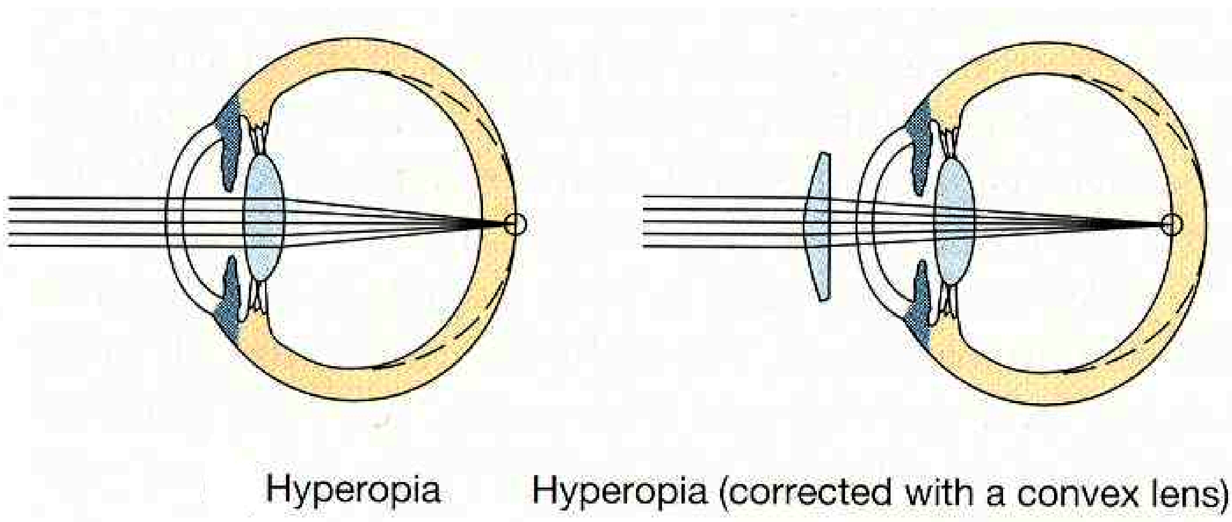


Myopia (*nearsighted*)



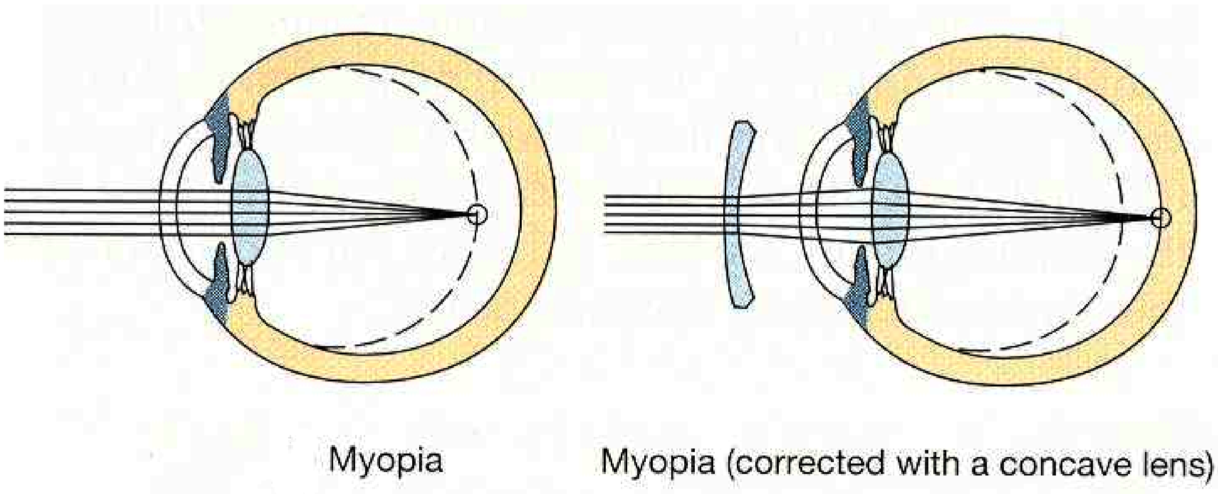
Problems in Retinal Image Formation

The solution to **hyperopia** is a corrective (**convex**) lens that augments the eye's defective refractive power by converging the light rays to a focus on the retina.



Problems in Retinal Image Formation

The solution to **myopia** is a corrective (**concave**) lens that reduces the eye's excess refractive power by diverging the light rays to a focus on the retina.



Evolution of the Eye

"***To suppose that the eye*** with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, ***could have been formed by natural selection, seems, I freely confess, absurd in the highest degree***."

Charles Darwin, *The Origin of Species, Chapter VI, Organs of Extreme Perfection*

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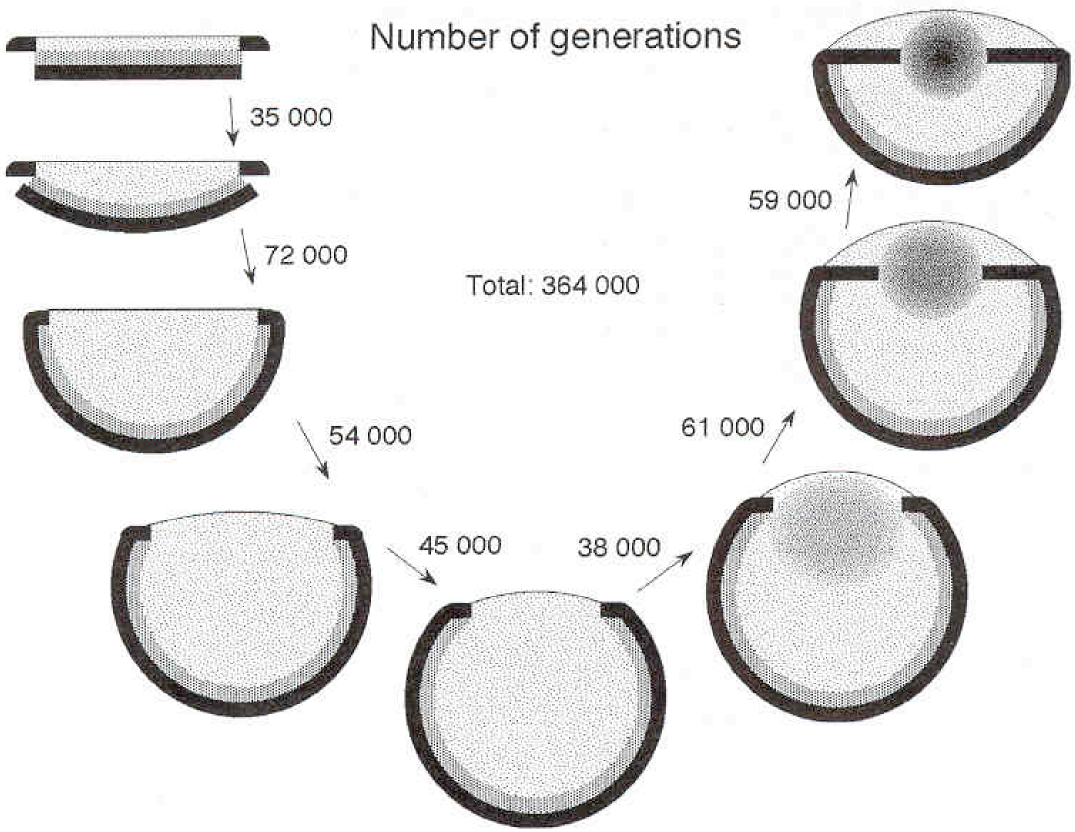
"**Reason tells me**, that if numerous gradations from a simple and imperfect eye to one complex and perfect can be shown to exist, each grade being useful to its possessor, as is certain the case; if further, the eye ever varies and the variations be inherited, as is likewise certainly the case; and if such variations should be useful to any animal under changing conditions of life, then ***the difficulty of believing that a perfect and complex eye could be formed by natural selection, should <u>not</u> be considered as subversive of the theory***."

Evolution of the Eye

A patch of light sensitive epithelium can be gradually turned into a perfectly focused camera-type eye if there is a continuous selection for improved spatial vision (Nilsson & Pelger, 1994).



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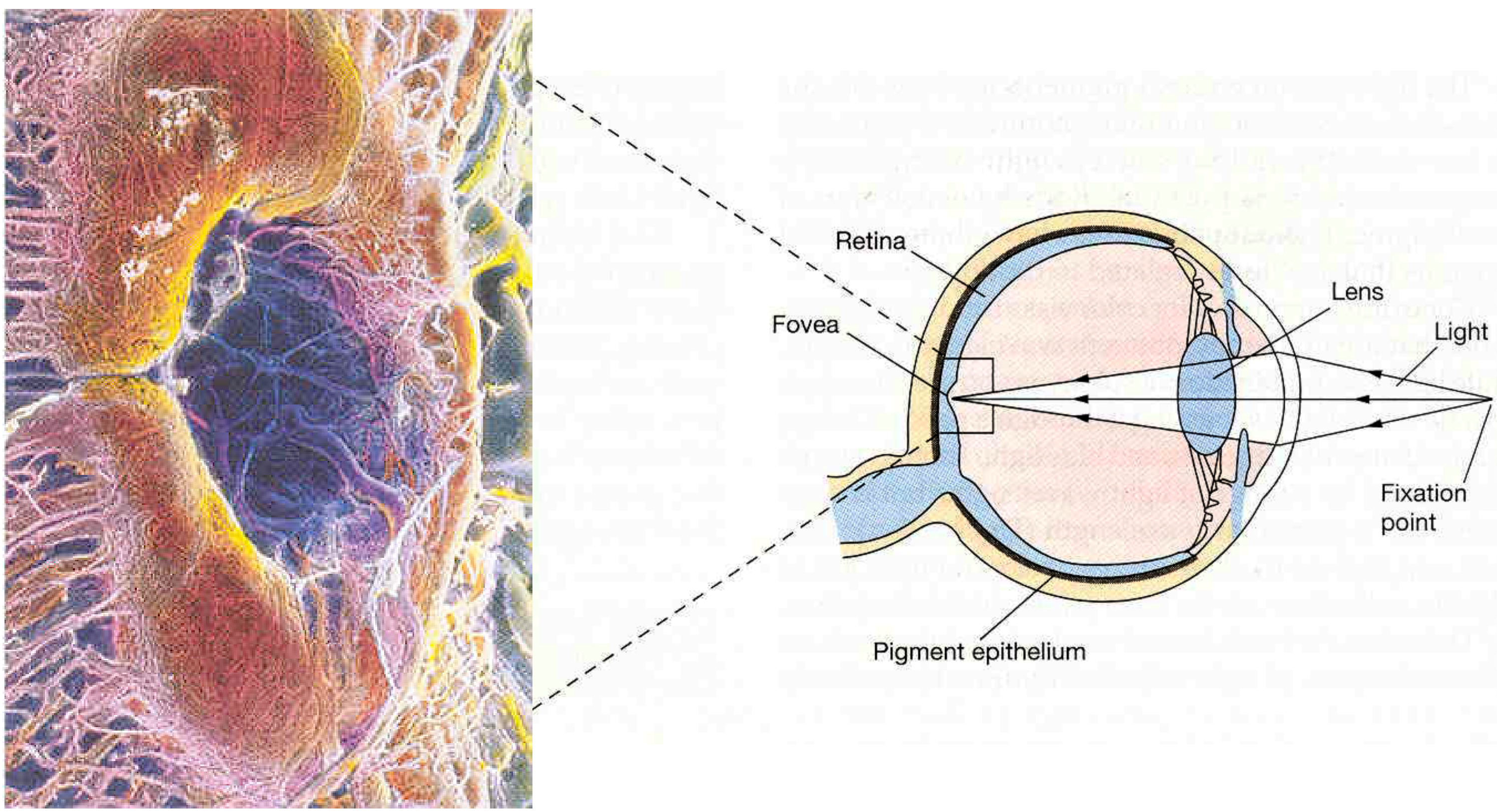
Rhoades & Pflanzer (4th edition)

Chapter 8: *The Visual System* (p. 273-288)

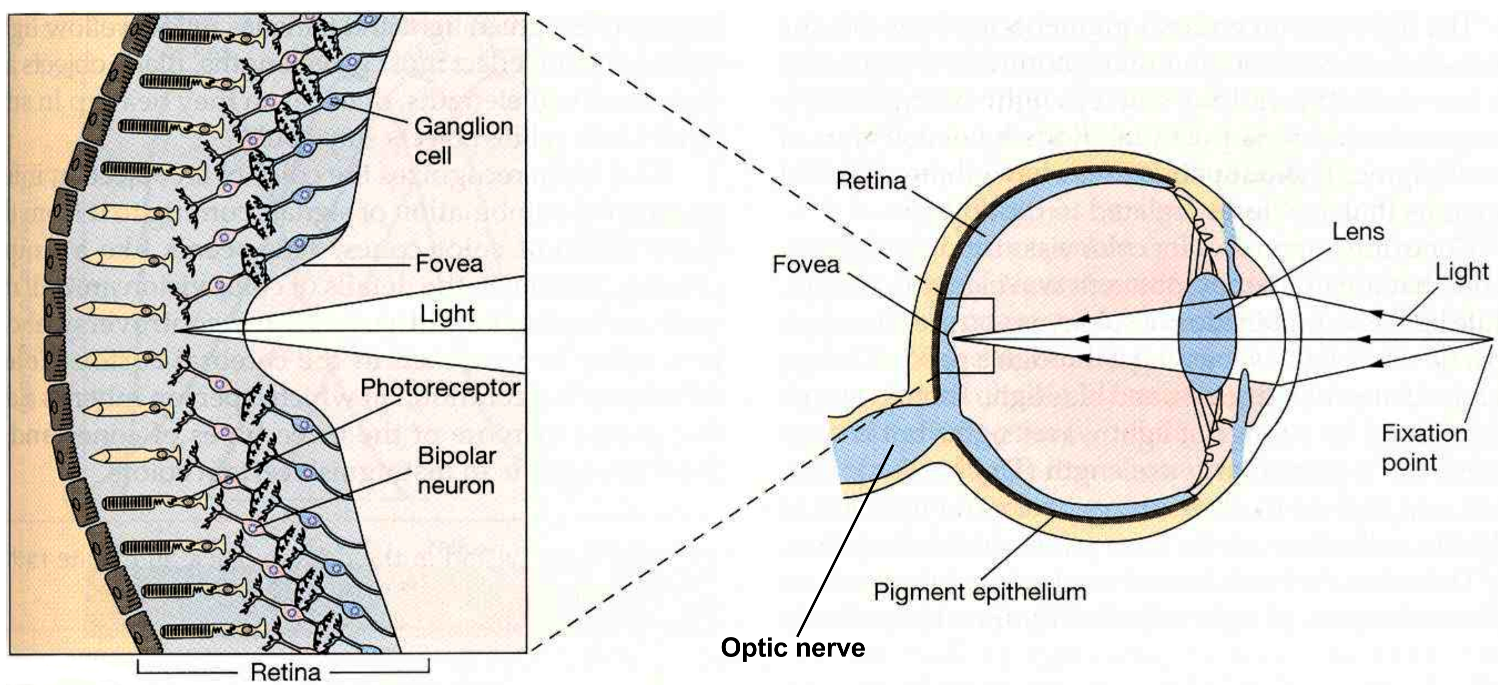
Retina

Light strikes photoreceptors only after passing through sensory neurons, except at the central retinal region (**fovea**) where acuity is best.

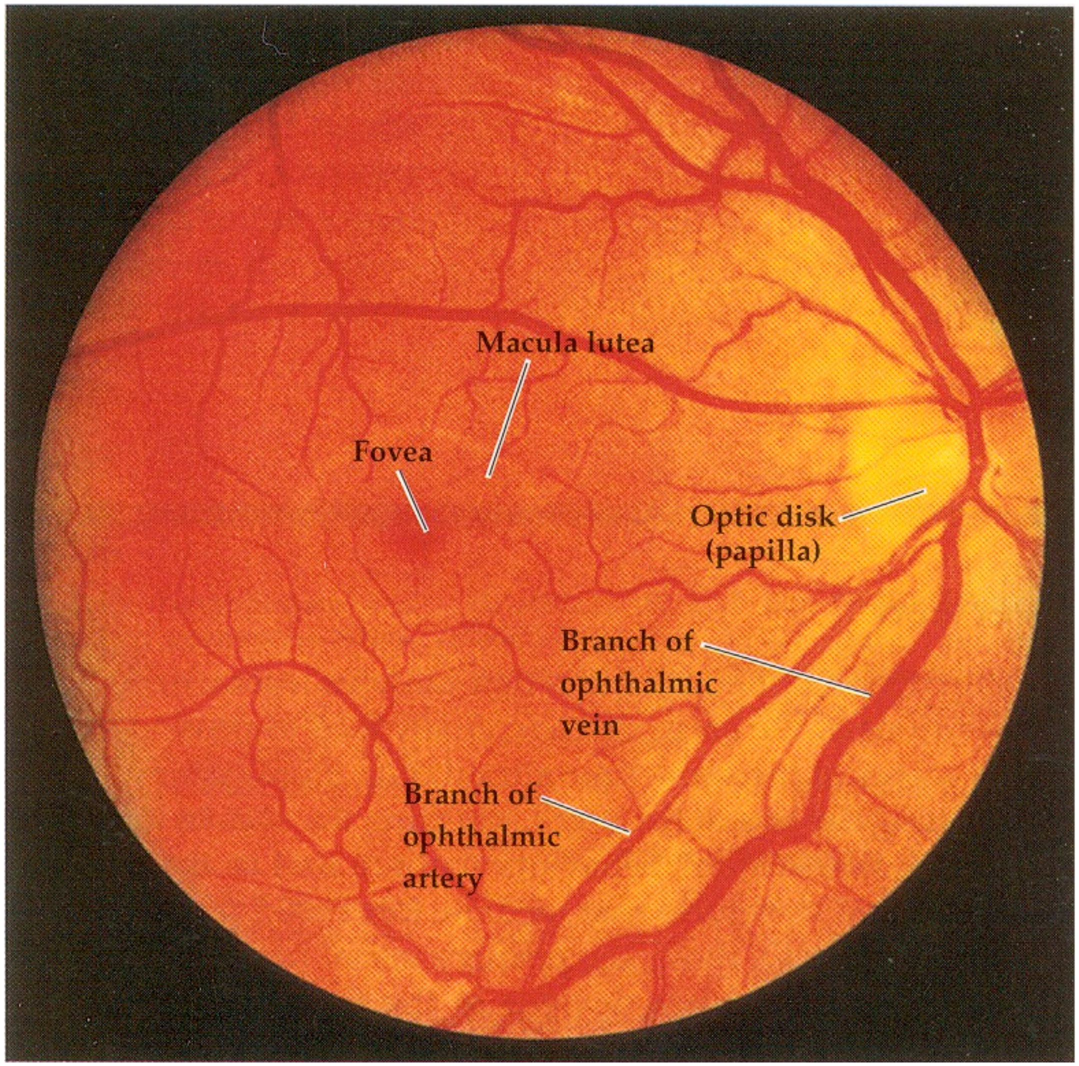


Retina

Visual information is transmitted from **photoreceptors** to **bipolar** neurons and **ganglion** neurons before exiting the eye via the optic nerve (*II cranial nerve*).



Retina

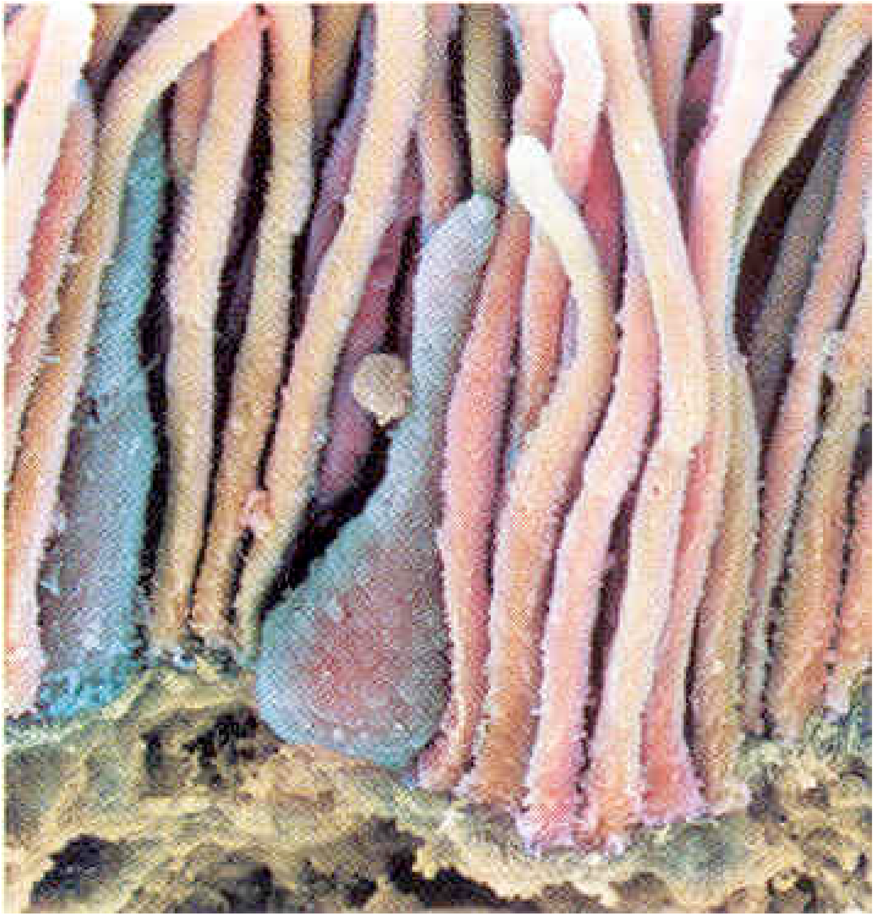


Macula lutea
Fovea
Optic disk
(papilla)
Branch of
ophthalmic
vein
Branch of
ophthalmic
artery

Blind Spot Demonstration

Photoreceptors

There are two types of photoreceptors: **rods** & **cones**.



They differ in:

1) shape
2) range of operation
3) distribution
4) connectivity
5) visual function

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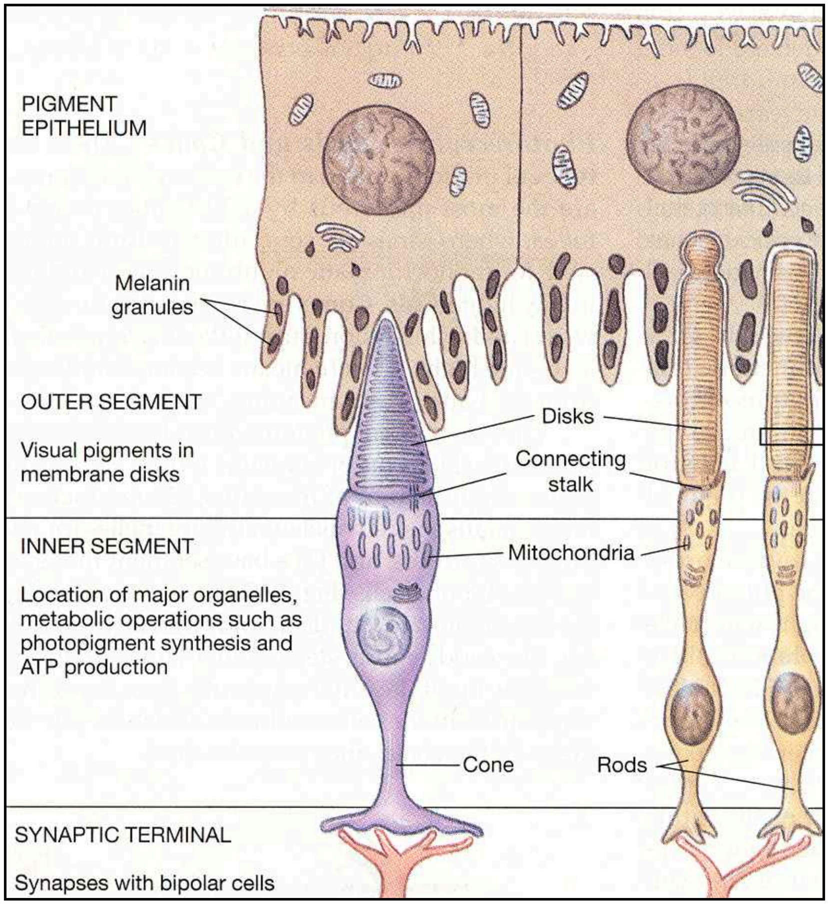

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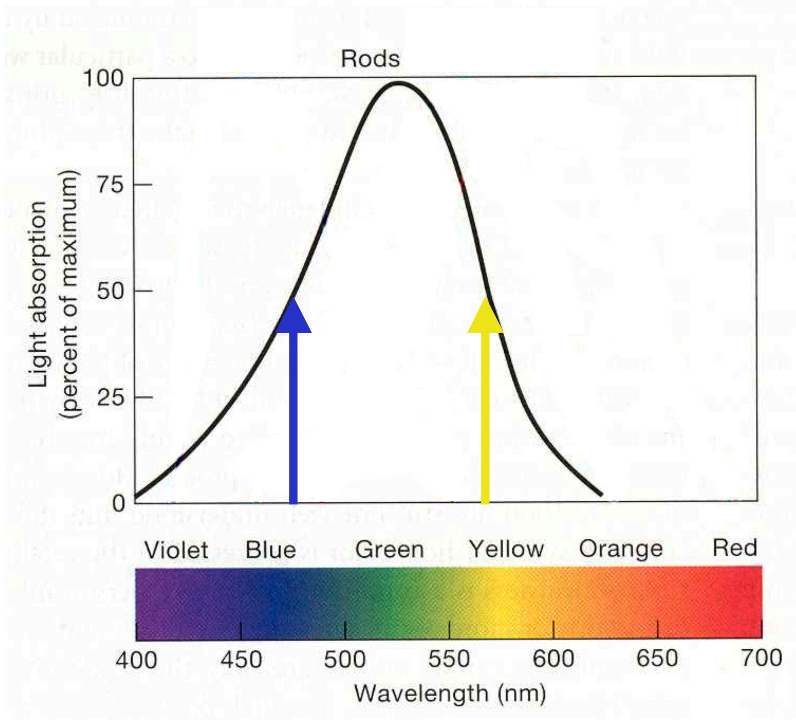

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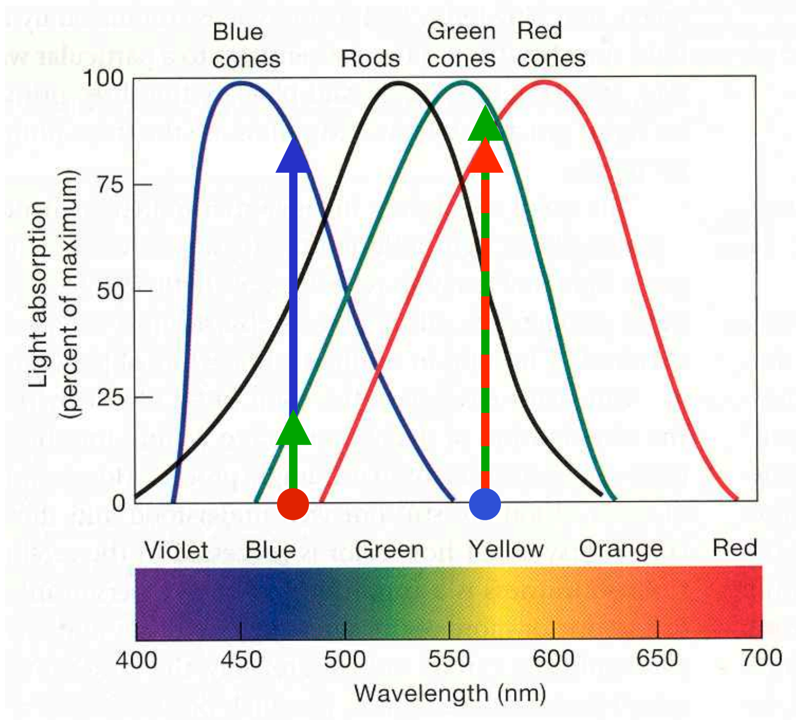

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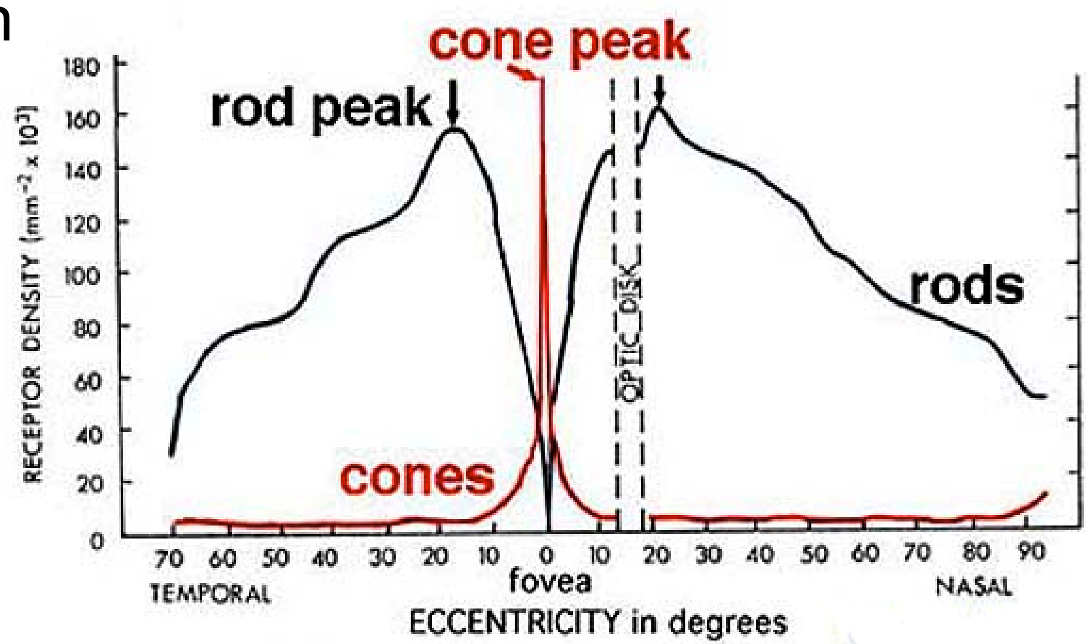

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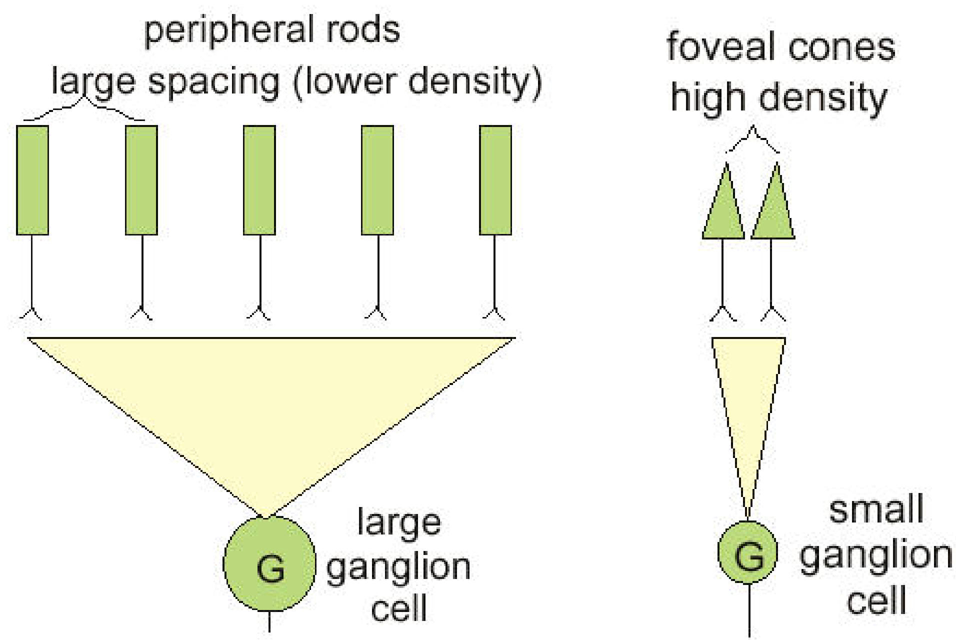

Photoreceptors

There are two types of photoreceptors: **rods** & **cones**.

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1) shape
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3) distribution
4) connectivity
5) **visual function**

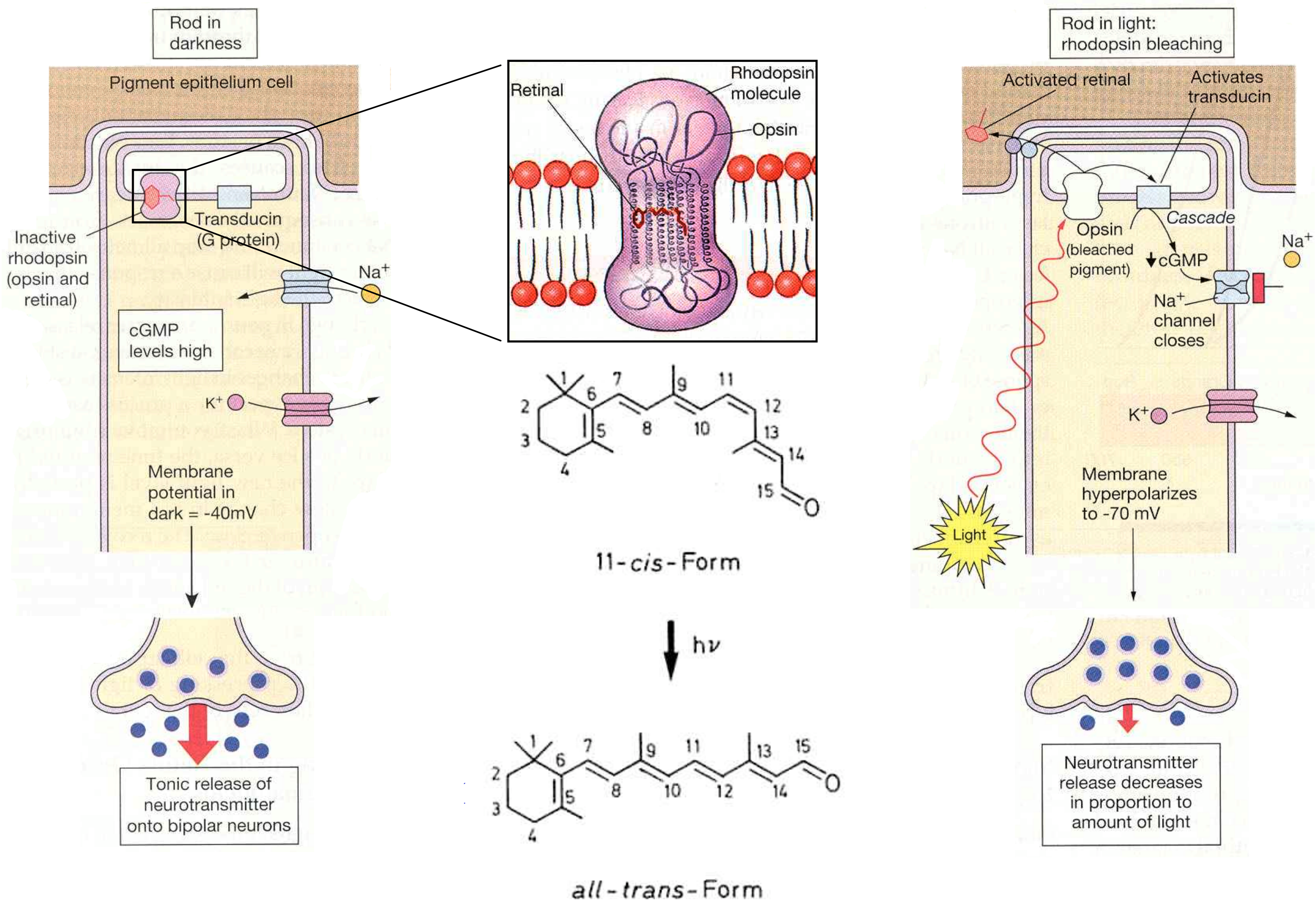
Rods:
achromatic nighttime vision, when light levels are low.

Cones:
high-acuity and color vision during daytime, when light levels are higher.

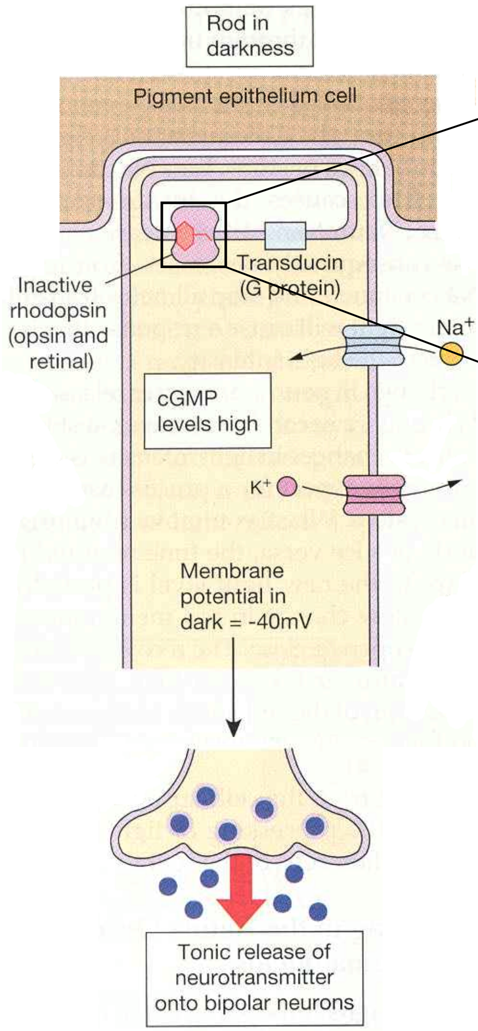
Photoreceptors

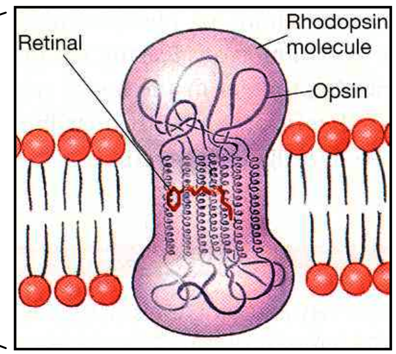
Rod System	**Cone System**
Achromatic	Chromatic
Peripheral retina	Central retina (fovea)
High convergence	Low convergence
High light sensitivity	Low light sensitivity
Low visual acuity	High visual acuity

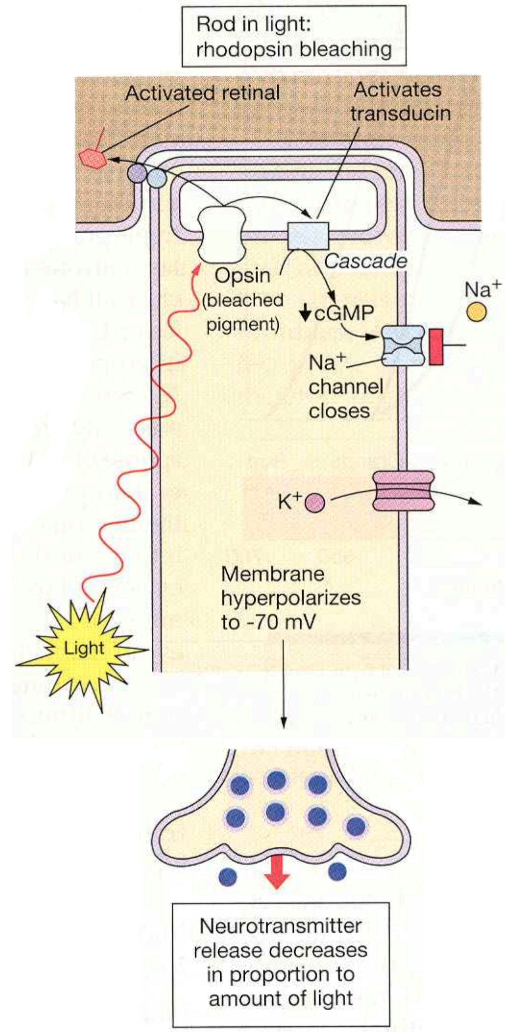
Phototransduction



Phototransduction







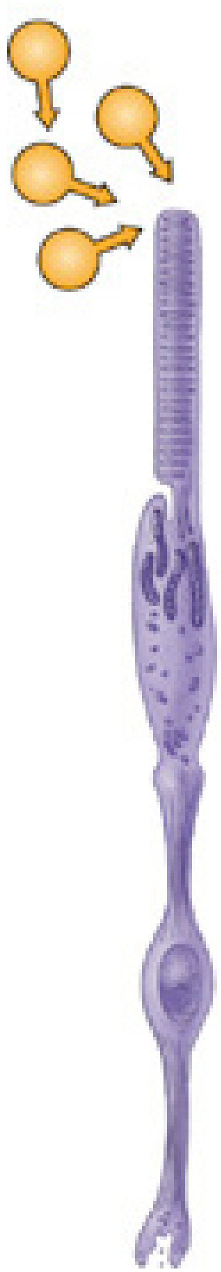
Retinal:
Vitamin A derivative

Opsin:
Membrane protein

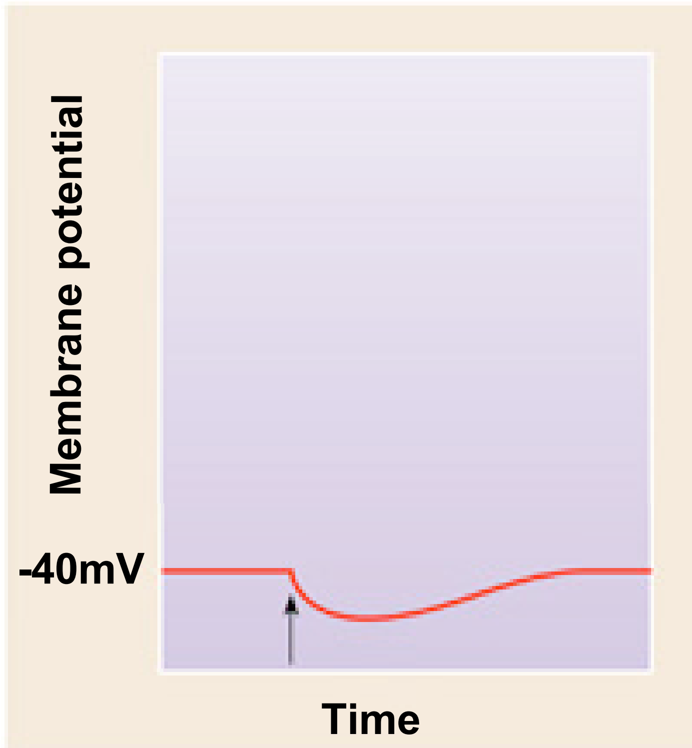
<u>High Gain Mechanism</u>

1 *opsin* ⇒ 1000 *transducin*
1 *PDE* ⇒ 1000 *cGMP*

Phototransduction



Dark current = -40mV (not -65mV)

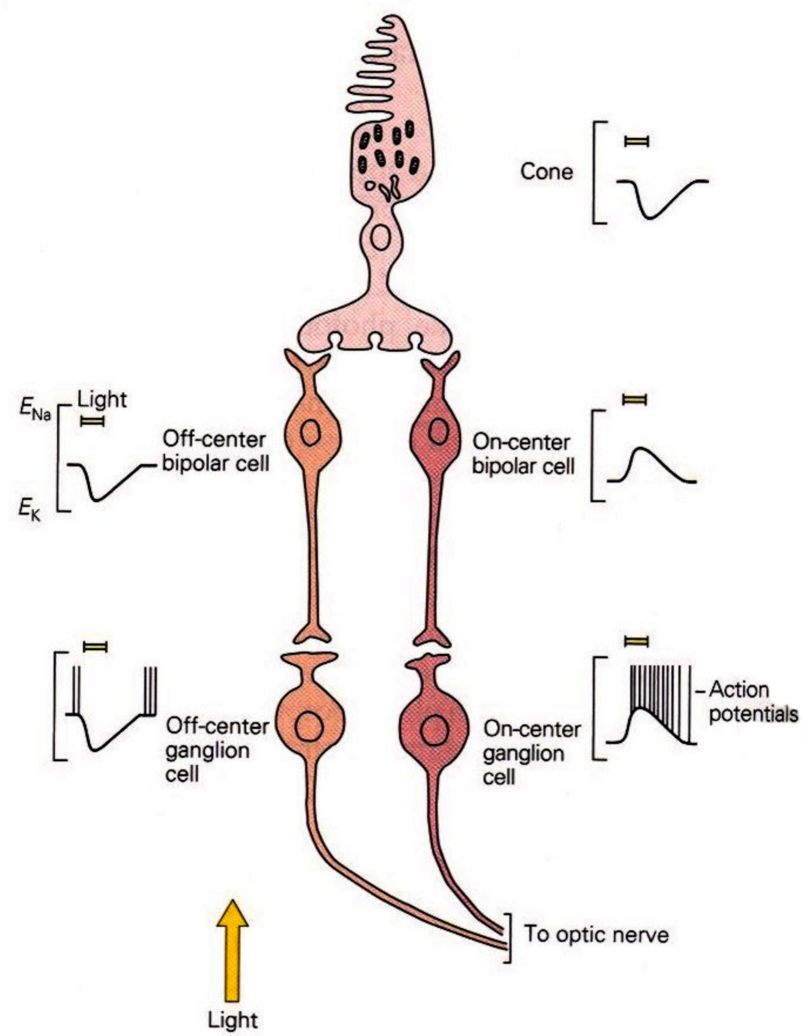


ON and OFF channels

The hyperpolarization of photoreceptors elicits both ***hyperpolarization*** and ***depolarization*** within bipolar and ganglion cells.

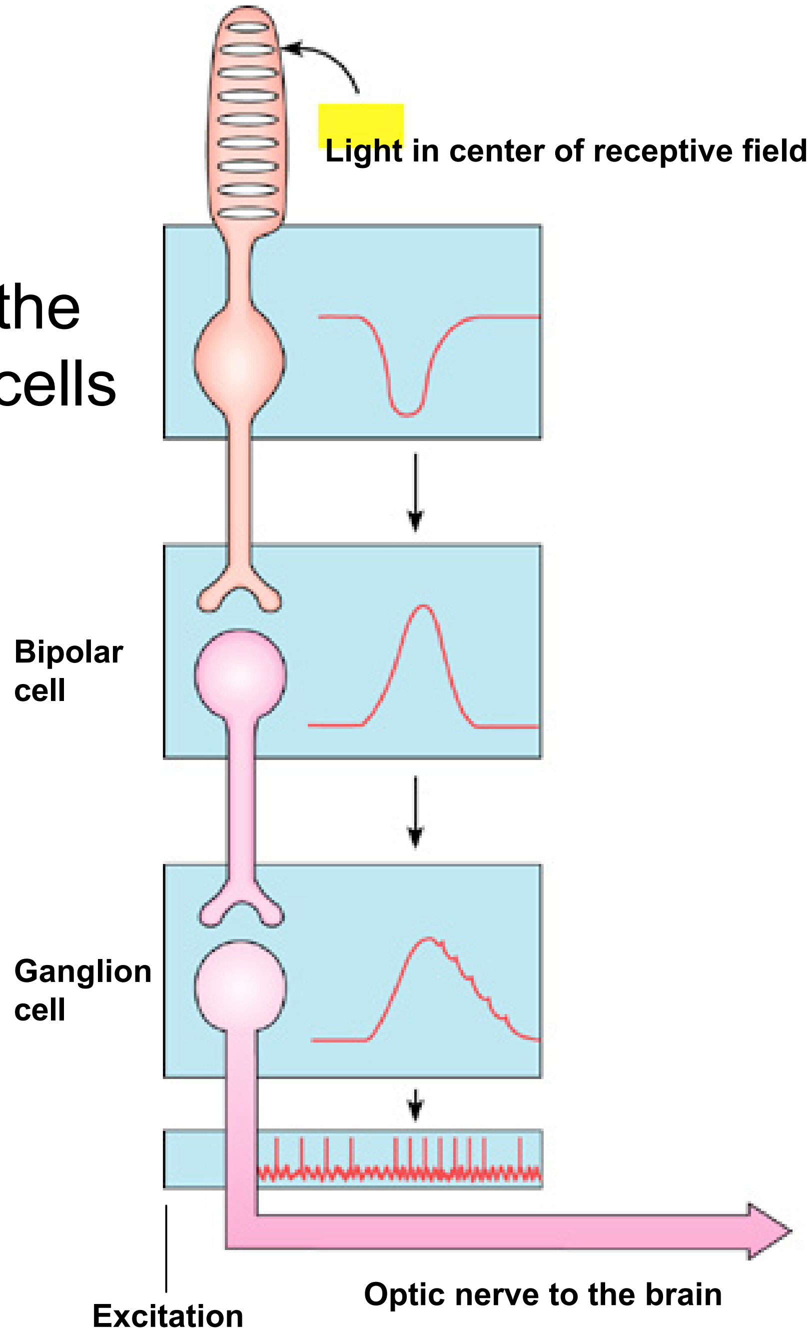
These ***graded potentials*** modulate the ***discharge rate*** of ganglion cells.

ON and **OFF** bipolar and ganglion cells respectively detect **increases** and **decreases** in luminance.



Receptive Fields

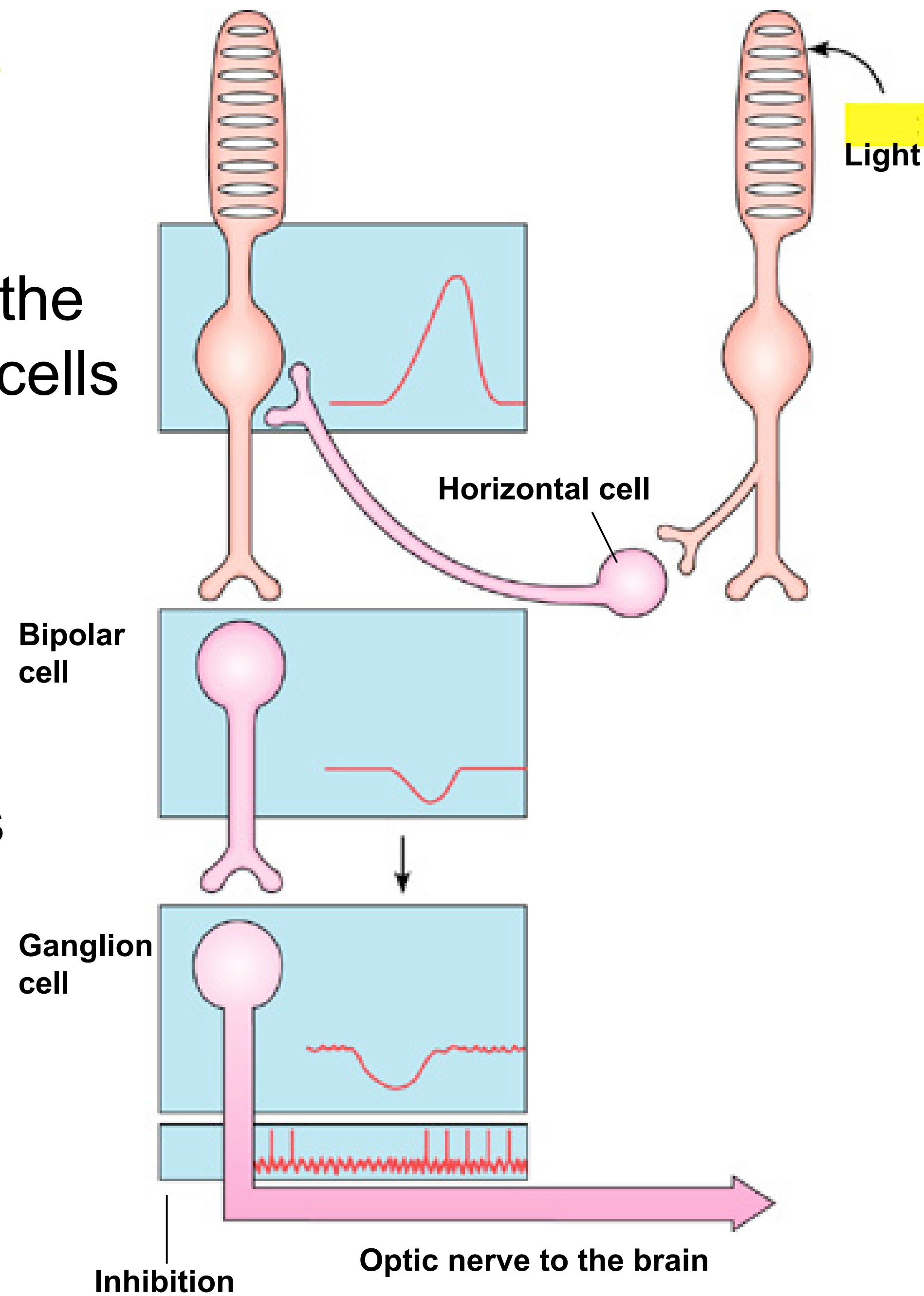
Thanks to *lateral inhibition*, the receptive fields of ganglion cells have a **center-surround organization**.



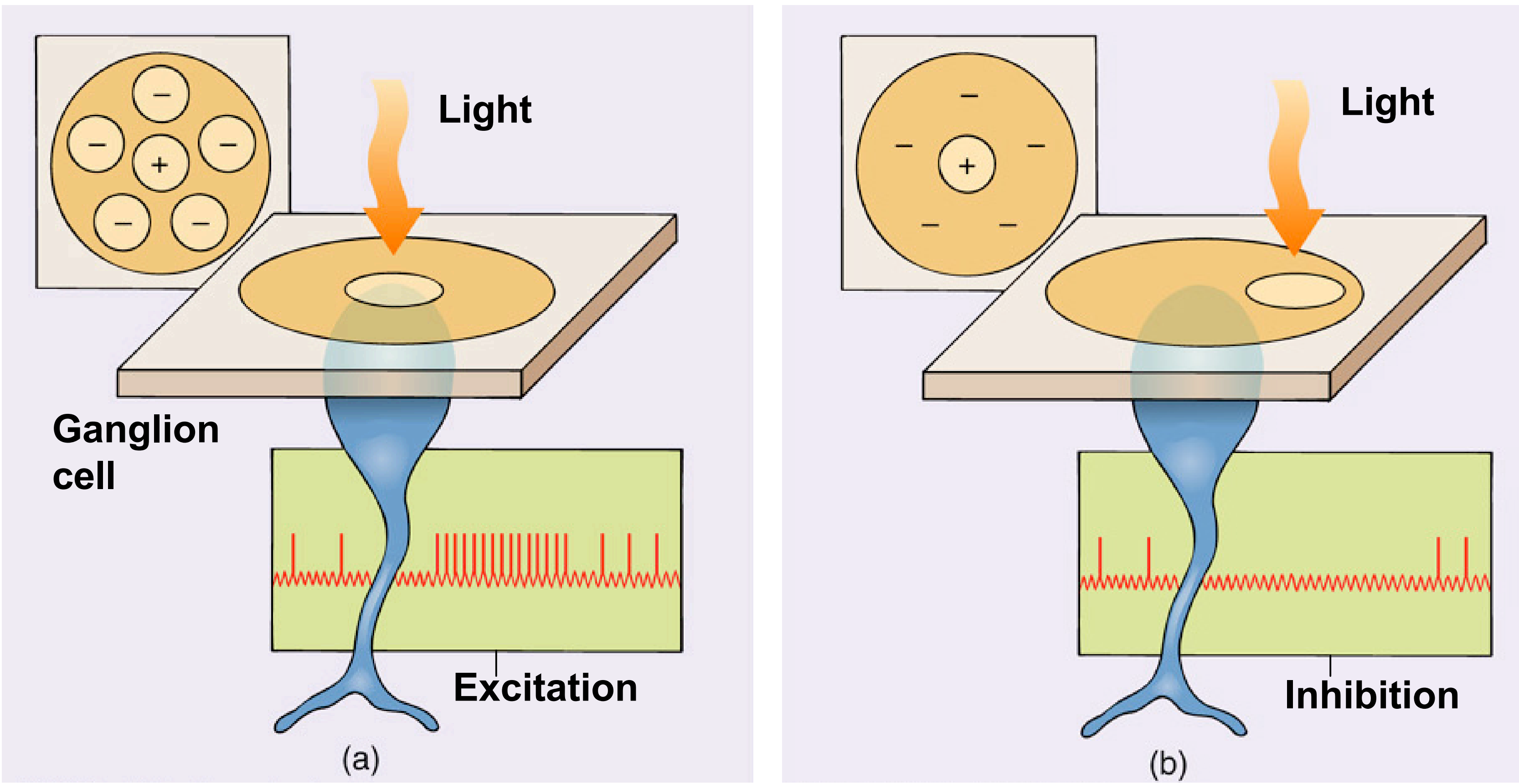
Receptive Fields

Thanks to *lateral inhibition*, the receptive fields of ganglion cells have a **center-surround organization**.

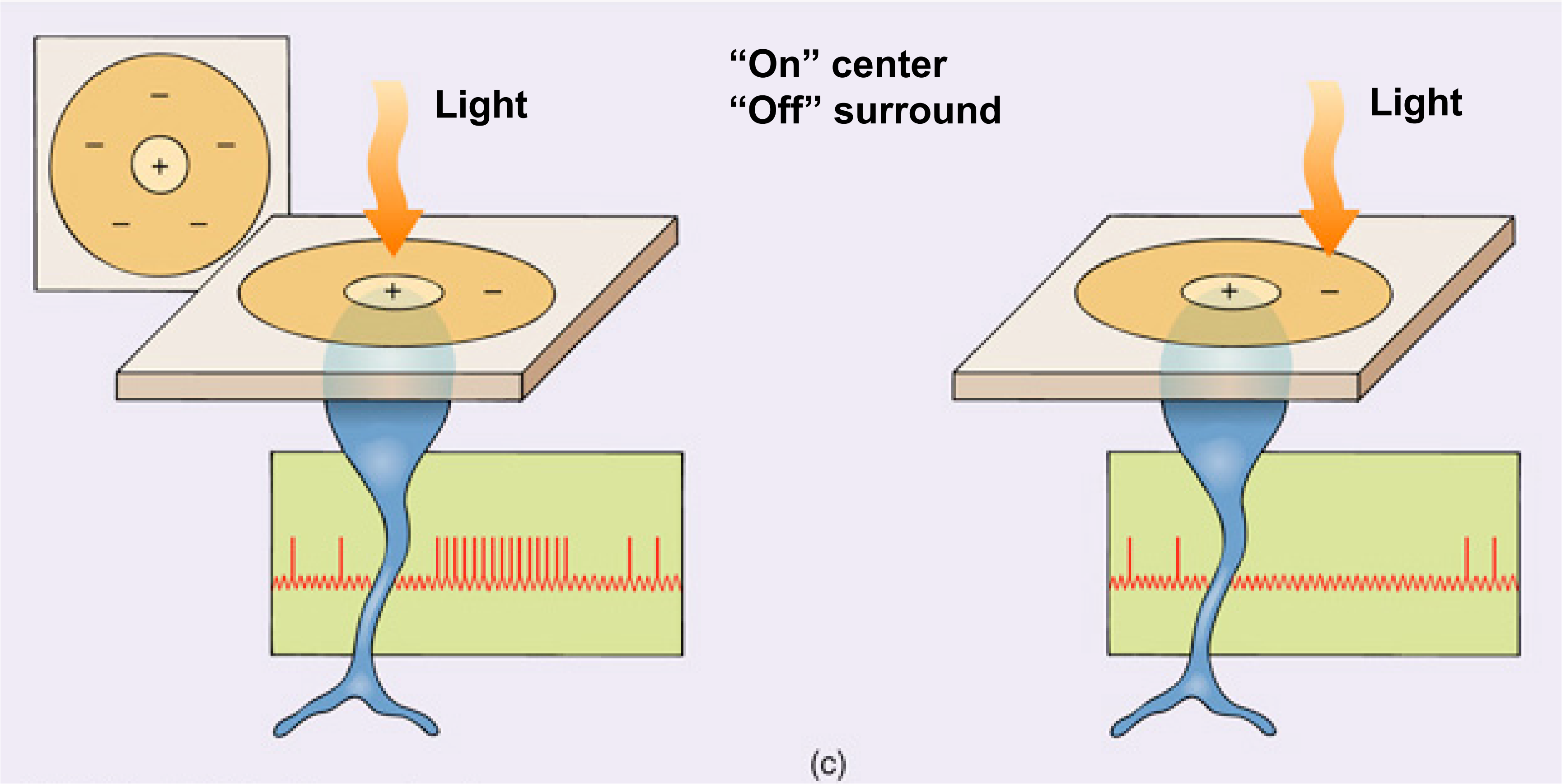
Stimulation of the region around their receptive fields elicit opposite responses via **horizontal cells.**



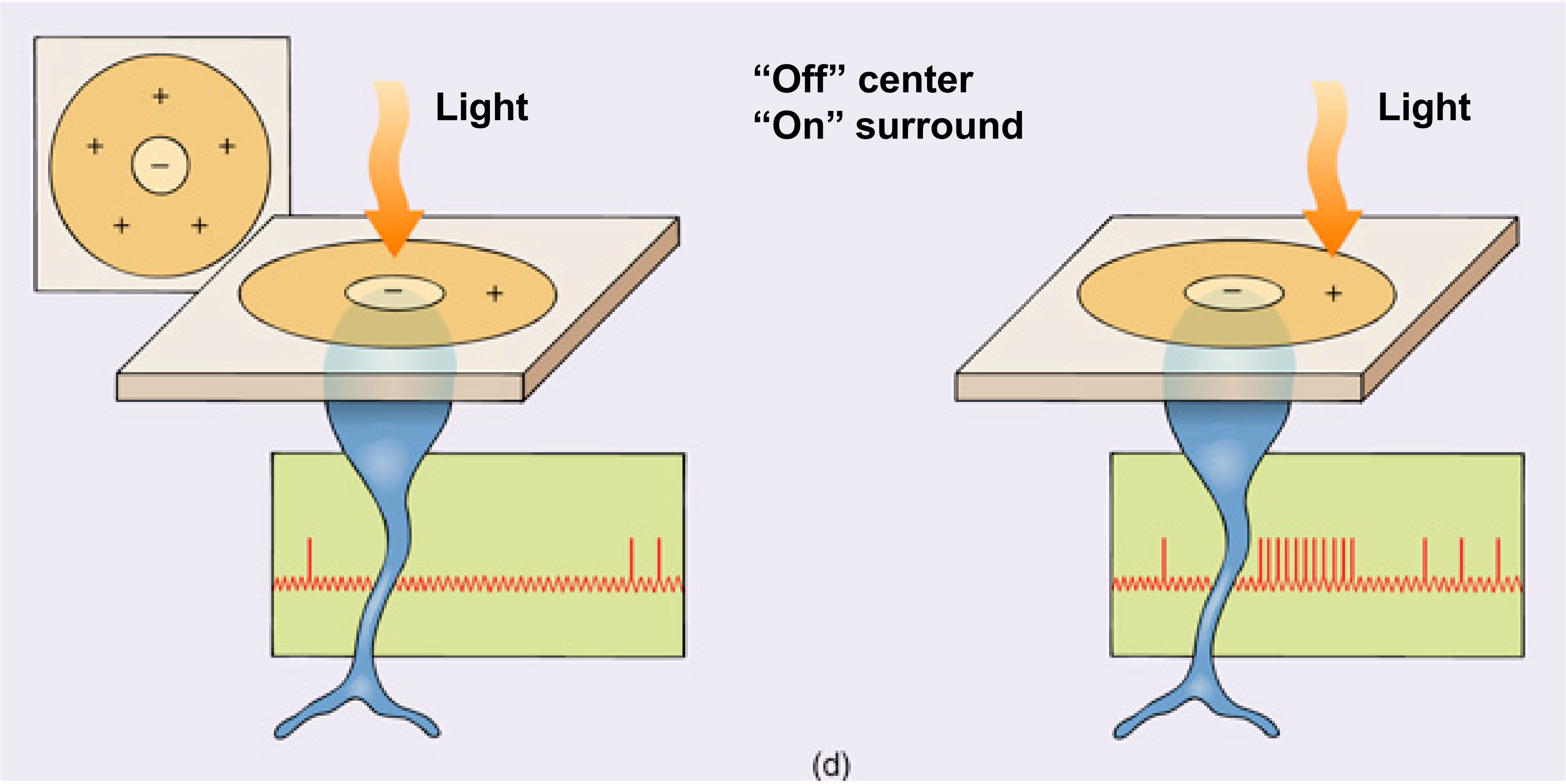
Center-surround Organization



Center-surround Organization

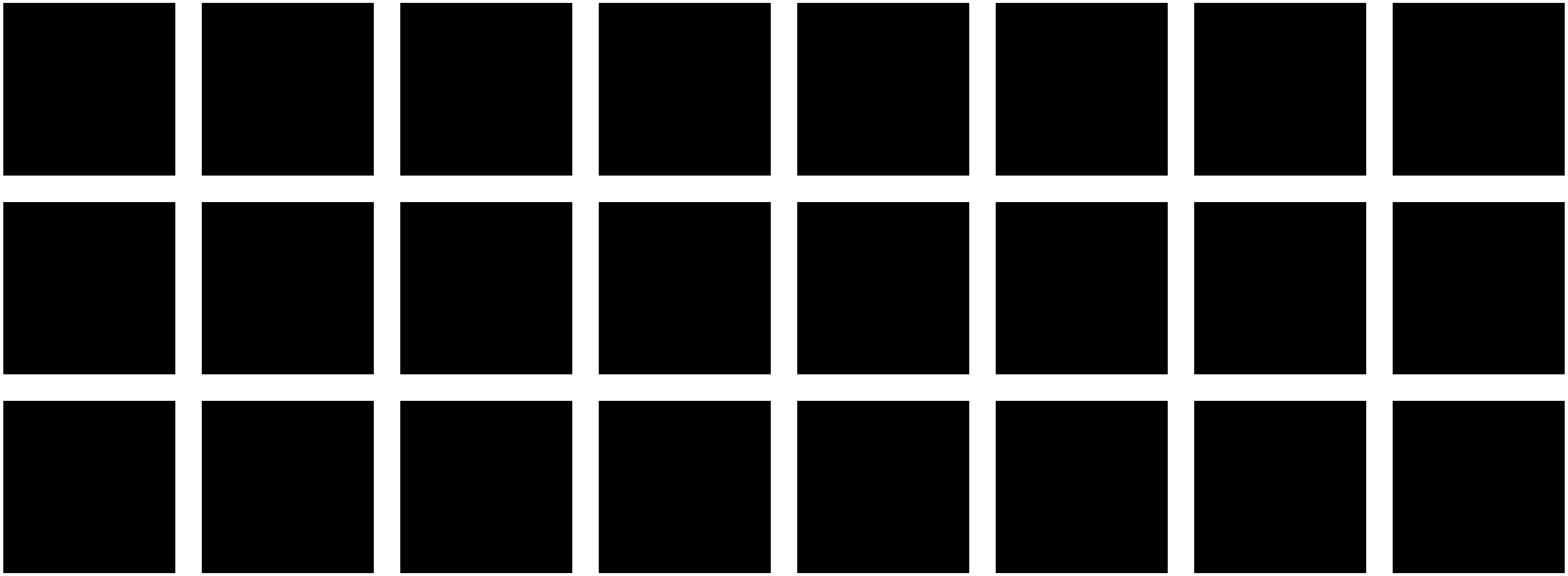


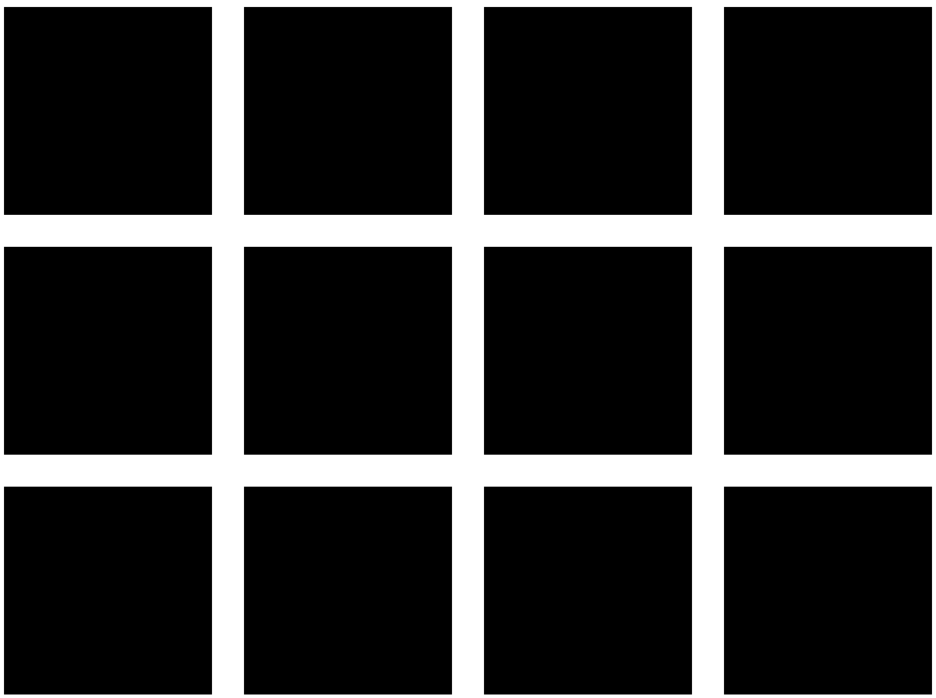
Center-surround Organization

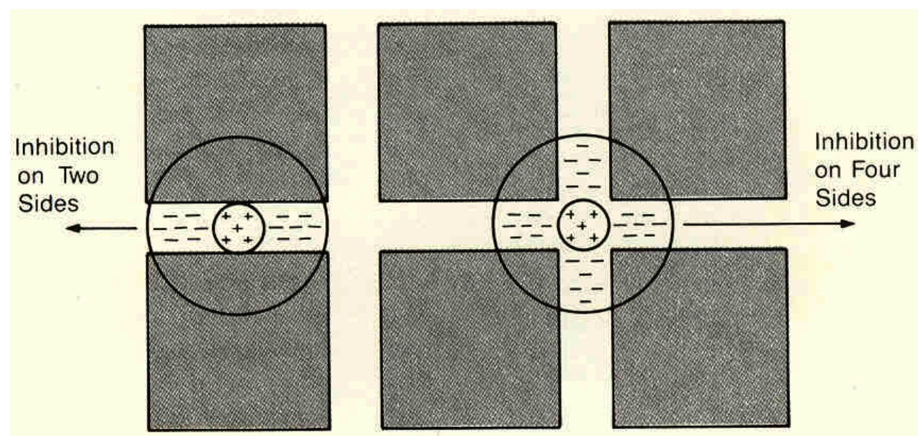


Center-surround Organization

Center-surround organization serves to emphasize areas of difference (**contrast**).
Our visual system detects local differences in light intensity, not the absolute amounts of light.





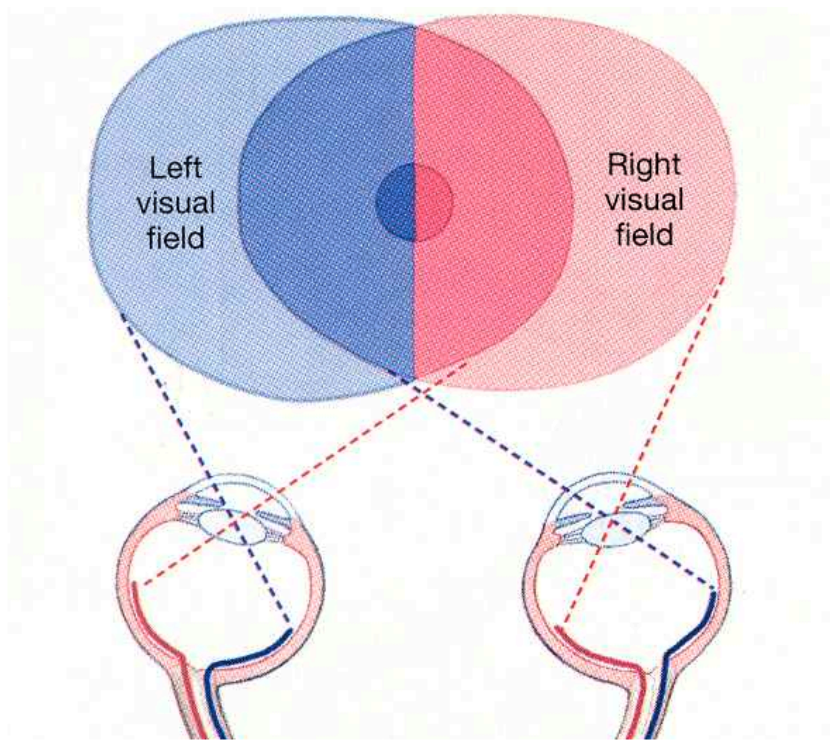


ON-center ganglion cell

Visual Pathways

Each eye sees a part of the visual space, ***monocular visual field*** (±45°).

The visual fields of both eyes overlap extensively to create a ***binocular visual field*** (±45°).

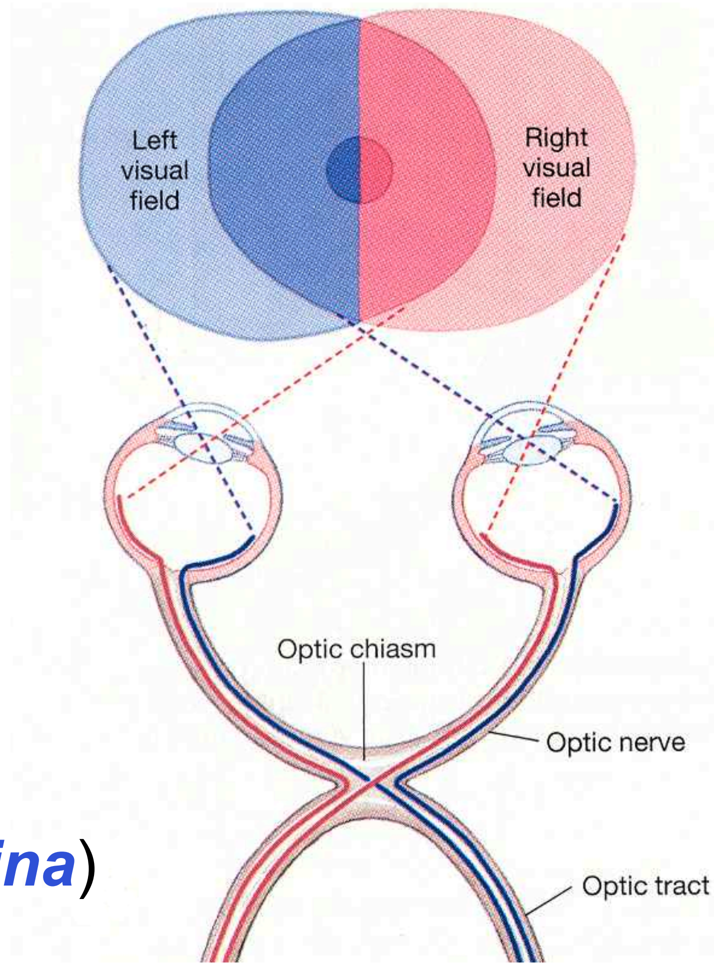


Visual Pathways

Nerve fibers from the *nasal half* of each retina cross over at the **optic chiasm**.

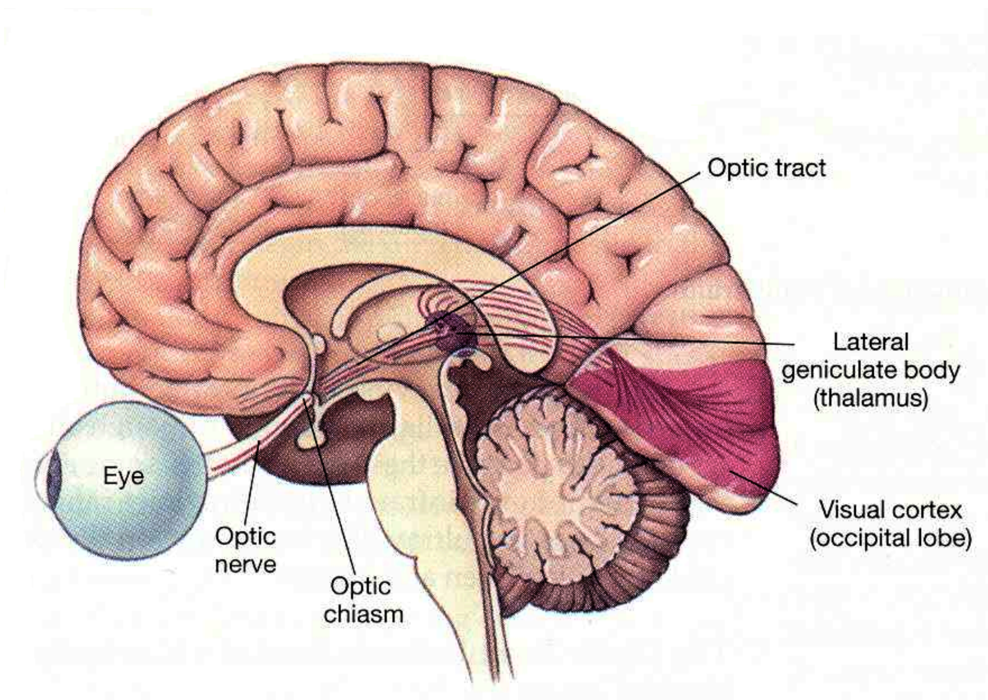
The resulting two **optic tracts** allow right and left visual fields to reach separately the left and right hemispheres.

60% do cross (***nasal retina***)
40% do not cross (***temporal retina***)



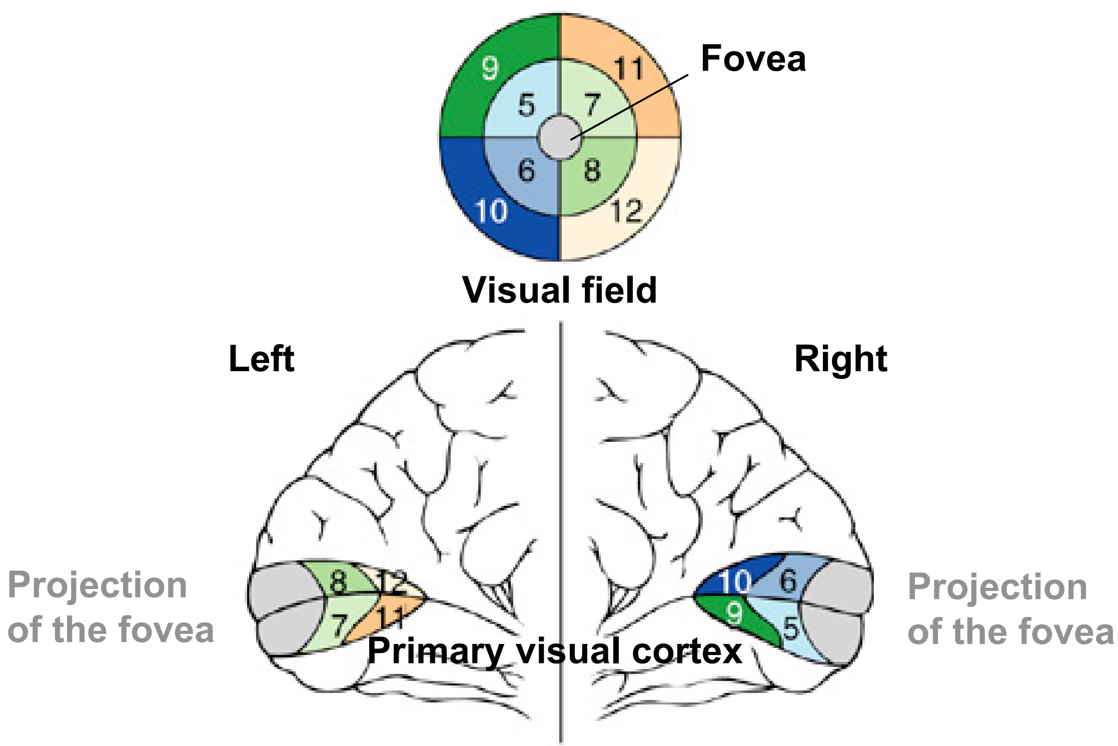
Visual Pathways

The optic tracts (composed of the axons of tertiary sensory neurons) project primarily to the thalamus (*lateral geniculate nucleus*), which projects to the **primary visual cortex** in the occipital lobe.



Visual Pathways

The entire visual field is precisely mapped onto the primary visual cortex, which is said to have a **visuotopic organization**.



Visual Pathways

Visual cortical areas beyond the primary visual cortex form two information processing streams dedicated to the recognition and the spatial relationships of objects.