PHGY 212 - Physiology

SENSORY PHYSIOLOGY
Vision

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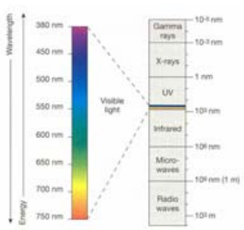
The Process of Vision

Vision is the process through which light reflected from objects is translated into a mental image.

It involves a sensory organ (the eye), in which light rays are focused by a lens onto the retina, where photoreceptors transduce light energy into electrical signals, which are integrated to create mental images after processing in the cerebral cortex.

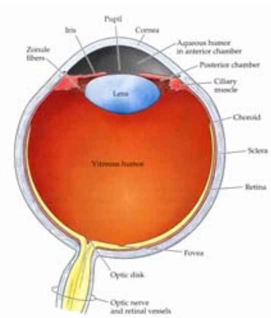
Visible Light

Visible light is composed of electromagnetic waves with frequencies between 4.0–7.5 x 10^{14} hertz and wavelengths between 400–750 nanometers (nm).



Ocular Anatomy

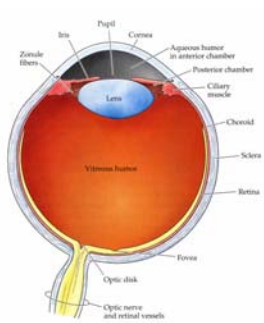
The eye is a fluid-filled sphere enclosed by three layers of tissue:
1) The outer layer is composed of the *sclera* and the *cornea*.
2) The middle layer includes the *iris*, the *ciliary body*, and the *choroid*.
3) The inner layer is the actual *retina* containing the *photoreceptors*.



Ocular Anatomy

En route to the retina, light successively travels through:

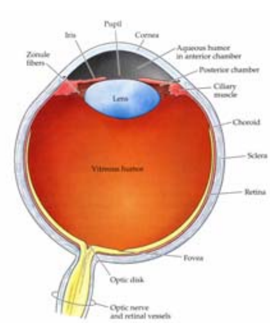
1) the *cornea*
2) the *aqueous humor* of the anterior chamber
3) the *pupil*
4) the *lens*
5) the *vitreous humor*



Ocular Anatomy

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

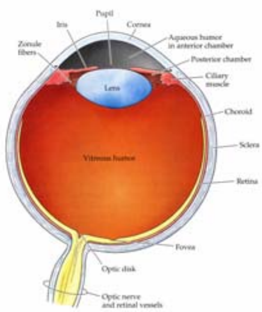
Its function is to modulate the amount of light that enters the eyes.



Ocular Anatomy

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

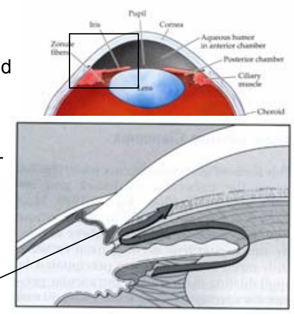
Together with the **cornea**, the *lens* help focusing the image on the *retina*.



Ocular Anatomy

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

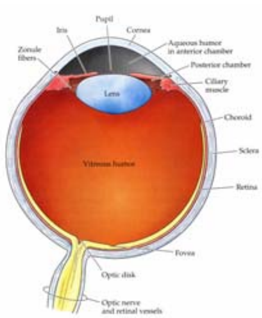
It regulates the intraocular pressure.



Ocular Anatomy

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

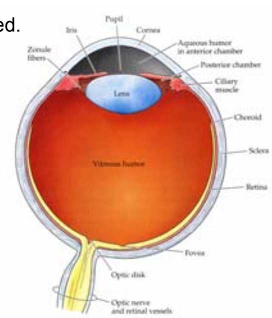
It accounts for the size and shape of the globe.



Ocular Anatomy

The **choroid** is a capillary bed.

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

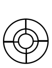


Control of Incoming Light

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

This control originates from the brain stem.

Circular muscles under *parasympathetic* control reduce pupils size.

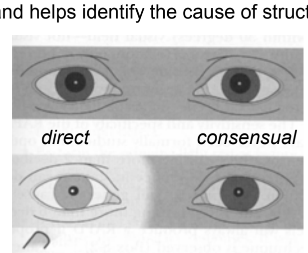


Radial muscles under *sympathetic* control increase pupil size.

Pupillary Light Reflexes

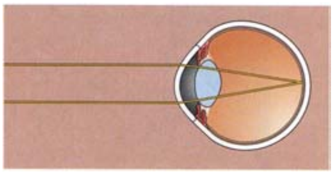
Shining a light into each eye can elicit a **direct** and a **consensual** *pupillary light reflex*.

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



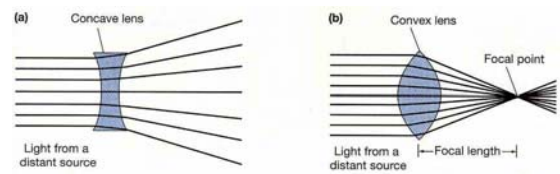
Retinal Image Formation

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.



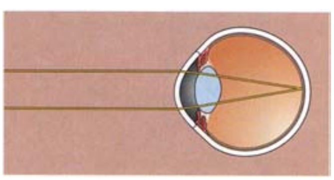
Retinal Image Formation

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.



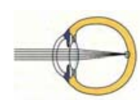
Retinal Image Formation

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**.

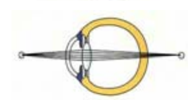


Retinal Image Formation

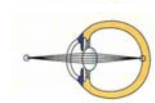
When an object is distant, the light rays are essentially parallel and brought to a focus on the retina.



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

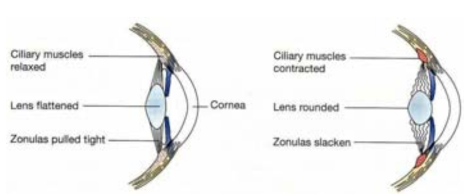


To bring the image into focus on the retina, the lens refractive power must be increased. This is the process of **accommodation**.



Retinal Image Formation

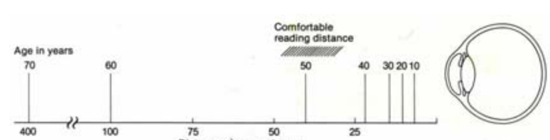
The lens changes its shape through the action of inelastic fibers called **zonulas**. Contraction in *ciliary muscles* relaxes these zonulas, which then allow the lens to assume its natural rounded shape.



Retinal Image Formation

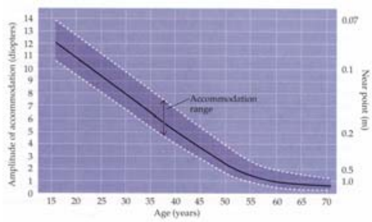
Accommodation has its limits!!!

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



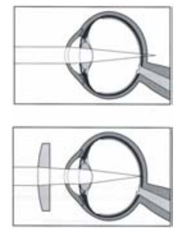
Problem in Retinal Image Formation

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



Problem in Retinal Image Formation

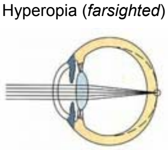
The solution to **presbyopia** is a corrective (**convex**) lens
that augments the focusing power
to bring the retinal image to a focus on the retina.



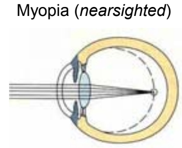
Problem in Retinal Image Formation

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*)

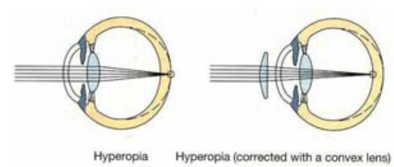


Myopia (*nearsighted*)



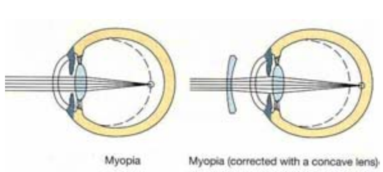
Problem in Retinal Image Formation

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.



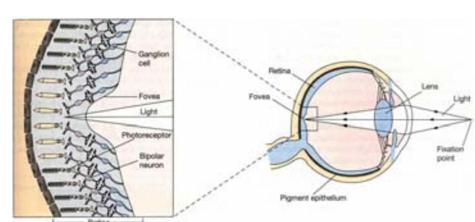
Problem in Retinal Image Formation

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.



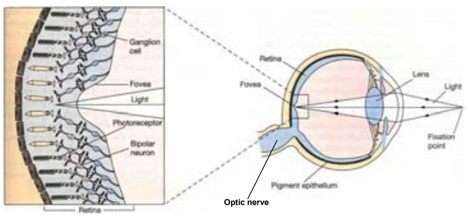
Retina

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

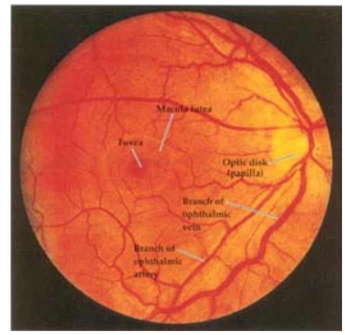


Retina

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



Retina



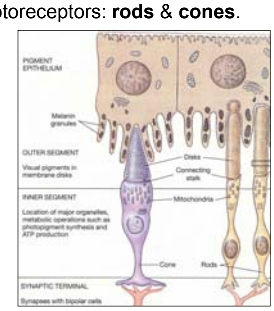
Blind Spot Demonstration

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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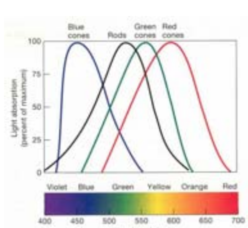

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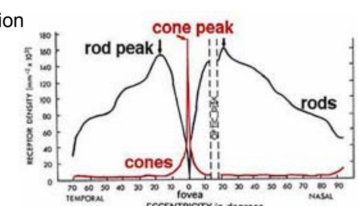

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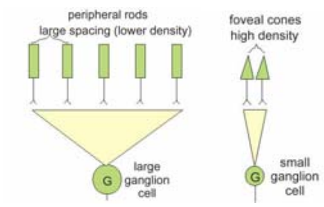

Photoreceptors

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

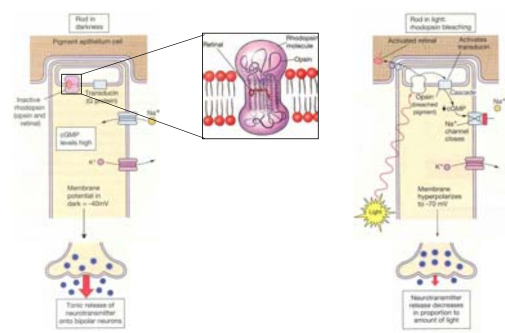
Rods:
achromatic nighttime vision, when light levels are low.

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

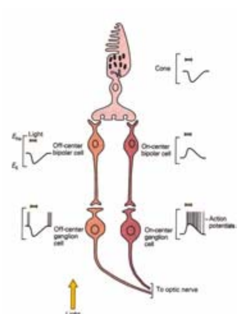


ON and OFF channels

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

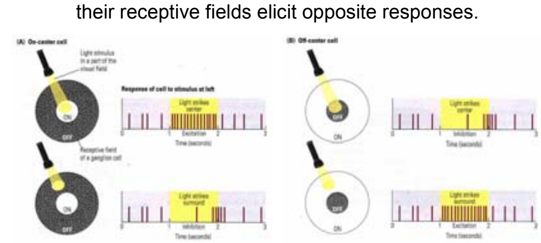
These graded potentials modulate the discharge rates of ganglion cells.

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



ON and OFF channels

Thanks to *lateral inhibition*, the receptive fields of ON and OFF ganglion cells have a **center-surround organization**: stimulation of the region surrounding their receptive fields elicit opposite responses.

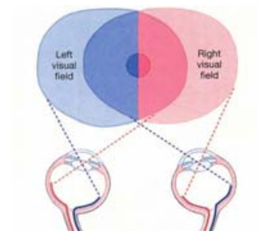


ON and OFF channels

Center-surround organization serves to emphasize areas of difference (**contrast**).
Our visual system detects local differences in light intensity rather than the absolute amounts of light.

Visual Pathways

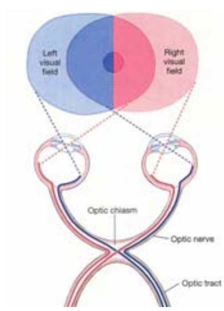
Each eye sees a part of the visual space (**visual field**).
The visual fields of both eyes overlap extensively to create a *binocular* visual field.



Visual Pathways

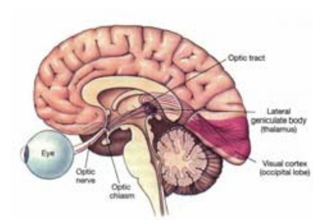
Nerve fibers from the *nasal half* of each retina cross over at the **optic chiasm**.

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



Visual Pathways

The optic tract projects primarily to the thalamus (*lateral geniculate nucleus*), which projects to the visual cortex in the occipital lobe.



Reading

Silverthorn (2nd edition)
pages 309 – 320

Silverthorn (1st edition)
pages 289 – 302