PHGY 212 - Physiology

SENSORY PHYSIOLOGY

Vision

Martin Paré
Assistant Professor of Physiology & Psychology
pare@biomed.queensu.ca
http://brain.phgy.queensu.ca/pare

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

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.
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.

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.

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

Accommodation has its limits!!!

The closest distance at which your lens can focus on objects is called the near point of accommodation.
Our lens hardens with age and ciliary muscles weaken. This gradual decreased ability in accommodation is called presbyopia.

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)

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.

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.

Light strikes photoreceptors only after passing through sensory neurons, except at the central retinal region (fovea) where acuity is best.
Visual information is transmitted from photoreceptors to bipolar neurons and ganglion neurons before exiting the eye via the optic nerve. There are two types of photoreceptors: rods & cones. They differ in:
1) shape
2) range of operation
3) distribution
4) connectivity
5) visual function
Photoreceptors

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They differ in:
1) shape
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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.

Rod System
- Achromatic
- Peripheral retina
- High convergence
- High light sensitivity
- Low visual acuity

Cone System
- Chromatic
- Central retina (fovea)
- Low convergence
- Low light sensitivity
- 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