Eye as an optical system

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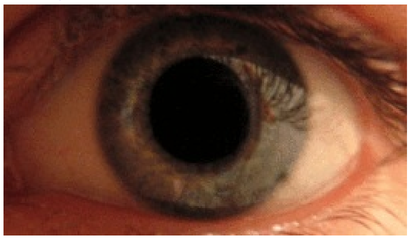

Image of a human eye

Human Eye—the Most Amazing Optical System

The eye is an adaptive optical system comprising of a cornea and a lens. Unlike most optical systems, the crystalline lens of the eye changes its shape to focus light from objects OVER A great RANGE OF distances on the retina. This essay will discuss the individual optical structures of the human eye and how they all combine to attain optical performance. In addition, the essay will discuss the eye defects and biophysics of vision.

Optical Structures

Cornea

The transparent front part of the eye, the cornea plays the most important part in refraction. The cornea is accounting for approximately two-thirds of the eye's total optical power. It is almost spherical with an outer radius of curvature of about 8 mmIn humans, the refractive power of the cornea is approximately 43 dioptres. While the cornea contributes most of the eye's focusing power, its focus is fixed. The curvature of the lens, on the other hand, can be adjusted to "tune" the focus depending upon the object's distance.

Pupil

The pupil is the black central circular opening in the iris, and it contains groups of smooth muscles that contract and dilate the pupil. In the eye's optical system, the pupil acts as an aperture that controls the amount of light flux that forms images on the retina. The aperture stop affects several optical processes (Charman, 1991). Thus, it is an important component of the optical system. In addition, the pupil also affects the quality of the image through its influence on aberration, ocular depth-of-focus, and diffraction. The pupil has a black appearance and the reason why it is black is due to the fact that the light the pupil allows to enter the eye does not exit the eye, instead it is absorbed by the retina (Smith, 1997). Although the pupil diameter is primarily influenced by the ambient lighting, there are other factors such as old age, drugs, emotions and accommodation that can influence the pupil diameter (Land, 2014).

Lens

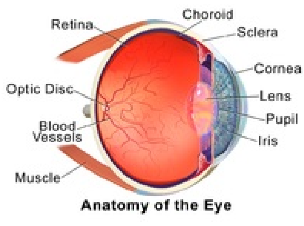

Diagram showing different parts of a human eye that are vital for the optical system.

The lenses of the eye are thicker at the center than at the edges, though they are not necessarily spherical. The lens is made up of fine hexagonal fibers that stretch in the interior of the posterior pole of the lens. The lens is bi-convex with a reflective index of approximately 1.38 in the center and 1.41 at the edges. The eye lens can adjust its shape by the action the ciliary muscles, which causes eye accommodation, hence maintaining focus on the retina for objects at varying distances. The lens is the only optical component of the eye that continuously grows with age. The focal length can be adjusted in order to focus objects OVER A WIDE RANGE OF distances through a process know as accommodation. Changing the shape of the eye decreases the radius of curvature, which in turn changes the focal length (Charman, 1991).

Retina

The retina is the light-sensitive portion of the optical eye, where images are formed. It is connected to the brain through the optic nerve. The retina optimizes the performance of the eye by wave guiding on-axis and off-axis via its curvature. It is made up of cones and rods, where the rods are sensitive to vision of low light levels, but they cannot distinguish colors. While the cones are sensitive to vision at higher light levels, and they distinguish colors (Charman, 1991).

Compartments of the Eye

There are three compartments in the interior of the eye:

1. The anterior chamber: This is the space between the cornea and iris, which contains aqueous humour
2. The posteriorchamber: This is the space between the iris, the ciliary body and the lens, which contains aqueous humour
3. The vitreous chamber: This is the space between the lens and the retina, which contains a transparent gel called the vitreous humour.

Ref: http://publicana.ru/files/opticheskaya-sistema-glaza.pdf

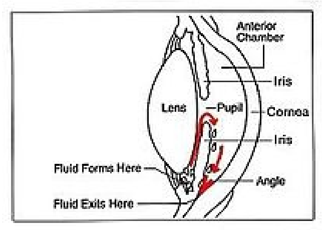

Image showing the Anterior chamber of an eyes. The posterior chamber is the space between the iris and lens and the ciliary body. And the vitreous chamber started right after the lens. It is the largest chamber of the eye.

The Basic Principles of Image Formation by the Optical structures

After entering into the eye through the cornea, light is refracted by the cornea and lens. Accommodation is the process by which the shape of the lens can be altered to change its power when the eye needs to focus at different distances. The iris is controlling the amount of light rays enter into its opening which is called pupil by it’s aperture stop mechanism. This aperture stop is a very important component of an optical system, affecting a wide range of optical processes.

Subsequently the light beam projected to the inner layer of the eye, the Retina , which is an extension of the central nervous system The image on the retina is inverted - like a camera and is connected to the brain by the optic nerve.

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Optical Power of the Eye

Due to the curvature of the cornea, most of the refraction occurs there, but eye’s optical power is at the interface between the cornea and outside air. Notably, the index of refraction between the cornea and the outside air also causes the refraction to occur in the cornea. In addition, the lens of the eye also provides an adjustable additional lens power (Gross, Blechinger & Achtner, 2008)

How to Calculate the Equivalent Power of the Eye

THIS PART NOT CLEAR

Equivalent power of the eye is the measure of the ability of the system to bend or deviate rays of light. The higher the power, the greater is the ability to deviate rays

Equivalent power F of the eye is given by

F = n’/P’F’

P’--is the second principal point, just inside

F’-- is the second focal point. Light entering the eye from the distance is imaged at F’

n’-- is the refractive index of the vitreous

The average power of the eye is 60 m-1 or 60 dioptres (D)

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Eye Defects

Myopia

This defect is also called nearsightedness, and it refers to impaired vision where a person sees clearly near objects, but distant objects are blurred. The defect is caused by the elongation of the eyeball or excessive curvature of the cornea. The defect can be corrected by a divergent lens which refocuses the image on the retina (Goncharov, Nowakowski, Sheehan & Dainty, 2008).

Hypermetropia

The defect is also known as farsightedness, it is the opposite of shortsightedness and it is a defect in vision where a person sees near objects with blurred vision, but distant objects are clearly visible. The defect occurs when the eyeball is too short or when the focal length is too great. The problem is corrected by using a converging lens of the required focal length (Smith, 1997).

Astigmatism

This eye defect occurs when the rays of light do not converge to a single focal point on the retina, either in front or behind. The problem is caused by an irregular curvature of the cornea. The condition is corrected by using a special spherical cylindrical lens.

Presbyopia

This defect is associated with an eye whose ability to focus objects gets diminished. As the age progresses, the power of accommodation decreases due to weakening of the ciliary muscles. The problems can be corrected by using bi-focal lens (Gross, Blechinger & Achtner, 2008).

Biophysics of vision

Wavelength Sensitivity

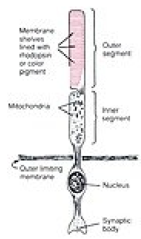
The color vision of the human eye is very complex because it involves simultaneous interaction of the two eyes, the brain, receptors and a network of neurons. The eye is sensitive to wavelength, and the human eye has three receptors and each senses colors which is absorbed at different wavelengths. Therefore, the wavelength determines the color, while the amplitude determines the brightness of the light (Charman, 1991).

Photoreceptors

The electrophisological process that sends visual message to the brain starts when the receptors absorb light. The receptor types are the rods and the cones

1.The rods associated with vision at low light levels. They reach their maximum density at about 20º from the fovea

2.Cones are associated with vision at higher light levels, including colour vision. Predominate in the fovea which is about 1.5 mm across. Their density is a maximum at the pit at the foveola in the middle of the fovea.



Structure of a Rod cell

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Stereopsis: 3D Vision

Stereopsis term derived from the Greek word stereo- meaning "solid", and opsis-meaning "appearance or sight". This is a term that is most often used to refer to the perception of depth and 3-dimensional structure obtained on the basis of visual information deriving from two eyes by individuals with normally developed binocular vision. Because the eyes of humans, and many animals, are located at different lateral positions on the head, binocular vision results in two slightly different images projected to the retinas of the eyes. The differences are mainly in the relative horizontal position of objects in the two images. These positional differences are referred to as horizontal disparities or, more generally, binocular disparities. Disparities are processed in the visual cortex of the brain to yield depth perception. (Howard, I. P.; Rogers, B. J. (1995). Binocular vision and stereopsis. New York: Oxford University Press.")

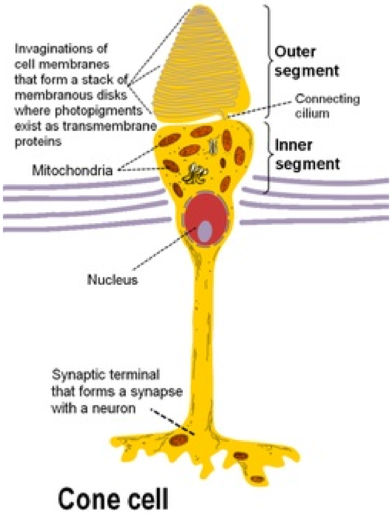
References

1. http://en.m.wikipedia.org/wiki/Optics_and_vision

2. http://publicana.ru/files/opticheskaya-sistema-glaza.pdf

3. http://www.colorado.edu/physics/phys1230/phys1230_fa01/topic36.html

4.



Structure of a Cone Cell.

http://www.ncbi.nlm.nih.gov/books/NBK10885/http://en.wikipedia.org/wiki/Rod_cell